Review on manuscript "Probing the sensitivity of polarimetric O2 A-band measurements to clouds with emphasis on potential OCO-2 and GOSAT retrievals" by S. Sanghavi, M. Lebsock, and G. Stephens"

The subject of the manuscript is very interesting and original and totally correspond to the topics of the Atmospheric Measurements Techniques journal. The authors discuss the sensitivity of O2 A-band polarimetric measurements at the top of the atmosphere to cloud parameters such as optical depth, effective radius, layer altitude and geometrical thickness, which is to my knowledge the first paper on this topics.

Unfortunately the paper suffer from a lack of rigor, there are a lot of errors or misleading affirmations and conclusions. There are too many figures which are for most of them usefulness, and even not really discussed in the text. If I refer to the evaluation criteria of the AMT journal I recommend not to publish the paper in his present form. The manuscript needs a significant revision before reaching the scientific level of the journal.

Major comments:

- Some results shown on different figures make myself wondering on the validity of the overall paper. It is for example well known that as the particle radius increase (or the mie size parameter x increase), the scattering phase function of spherical particles (element F11 of the scattering matrix) increase in the exact back-scattering direction or at least it do not decrease (e.g. at scattering angle = 180 degrees), which is note the case on figure 18! Concerning the F12 element the result shown on this figure 18 are questionable, indeed in the rainbow region (scattering angle around 140 degrees) the F12 element decrease as the particle size increase, which should be the opposite (see Hansen and Travis (1974))!!! There are also strange behavior on figures 20 and 22 in regards of figure 18, especially for view angle between 0 and 40 degrees. Why Q = -0.01 at theta view = 0 whereas figure 18 shows that at this angle the cloud F12 is almost null (or at least positif) and the rayleigh F12 is positive, it would be interesting to see the same figure for a pur rayleigh atmosphere and a cloud without rayleigh.

- The last section, section 5, greatly disappointed me because of many wrong conclusion especially in regards of Q (see specific comments below), the authors really need to raise the scientific level of this section.

- Some other figures can lead to wrong conclusion because the studied quantity mix two different effects. For example for figures 7 to 16, authors looked at the effect of different cloud parameters on the measured I (intensity) and Q/I (degree of polarization). The problem of looking at Q/I is that they mixed the effect of cloud parameter on polarization Q and intensity I which can be opposite. By looking such quantity one can have wrong deduction on the polarized signal due to I. The author should look only at Q!! especially for consistency because in the last part of the manuscript they do not analyse Q/I but Q!!!

- The authors do not talk about measurement noise at all, neither about the effect of the radiative transfer model accuracy on the sensitivity study. For example it is well known that when dealing with large particle in the visible part of the spectrum (large mie size parameter), to reduce computational time one need to truncate the element of the phase matrix (there are different method for that), this truncation affect the accuracy of the computation, especially when looking at polarization. What are these effects on the results presented in the manuscript?

- The author talk about sensitivity throughout the manuscript, but to my point there are not looking at sensitivity but absolute value. A sensitivity is the variation of the signal due to a small change in the studied (cloud) parameter. S=dF/dx (what Rodgers calls the Jacobian). This study would have been much more interesting if the authors would have studied real sensitivity (or normalised sensitivity as dF/dx * x/F).

- The authors argued that they studied the entire cloud state space which is far to be true, first because the discretisation of each cloud parameters is too large (5 median cloud droplet, 4 cloud optical depth, 6 top layer altitude and 3 geometrical thickness), and second because the range of some cloud parameter are not representative of the natural variability (e.g.the geometrical thickness for example). The cloud layer altitude range between 2.4km to 12.4 km, but are the particles still liquid (and then spherical) at 8.4, 10.4 and 12.4 km? Moreover the author should address the effect of the width of the size distribution on their results, because this parameter has an important effect on polarization.

- I am wondering what section 2 bring to this study, especially when the authors conclude "While this served as a good assumption to study the nature of the individual lines constituting the O2 A-band, it does not suffice to describe backscattering by actual clouds, which are better represented by a vertical distribution (ignoring variations in the two horizontal dimensions) and as a distribution of differently sized droplets. In the following section, we explore the scattering characteristics of a (liquid) cloud as a function of the size of its constituent droplets ».

The authors can find below some specific comments on the text, which are not especially minor comments.

- page 9604, line 8: what is the cloud parameter called « viz. »?
- page 9609, line 7: we do not see the altitude 30km on figure 2, by the way this figure is very hard to understand. you missed « km » in the legend.
- page 9609, line 24: When looking at figure 3 the the critical value of tau_abs is 0.3 and not 1.15, why?
- page 9610, line25: Why choosing these values for the imaginary part of the refractive index? I do not see what the discussion about these imaginary part of the refractive index bring to this study? Do we need figure 4, it is a well known figure that everybody can find in different book (e.g. Van de Hulst, Lenoble, Hansen and Travis, ….).
- page 9611, line 10: Why choosing this particular value of the width sig0=1.13?
- page 9611, line 12: rho(r) is not a probability but a probability density function (PDF), rho(r)dr is a probability!
- page9612, line 1: The authors choose to plot Pv and Ph, because OCO-2 is measuring Iv and Ih, but to understand what polarization bring in the O2 A-band, one has to work with I and Q. In the manuscript the authors use both (Iv,Ih) or (I,Q) convention, which make the manuscript sometime confusing, it would help and clarify the manuscript if the authors choose to use only I and Q, which are well known in the community. This would reduce the number of figures and would make the manuscript more consistance. So I would recommend to show directly F11 and F12 instead of Pv and Ph.
- page 9612, line 24: Why choosing a solar zenith angle of 60 degrees?

