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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.

Anonymous Referee #1

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This paper consists of two parts: At first, a new retrieval of cloud top height through Oxygen A-Band spectroscopy is introduced and validated (part I). Secondly, a seven year climatology of this parameter is derived, and an analytical parameterization is provided (part II).

Apart from minor comments, I found the paper relatively clear and easy to follow. However, there were a few places where further explanations are needed. On many occasions, one could only understand the current manuscript when also reading Kokhanovsky 2007a (or Rozanov and Kokhanovsky 2004). However, if the current manuscript is more than a mere "add-on" to the 2007 manuscript, more details are needed, as specified below. In general, the retrieval section is too short, as is the

validation aspect.

MAJOR COMMENTS

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Part I - retrieval and validation

p4996: As pointed out earlier, all of this work is based on the assumption of water clouds. Therefore, the optical thickness (p4996,l1) may be off. As long as optical thickness is not provided as a final product, that is probably fine, as long as the spherical albedo is correct, which does seem to be necessary for the retrieval (although it's not explained what role it takes for the determination of CTH; Eq. 8 is not based on albedo, but on reflectance).

p4997, Eq. 8 and explanation. In my opinion, there are several shortcomings in this paragraph:

(1) It is unclear how the retrieval actually works. The spectral reflectance comes from Eq. 1, ok. Although it isn't specified in the manuscript (this needs to be done!), I assume that R(h_0) is calculated with the forward model, in this case the analytical formulae from Eq. 2-5. Obviously, R(h_0) and R'(h_0) (Eq. 7) are calculated across the entire Oxygen A-Band wavelength range - is this correct? If so, what is the wavelength range? What is not described well enough is how the formulae for asymptotic theory serve as a forward model that accounts for Oxygen absorption within and above the cloud layer. The authors do mention that the correlated-l concept is used, but how does that work in asymptotic theory? Please provide the missing explanation / formulae.

(2) How is the correlated_k method implemented within asymptotic theory? How is the radiative transfer performed above the cloud layer, with single scattering approximations that are outside the framework of asymptotic theory? In Rozanov and Kokhanovsky (2004), a *semi*analytical algorithm was presented, based on SCIATRAN (which can account for molecular scattering and absorption). How is this done

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with asymptotic theory alone?

(3) Although the reference Rozanov and Kokhanovsky (2004) is given on line 5, this does not explain how the retrieval of {h,l} is actually done *here* - in the same way? In Rozanov and Kokhanovsky, SCIATRAN is used, which is not mentioned in the current paper. Is it correct (as explained in Kokhanovsky et al. 2007a) that one imagine to write the cost function in vectorial form where the rank of the matrix is determined by the number of wavelengths used, and where h_0 is a parameter? If so, this needs to be stated. Also, the wavelength index cannot just be dropped without explanation. Follow the Rozanov and Kokhanovsky 2004 paper (around Eq. 17) to explain this.

(4) In Eq. 8, I am missing "l" as a parameter. How, then, can "l" be found by minimizing F?

(5) How do asymptotic theory and the minimization described in Eq. 8 account for the fact that photons do, in fact, penetrate into clouds, and that clouds are not just a simple "reflector"?

**** If the above points are sufficiently explained, then this method has great potential because using the analytical formulae of asymptotic theory will make non-LUT-based trace gas retrieval techniques that account for clouds much faster and more efficient. However, more work is needed to make the applicability clear to the reader. *****

p4998,l25: A 1% variability of the asymmetry parameter is introduced. Three clarifications are needed:

(1) A 10% variability would be more appropriate since the cloud can be composed entirely of ice.

(2) Is there any spectral dependence of the asymmetry parameter across the Oxygen-A band?

(3) What does Figure 1 actually show? Where does CTH_retrieved come from, where does CTH_true come from? Without clarification, one can only assume that a model

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cloud was placed at altitude CTH_true, and the spectrum was calculated using asymptotic theory. The CTH was then retrieved. Clarifications needed:

(3a) Is this the way it was done?

(3b) Wouldn't is be more appropriate to calculate the spectrum with an independent RT model?

