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Atmospheric Measurement Techniques Discussions

Interactive comment on "MERIS albedo climatology for FRESCO+ O_2 A-band cloud retrieval" *by* C. Popp et al.

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We would like to thank reviewer 1 for the positive assessment of our manuscript and the constructive comments. We followed them as described in detail below. In the following, the reviewer's comments will be in italics, our responses in normal typeface.

1. Response to general comments

The authors describe in this paper the generation and integration of a new albedo data base based on MERIS observations into the FRESCO+ algorithm. FRESCO+ is an established algorithm for cloud properties retrieval from high-resolution O2A-band satellite observations. Typically, GOME and its successor instruments use this spectral

band for retrieving cloud information (coverage, height, pressure, optical thickness, albedo). Here, it is applied to SCIAMACHY/ENVISAT measurements and retrieved cloud parameters are compared with another cloud properties retrieval scheme called HICRU. Furthermore, it is shown how the now albedo data base per-forms with respect to cloud properties if results are compared to FRESCO+ simulations using the pre-existing GOME-LER data base.

The paper is well written and organized and of some relevance for the scientific community. Cloud properties need to be known for accurate trace gas column retrievals but are also relevant as a stand-alone data set. Improvements in this field are welcomed and appreciated. The authors could improve their paper if a more elaborated discussion on the impact of the main product of GOME-like sensors would be added. Even if the new MERIS-based albedo climatology does not cover the most important spectral range (for trace gas retrievals of several reactive species like O3, SO2, BrO, HCHO, OClO) between 315 and 380 nm there will be an indirect effect via the cloud coverage on trace gas results. How does the new climatology improve retrieved (total and tropospheric) trace gas columns? This is actually the most interesting question but it remains unanswered. That is why I assign only "some scientific relevance" to this paper. I recommend adding a section on this topic and showing some results, maybe two figures. Also the conclusions should contain a corresponding paragraph. If results show a minor impact only it should clearly be said here. I recommend publication of this paper after minor revision.

Author response: We agree that addressing the impact of the new albedo climatology and therewith also of the new FRESCO+ cloud parameters on trace gas retrievals is important. Our approach was to concentrate here exclusively on clouds and leaving the discussion of the effect on trace gases to follow-up studies. Nevertheless, we added a new section (4.2.3 Impact on trace gas retrievals) in the revised manuscript where we focus on this aspect. We processed NO2 tropospheric vertical column densities (VCD) based on the FRESCO+ GOME and FRESCO+ MERIS cloud parameters and discuss

the differences for July 2006 over Europe and Northern Africa. In addition, we briefly compare GOME total ozone columns between the TOGOMI version 1.3 (processed with FRESCO+ GOME cloud parameters) and version 2.0 (processed with FRESCO+ MERIS cloud parameters). Also two figures are added to this section showing preliminary results. However, an in-depth analysis of the impact of the new albedo data set on the retrieval of different trace gases is beyond the scope of this study and is left for a future study.

2. Response to specific comments

p4604/13: The authors describe the generation of a monthly data base. Is there any (which type of?) interpolation (in time) performed when the data is allocated to the SCIAMACHY observations? If not, how is this justified?

Author response: There is no interpolation in time performed when the data is allocated to the SCIAMACHY observation, i.e. the same albedo value per grid cell is regarded representative of the entire month. The provided monthly albedo value per grid cell is an average value of each month (based on MERIS measurements throughout the specific month). We therefore consider the monthly averaged value equally representative of each day of the month. Since the surface albedo varies smoothly with the seasons, no significant jumps are expected by not interpolating between monthly mean values. In addition, not interpolating in time is also consistent with the use of the GOME data base in FRESCO+.

p4604/25: The authors mention the importance of scenes with small cloud fractions when errors of retrieved trace gas columns become large. The discussion of this issue could be more elaborated. It could be added to the actually missing discussion of the impact of the differing cloud properties from two albedo data bases on retrieved trace gas columns.

Author response: We apply an upper threshold in cloud fraction of 0.3 to the processed NO2 VCD which are presented in the added section 4.2.3. Therefore, all results there

are discussed with regard to small cloud fractions.

p4605/20: I would give credit to the first paper on stage dealing with cloud property retrievals in the O2A-band. The paper of Kuze and Chance (1994) could easily be added here.
A. Kuze and K.V. Chance, "Analysis of Cloud-Top Height and Cloud Coverage from Satellites Using the O2 A and B Bands", JGR, 99, p14481-14491, 1994.

Authors response: Thanks for this valuable hint. The reference is now included in the revised manuscript.

p4608/25: The authors mention application of the new method/algorithm within OCRA/ROCINN. Maybe there would be some improvement since the albedo data base there is based on the PMD measurements which have lower spatial resolution. One could however think about the other way round: FRESCO+ might use the ROCINN based cloud-top albedo, in order to overcome the often questioned fixed cloud-top albedo of 0.8 which finally leads to an effective cloud coverage only. Although this quantity is now well-understood it is a drawback when using the cloud data set from FRESCO+ as independent data source (for clouds). Can the authors comment on this?

Author response: FRESCO+ is an independent data source for clouds, but cannot separate geometric cloud fraction and cloud albedo or optical thickness. This is mainly determined by the large pixel size of the instrument (30x60 km2 for SCIAMACHY's O2 A-band channel). That is why either cloud fraction or cloud albedo (or optical thickness) has to be assumed. The resulting effective cloud fraction is a useful quantity in the cloud correction of the trace gas retrievals. Recently we also found that the effective cloud fraction can be converted into surface solar irradiance (see Wang et al., AMTD, 2011, http://www.atmos-meas-tech-discuss.net/4/873/2011/amtd-4-873-2011.html).
If the cloud albedo from OCRA/ROCINN, using the PMD measurements, would be the real cloud albedo, then we could indeed use it in FRESCO+ and retrieve geometric cloud fraction and cloud pressure. However, for the PMD pixel size of 7.5 x 30 km2

the albedo is still an effective albedo of the clouds in the pixel. Only with imagers like MERIS, which has a 1x1 km2 resolution, clouds can be reasonably resolved.

p4609/12: European Space "Agency" instead of "Administration" ?

