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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.

C. Popp et al.

christoph.popp@empa.ch

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We would like to thank reviewer 2 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.

(a) Page 4605, line 26: Replace the word 'Monitoring' by 'Measurement'. The official terminology (esp. w.r.t. SCIAMACHY) is 'Polarisation Measurement Device' for PMD.

Authors response: replaced

(b) Page 4606, line 6: Include reference for SCIAMACHY: Bovensmann, et al., SCIAMACHY: Mission Objectives and Measurement Modes, J. Atmos. Sci., 56, 127–150,

doi:10.1175/1520-0469(1999)056, 1999.

Authors response: reference is included in the revised manuscript

*(c) Page 4606, line 7: Include reference for GOME: Burrows et al.,
The Global Ozone Monitoring Experiment (GOME): Mission Concept and First Scientific Results, J. Atmos. Sci., 56, 1999. and GOME-2:
Munro et al., GOME-2 on MetOp, in: Proc. of The 2006 EUMETSAT Meteorological Satellite Conference, Helsinki, Finland, 12–16 June 2006, EUMETSAT P.48, 2006.*

Authors response: both references are included in the revised manuscript

(d) Page 4608, line 3: FRESCO+ uses an assumed cloud albedo of 0.8 for the radiative transfer calculations. How did you find this value of 0.8? What happens to your retrieval results, if you would increase or decrease this value? How large is the impact on the effective cloud fraction determination, for example? For large solar zenith angles the cloud reflectance is lower than for small solar zenith angles at certain azimuth angles (e.g., 90 deg). How do you deal with that in your retrieval w.r.t. a fixed cloud albedo of 0.8? Moreover, does this fixed cloud albedo mean, that FRESCO+ is not able to detect thin clouds (e.g. cirrus clouds)?

Authors response: The FRESCO+ algorithm cannot separate between the geometric cloud fraction and the cloud albedo (or optical thickness) in a SCIAMACHY pixel, because of the large pixel size (30x60 km2 for SCIAMACHY's O2 A-band channel). This means that either the cloud fraction or the cloud albedo (or optical thickness) has to be assumed. We chose to assume the cloud albedo to be 0.8 (i.e. a high value), since this leads to the smallest error in trace gas retrievals for cloudy pixels, as shown e.g. by Koelemeijer and Stammes (1999) and Stammes et al. (2008). The resulting cloud parameter is the effective cloud fraction, which is a radiometric equivalent cloud fraction, as written on p. 4608/9.
If we would assume a higher (respectively lower) cloud albedo, the effective cloud fraction would be smaller (respectively larger). In this paper, if we would assume a cloud

albedo of 0.9, the retrieved effective cloud fraction is about 0.89 x the effective cloud fraction with cloud albedo of 0.8 (see Fig. 8). This is also discussed in Wang et al. (2011, AMTD http://www.atmos-meas-tech-discuss.net/4/873/2011/).
In general, clouds have a BRDF, so the reflectance is directionally dependent. This BRDF is not (and does not have to be) included in the FRESCO+ algorithm, because the effective cloud fraction is used to correct trace gas measurements for cloud reflectance in the same pixel under the same viewing and illumination angles. So the effective cloud fraction is the pixel-averaged cloud reflectance under the actual viewing and illumination conditions.
We now explain this more clearly in Sect. 2.
In principle, FRESCO+ can detect thin clouds, including cirrus, because it can detect effective cloud fractions down to small values, close to 0. This is not limited by the assumption of the cloud albedo. However, the cloud pressure found by FRESCO+ in case of optically thin clouds is not correct, and is usually much higher than the real cloud pressure due to transmission of light through the thin cloud (cf. Wang et al., ACP, 2008).

(e) Page 4608, line 4: In the RT calculations you use a mid-latitude summer atmosphere profile. Is this profile used for all the retrievals, i.e. globally? If so, then, how does this effect your retrieval results obtained for low and high latitudes?

Authors response: We used the mid-latitude summer atmosphere profile for all the retrievals, because the FRESCO+ look up tables are made using this atmospheric profile. Koelemeijer et al. (2001) showed that the effective cloud fraction does not depend on the atmospheric profile, and that the cloud pressure is 1-2 hPa higher if one would use the tropical atmosphere profile. The reason is that the spectral resolution of SCIAMACHY (and GOME) is insufficient to resolve the temperature dependence of the O_2 A-band lines at a high precision. Because of the other simple assumptions used in the FRESCO+ algorithm, it is considered sufficient to have an error of only 1-2 hPa due to the fixed atmospheric profile.

(f) Page 4609, line 7: Include the following 2 references w.r.t. geometric cloud fractions, namely OCRA algorithm using SCIAMACHY PMD observations:
Loyola, D.: A new cloud recognition algorithm for optical sensors, IEEE International Geoscience and Remote Sensing Symposium, IGARSS, Seattle/WA, 6–10 July 1998, pp. 572–574, 1998.
and MICROS using the synergy between SCIAMACHY and MERIS measurements:
Schlundt et al., Synergetic cloud fraction determination for SCIAMACHY using MERIS, Atmos. Meas. Tech. Dis-cuss., 3, 3601-3642, doi:10.5194/amtd-3-3601-2010, 2010.

Authors response: both references are included in the revised manuscript

(g) Page 4611, line 7: What is the reason for the absence of albedo values for deep ocean pixels in the Albedomap dataset and therefore, also in the MERIS BSA climatology?

Authors response: The reason is that in the Albedomap project the MODIS BRDF parameters (MOD43) are used to integrate the MERIS surface directional reflectance to albedo values and the MODIS BRDF parameters are not available for open ocean pixels. The MOD43 products are processed by the MODIS Land Team and are based on the RossThick-LiSparse-R semi-empirical model to derive the BRDF parameters over land and shallow water. While the RossThick-LiSparse-R semi-empirical model is well suited for a wide variety of land covers other (specular, glitter) BRDF models better describe the anisotropy of open ocean surfaces, e.g. taking into account non-linear parameters like wind speed or the refractive index of water (e.g. Cox, C. and Munk, W.: Statistics of the Sea Surface Derived from Sun Glitter, J. Mar. Res., 13, 198–227, 1954.).

(h) Page 4622, line 22: Replace the word 'Monitoring' by 'Measurement'.

Authors response: replaced

(i) Page 4636, Figure 2: Please enlarge both figures.

Authors response: done.

(j) Scatter density plots (Fig.3,Fig.7,Fig.9): color bar and its labelling (font size) could be slightly larger. The same holds for the labelling of the x and y axes.

Authors response: Colorbar and all labelling are now enlarged

(k) Page 4638, Figure 4: Use a larger font size to label axes.

Authors response: Labelling enlarged

(l) Page 4639, Figure 5 and page 4640, Figure 6: All the figures (a-f) and thus, labels and also color bars, are definitely to small. For the cloud fraction maps I would suggest to use a bright color for drawing coastlines, which would make a comparison between the figures much easier.

Authors response: Figs. 5 and 6 have been improved accordingly.

(m) Page 4644, Figure 10: Use a larger font size to label axes. The color bar is too small. In general, I would suggest to be more consistent in presenting the plots w.r.t. plot and color bar sizes, font sizes, etc.

Authors response: We enlarged the labelling and colorbar and made the plots more consistent.

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