(3c) Is it possible to test various different cloud fractions? Was the cloud fraction in the validation runs set to 1?

(4) Likewise, what does Figure 2 show? Was the forward calculation (using CTH_true) run with one particular g, and the retrieval with another? Again, the range of g's should be larger to account for the possibility of ice clouds, or ice clouds should be excluded from the beginning. Also, further validations should be conducted such as the dependence on cloud fraction.

p4999,l1: Phase functions are mentioned here. But isn't the radiative transfer based on asymptotic theory which relies only on the asymmetry parameter? Why would rainbow features show up in g? Possibly the only way to interpret the red dots in Figure 2 is to assume that the authors did, indeed, use a different model for calculating the spectra that does allow using the full phase function as input, and asymptotic theory for the retrieval. If so, this needs to be stated somewhere.

The validation part should be expanded. The best Figure seems to be Figure 6. But only Delta CF is shown, not CF itself. I would highly recommend to discuss the error in CTH as a function of CF and optical thickness, as well as thermodynamic phase. The dependence on phase is especially important since the entire retrieval algorithm seems to be based on water.

For the depth of the Oxygen-A Band, there are two factors besides the Oxygen absorption itself that matter, both of which are mentioned by the authors, but not sufficiently explained (a) multiple scattering in clouds; (b) 3D effects (i.e., modifications of the path

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length distribution through heterogeneous clouds, especially in scenes with CF<1).

(a) Although mentioned as an advantage of the current algorithm to account for multiple scattering in clouds and the associated deepening of the Ox A Band (p5002,l24), I do not find an explanation how that's done. This needs to be made clear.

(b) p4994,l21-l22 states that 3D calculations are not necessary to account for cloud heterogeneities since GOME has such coarse resolution. This is not the correct explanation. Instead, Kokhanovsky et al. (2007a) state that since the CTH retrieval involves spectral ratios, it is not affected very much by 3D effects, as long as CF is known from an independent source. This statement should be true regardless of cloud fraction and of satellite resolution. I am surprised about the results of Kokhanovsky et al. (2007a) (I would expect a deepening of the Oxygen A absorption lines when running RT in full 3D mode, and not IPA mode), but this is not of relevance for this review. However, Kokhanovsky et al. (2007a) should be cited correctly.

Part II - climatology

* In part one, the algorithm is only introduced for water clouds, but the CTH in the paper have a maximum altitude of 14 km - how does this work?

* Revise the statement "The reliability of the dataset for studies on a regional scale has been illustrated." As stated by the authors (p4998,l16), the GOME retrieval does not work for thin high clouds, and it possibly does not work for ice clouds. While a validation of the algorithm was provided for a case study in part I, the climatology in part II was not validated by an independent dataset. Therefore, I don't think that this statement would be adequate, unless more validation is provided.

* Is it correct to say that clouds with an optical thickness < 5 are not part of the climatology? This means that Ci are almost entirely excluded, correct?

* When providing an average CTH, provide the range of optical thickness for which this was provided, and whether the "average" CTH is weighted with respect to optical

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thickness.

MINOR COMMENTS:

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p4992,l2: "clouds": specify which clouds (water/ice)

l12: Insert "the" before "Pacific"

l19: delete comma after "but"

p4993,l5: replace "moderate high" with "a"

p4998,l9: replace "through" with "throughout"

l20: replace "particles" with "particle"

l20-l21: "For this reason. . .appreciably." Fix English - is the word order off?

l26: replace "discloses" with "show"

p4999,l19-l20: Provide a little bit more detail about this.

p5003,l18-20: I don't understand this statement. Does it imply that even though the retrieval is only valid for water clouds, it will function because water clouds are somewhere to be found in this data set?

p5004,l29: replace "hemisphere" with "hemispheres"

p5004(l29)-p5005(l1) Fix word order ("appear") should not be placed at the end of the sentence.

p5005,25: replace "variations, nevertheless" with "variations. Nevertheless"

p5007,l1: replace "as well" with "either"

Interactive comment on Atmos. Meas. Tech. Discuss., 4, 4991, 2011.