Author response: Corrected.

p4610/1: Here, and only here, the authors mention (too) briefly the impact of wrong cloud coverage results on NO2 trop. columns. This discussion should be enhanced and results should be presented. See also the general comments.

Author response: The discussion is enhanced and results presented in the new section 4.2.3.

p4613/19: This means that the data base does not account for solar zenith angles of larger than 50 degrees? If yes, this limitation should clearly be stated in the abstract and in the conclusions.

Author response: The data base is not limited to solar zenith angles lower than 50 degrees. Black-sky albedo in the Albedomap data set is reported for the mean solar zenith angle of satellite overpass time of the period used to integrate the black-sky albedo and is therefore a function of the location. The range of solar zenith angles given here only refers to the range where the black-sky albedo is almost identical to the blue-sky albedo (the "actual" albedo) as described in the cited paper (Liu, J. et al. (2009).: Validation of Moderate Resolution Imaging Spectroradiometer (MODIS) albedo retrieval algorithm: Dependence of albedo on solar zenith angle, J.G.R., 2009.). We clarify this point in the revised manuscript.

p4613/20: To say that something is "difficult to calculate" is quite honest but not an argument for not doing it. In principle, it would be possible to use the blue-sky albedo provided that for example the high variation of the AOD is parameterized or a climatology is used or another sensor is used or . . .

Author response: We agree that this would in principle be possible. However, as in-

dicated by the papers cited in this paragraph, the difference between black-sky and blue-sky albedo is (usually very) small for a cloud-free sky so we use the black-sky albedo without taking the extra effort.

p4617/18: Now I'm a bit puzzled: If the average difference between the data sets is such as small, it should be better explained and highlighted why using this new database is such an improvement over existing methods. Again, this could be done by showing the impact on retrieved trace gas columns using different albedo data sets within FRESCO+.

Author response: The globally averaged differences are indeed quite small but the regional differences can be substantial as illustrated e.g. by Fig. 4 for South America, North Africa or East Asia. We now show the corresponding impact on NO2 tropospheric VCD over Europe and North Africa in the added section 4.2.3.

p4618/1-12: I like this extra evaluation, also because the authors finally say here something about the impact on trace gas columns.

Author response: Thank you.

p4618/21: It is maybe better to change the order of sentences hereafter. I think it is better to argue first with the better temporal sampling, presumably having the larger impact, than with the different length of analyzed data sets. In the sense of a "climatology" (what we would like to use) these data sets are anyway too short.

Author response: The order of the sentences is changed in the revised manuscript.

p4619/25: Are there any radiative transfer calculations/results quantifying the effect of mineral aerosols?

Author response: A quantification of the effect of mineral aerosols on the TOA reflectance can be found in e.g. Kaufman et al., (GRL, 2001, "Absorption of sunlight by dust as inferred from satellite and ground-based remote sensing"). This reference shows that by introducing realistically absorbing mineral aerosols in the atmosphere,

bright surfaces appear darker than without aerosols. This reference is added to the paper.

p4620/1pp: A general remark about the cloud (types) "seen" by FRESCO+ would be helpful. GOME-like sensors often fail when detecting optically thin (cirrus) clouds. These contribute especially in the tropics to the total cloud coverage although partially being semi-transparent in the VIS spectral range. MODIS on the other hand detects these clouds. The MODIS and MERIS footprint resolution is much higher which will also have an impact on cloud detection.

Author response: We added the following remark in section 4.2.1.: "The global cloud patterns are clearly detectable in both FRESCO+ results, e.g. higher cloud fractions in the tropics and at higher latitudes or the northward movement of the ITCZ in summer. As FRESCO+ retrieves an effective cloud fraction (radiance fraction of a thick cloud with Ac of 0.8, c.f. Sect. 2) the global maps do not represent the geometrical cloud fractions which are usually higher. For instance, cirrus clouds with a low optical thickness are compensated in the FRESCO+ algorithm by reducing the effective cloud fraction. Such an effect would probably not be apparent in geometrical cloud fractions, especially when retrieved from sensors with a high spatial resolution (e.g. MODIS)."

p4625/15: A discussion of the impact of the different albedo climatologies and retrieved cloud parameters on further retrieved trace gas columns should be added.

Author response: This aspect is now covered in the added section 4.2.3.

p4625/13, item 3: Yes, but please present such results in the paper. See also the comment to p4625/15.

Author response: These results are now discussed in the new section 4.2.3 and illustrated in the new figures added there.

p4636: Fig 2: Larger images needed ! One image per double-column?

Author response: We enlarged Fig. 2 to a double column figure.

p4640: Fig 6 a-d): Especially Figures b) and d) are not very conclusive since they look like blue-filled squares only. At least the coast lines should be visible for better orientation. Maybe it is even better just showing images e) and f).

Author response: We removed Fig. a) and b) (FRESCO+ GOME) but left Fig. c) and d) (FRESCO+ MERIS) as an orientation of the absolute value of the effective cloud fractions. The coastlines are now better visible in the up-dated figures.

Interactive comment on Atmos. Meas. Tech. Discuss., 3, 4603, 2010.