**Atmospheric
Measurement
Techniques
Discussions**

Interactive comment on "Seven years of global retrieval of cloud properties using space-borne data of GOME-1" *by* L. Lelli et al.

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This paper presents, to our knowledge, a unique retrieval using the O2-A band in which 2 pieces of information are retrieved: Geometrical cloud-top height and thickness. In addition, the geometrical cloud fraction is from a DLR algorithm based on analysis of the Polarization Measuring Device (PMD) data of GOME-1. Cloud optical thickness is then calculated using a wavelength of 758 nm outside the O2 A band. As this algorithm is unique, it is of great importance that the resulting retrieved cloud parameters be thoroughly validated.

General comments

In Sect. 2, there is discussion on the fact that when a cloud is modeled as a Lambertian diffuser, that a cloud height retrieval provides a value closer to the altitude of the middle of the cloud. This is certainly a true statement that has been recognized for some time as stated in the manuscript. However, the paper may leave a reader with the impression that cloud top height is the goal of these retrievals. The OMI science team has long recognized that a single piece of information retrieved using similar approaches with UV and visible measurements is not the cloud-top pressure. Note that for OMI two methods are used - rotational-Raman scattering in the UV and oxygen dimer absorption in the visible. We would like to bring to your attention several relevant papers on this topic that have not been referenced.

From the start of the mission, the OMI cloud pressure retrievals were not referred to as cloud top pressure, but rather as "effective cloud pressure". Since then, we have adopted a more descriptive term: the "optical centroid pressure" (or OCP), recognizing that what we retrieve is more similar to a reflectance-weighted pressure (please see papers by Vasilkov et al., 2008 and Sneep et al., 2008). Our latest paper (Joiner et al., 2011) discusses this in detail and provides a fast simulator that predicts the OCP given a profile of cloud optical extinction that can be vertically inhomogeneous or even absorbing. Vasilkov et al. (2004), Ziemke et al. (2009), Joiner et al. (2009), and Vasilkov et al. (2010) exploit cloud OCPs to provide accurate retrievals of total and tropospheric ozone, in particular over snow/ice and to derive ozone concentrations inside the tops of deep convective clouds (in combination with measurements from the Aura Microwave Limb Sounder). In these papers, it is shown that gaseous absorption takes place throughout the volume of a cloud (with many types of clouds being vertically inhomogeneous) and does not stop at the cloud top level. It is demonstrated that the cloud OCP concept (within the context of the mixed Lambertian model) correctly accounts for this absorption if the trace gas is well-mixed within the cloud volume. For convective clouds this is a reasonable assumption. The cloud OCP concept is therefore also appropriate for short-wave flux calculations (Joiner et al., 2009; Vasilkov et al., 2009) whereas the cloud-top pressure is more important for long-wave fluxes. If

the trace gas is not well mixed inside the cloud(s), the vertical structure of the clouds becomes important and cannot be accounted for by a vertically homogeneous cloud model.

In addition, Joiner et al. (2010) shows how cloud OCP may be combined with coincident cloud-top pressure from thermal IR measurements to detect multi-layer clouds. This approach was uniquely validated by using nearly coincident CloudSat radar measurements along with OMI and MODIS data. The paper shows that in some areas, such as over the tropical Pacific, the fraction of cloudy pixels containing distinct multi-layer clouds can frequently be 50% or more at OMI spatial resolution. This paper also shows that the frequency of multi-layered clouds in a pixel increases with pixel size. The occurrence of distinct multi-layer clouds should therefore be a significant issue for GOME-1 given its much larger pixel size.

This leads to a more general question about the SACURA approach - how does the algorithm behave when clouds are vertically inhomogeneous, not only in multi-layer clouds but also in deep convective and other types of clouds? After looking at a large number of CloudSat profiles, we find that the condition of vertical homogeneity is rarely met (see Ziemke et al., 2009 showing average cloud extinction profiles for tropical deep convective clouds that peak at different pressures depending in general on the total optical thickness). This issue has indeed been examined in previous papers by coauthors. However, a more extensive and detailed simulation would be beneficial. We have a set of a few thousand representative CloudSat extinction profiles from a single day that we would be happy to share with you. We used these profiles for our own simulation study in Joiner et al. (2011).

One of the unique aspects of the SACURA algorithm is that it attempts to retrieve more than one piece of information about cloud vertical structure. Most of the paper is devoted to CTH, but the algorithm also provides an estimate of cloud base. This can be compared with cloud base from the ground-based measurements (radar, lidar, ceilometer) that should be quite accurate. Is the cloud base from your algorithm ac-

curate or is it mainly error sink that allows for a better CTH estimate? For instance, what happens when clouds become optically thick in the middle and very little light penetrates to the cloud base? Likewise, what about cloud optical thickness? Have the optical thicknesses been compared with any other standard data sets such as MODIS? More discussion on this should be given.

More discussion on the ground-based data is needed. CTH itself is not a well-defined quantity as the authors acknowledge; IR instruments are sensitive to the radiative height which is not the same as what a lidar measures (see also Menzel et al., 2008). Lidar will not penetrate through a thick cloud. A millimeter-wave radar has more sensitivity in optically thick clouds than a lidar and sensitivity depends upon wavelength. At what wavelengths are these radars operating? In the comparison with ground-based data, which radar is used (Fig. 4)? The number of overpasses selected is quite small. Are these the only overpasses available? How was the selection made? A larger sample size would provide more confidence in the retrievals.

The overall poor agreement between ground-based measurements and GRAPE is disconcerting. The GRAPE algorithm should work well for the deep cloud scenario. We have looked at many MODIS cloud-top pressure (CTP) retrievals (based on the CO_2 slicing approach) over deep clouds as compared with nearly coincident CloudSat data and we see no such errors. Perhaps a comparison should also be made with Terra MODIS which orbits with local time near 10:30. Exact coincidence is not necessary for separate comparisons with ground-based data.

There are differences between SACURA CTH distributions (Fig. 8) and those of lidar, lidar/radar, and thermal IR shown in Stubenrauch et al. (2010). The lidar/radar measurements were screened for subvisible cirrus. Stubenrauch et al.'s plots go to zero-1 km and show a large fraction of clouds at low altitudes for a wide range of latitudes. In contrast, SACURA retrievals do not show high fractions of low clouds (below 5 km) in the northern hemisphere either in winter or summer and do not show many high tropical clouds in the boreal winter. More discussion is needed here.

The CTH PDFs over land in Fig. 11 show a unimodal distribution. Please see references in Joiner et al. (2011) that suggest/show distributions that are bimodal over land. Again, more discussion is needed.

Specific comments:

In Fig. 2, why do the glory and rainbow effects occur only for a limited range of CTH (i.e., not below 6 km and for some angles not above 10 km)?

In Fig. 3, why do the SZAs where the errors peak not match the glory and rainbow angles where the CTH errors peak in Fig. 2? Is there an explanation for the large errors at high SZA?

On p. 5000, it says that only a quality flag of 5 (best convergence) is used. What is the meaning of other values of the quality flag and how does choice of this quality flag value affect the results?

Figs 4 and 5: Would perhaps be better to show differences as a function of cloud fraction and/or cloud optical thickness.

Fig. 6: There are significant differences between SNG and ROC, sometimes positive, sometimes negative, sometimes quite large. The discussion does not explain all the differences. More discussion/analysis would be helpful.

The bottom part of Fig. 6 is hard to see. Suggest breaking it out and showing with larger vertical spacing so that differences (which appear substantial) can be better seen.

Technical corrections:

p. 5006, L 13: typo, negative should be negatively

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