- page 9613, line 7 and 8: Be consistent, Q/I is called some time polarization response or degree of polarization. Again when looking at figure 7, one could think that high absorbing wavelength are highly polarized which is not the case, it is just due to very small value of I (see major comments).
- page 9613, line 25 to the end: The explanation of why Q is only sensitive to the first fews order of scattering is confusing. Q is not diminishing with high order of scattering, but the contribution of higher order of scattering to Q at the top of the atmosphere. I do not understand the sentence « … due to the blurring of the differences between the components Ih and Iv». The authors should read Chandrasekhar (1960) to understand why after few order of scattering the light becomes unpolarized.
- page 9614, line 20 to 22: What is happening if the geometry of observation fall in the rainbow region where the liquid cloud polarized the light? You should discuss this case.
- page 9614, line 24: On figure 8 I like the representation of the radiance as a function of total column absorption, but could you explain what is the large discontinuity around tau_abs = 15 or 25, especially for ztop = 12.4km.
- page 9615, line 10 to 17: In the text the authors explain the physical difference between I and Q, which is interesting, but the figures do not depict I and Q but I and Q/I, which make difficult to relate the text with the figures. Again by looking Q/I instead of Q one can miss interpret the polarized signal due I (see major comments).
- page 9615, line 24: Do we still have spherical particles for a cloud top layer at 12.4km?
- page 9616, line 7 to 12: The authors should explained what is a « maximum sensitivity », again here we are not looking at sensitivity, but absolute value. Is this « sensitivity » be the same if the geometrical thickness is greater that 0.6km, which is often the case? Nothing to say about the effect of deltaz on the polarized signal?
- page 9620, line 7 to 10: The authors says exactly the inverse of what we can see on figure 19 and 21. Figure 19 shows that for low optical depth there is more « sensitivity » to r0 mainly for theta view < 0, whereas for larger optical depth (fig. 21) both backscattering and forward scattering seems to be « sensitive » to r0. Which is something I do not understand … are there the right figures?
- page 9620, line 16-17: Why would the size dependance intensity diminish with increasing theta view for the small optical depth case? The intensity of such cloud is driven by single scattering, which is driven by F11, and F11 shows increasing size dependance at such angle!!!!
- page 9620, line27 to page 9621, line 6: I do not understand this explanation, cloud you rephrase it. Which aureoles are you talking about?
- page 9621, line 14: why are we studying Q now and not Q/I ??
- page 9621, line 18: First time I see the peak around 90 degrees in scattering angle on Q! Can the authors explain why Q would be negative at theta view = 0 degree, whereas neither the cloud or molecules show negative F12?? By the way Q is positive in the rainbow region as the F12 for cloud and rayleigh! The authors need to give a robust explanation on this behavior around 90 degrees in scattering angle. I need to see the same plot but for rayleigh alone and cloud alone!
- page 9621, line 23: The authors has to give a robust explanation on this behavior, why the polarization in the rainbow is stronger for small particle???
- page 9622, line 5: Be careful to what you say, it is not the nadir view which is insensitive but the geometry of observation for which the scattering angle is equal to 120 degrees, for another solar zenith angle the nadir view would be sensitive.
- page 9623, section 4.3: Nothing is said on the advantage of high resolution measurement to retrieve cloud optical depth … for exemple when the ground contribution is not well known.
- page 9624, line 1: First, on figure 23 the caption seems to me very short! Second, I think that

figures 25 and 26 are usefulness. Third, the problem of such representation is that the color bar could be misleading because the range (from red to blue) for each figure is different, and therefore a color variation can be badly interpreted as « sensitive » whereas the absolute variation is very small. The authors should have plot true sensitivity or normalized sensitivity in order to have a unique color bar from 0 to 1. This would benefit for the comparaison of different cloud parameters sensitivity!!!!

- page 9624, line 20: If I understand the color bar from figure 23, the blue color is low « sensitivity » and red large « sensitivity », so why on figure 24 the authors reverse the color panel!!!! Please be consistent and rigorous!!!! Maybe you should have plot the absolute value of Q…
- page 9624, line 27: The authors state that "Sensitivity to droplet size is greater for smaller r0 » THIS IS WRONG, the larger value of |Q| is for large r0!!!!!! This error on the color panel lead to wrong conclusion!!!!
- page 9625, line4 to 10: Remove this paragraph, the conclusion is wrong because the authors do not think with true sensitivity, I mean a variation of the signal due to a small variation of the parameter!
- page 9625, line 12: On the fourth panel of figure 27, the variation of I from red to blue is 6.5610^-4 to 6.5610^-4!!!! We can see the same thing on figures 28, 29, 30… How can we conclude about sensitivity with such variation????

The author have to re-interpret this part completely in regards of polarization, because a lot of conclusions are wrong to my point. I am stopping here the review, this is too bad because the subject is interesting….