Review of Ding et al, for AMT, 2016

Passive satellite measurements of backscattered solar radiance provide information as to the total loading of aerosols in the atmosphere. Recent research has suggested that the use of oxygen A and B bands (O2-A and O2-B) can help to derive vertical profiles of aerosol, and future satellite missions may have these capabilities. This paper attempts to quantify the information content provided by backscattered radiance and degree of linear polarization (DOLP) in the O2 A and B bands, for the problem of retrieving aerosol vertical profile. Quantitatively, DOLP in O2 A and B bands is found to be more sensitive to aerosol peak-height (H) and half-width (γ) than radiance itself, especially over the bright surfaces (with large visible reflectance). Assuming the surface and/or aerosol column (optical depth) is well constrained, the sensitivity increases with H. Further analysis demonstrates that more measurements in more bands helps to increase signal.

Major comments: I have very few, if no major comments. I think this paper is a very well written paper, and very informative. I was on a roll for identifying minor issues (comments below, e.g. run-on sentences), but ran out of steam by the end.

- There are a few plots I would like upgraded, but mostly it is plotting style rather than content. I would like to see the "baseline" of black surface (As = 0.0), even though as I work through the paper, I understand that complete absorption is like creating its own black surface. I think the colors (red, green, blue) are overused in the plots, as sometimes it represents different surface, and otherwise different altitudes/levels.

- Overall, I am very satisfied with the introduction, as well as the theoretical and discussions in Figures 1, 2 and 3. But then there is section 3.4, where discussion seems to "speed up". Each figure has decreasing amount of text associated with it. Figure 11, in particular, should include more discussion.

- The summary is weak. The purpose of the study (to be ready for future satellite missions that have O2-A and B capabilities) is well defined in the introduction. So now that you have done this study, what next? How might you apply the retrieval to real data? Do you see any collaboration with data from other instruments? For example, what about OMI-type measurements in the UV that are sensitive to aerosol height and loading? Since the EPIC instrument has O2 bands, plus UV bands, and PACE should have both, plus DOLP, you really are on the cusp of something very special.

- For the final sentence, something stronger than "For future studies, real measurements of DOPL in O2 A and B bands are needed to further evaluate their potential as well as their combination with DOLP in atmospheric channels for retrieving aerosol profiles over land."

Medium comments and questions

- What is the relative vertical distribution of molecular scattering versus molecular absorption (e.g. Fig 1e/f)? This would provide physical intuition to these figures.

- I wonder about the utility of trying to calculate DFS when you combine radiance and DOLP together? Right now they are separate, but a real retrieval might use both sets of information. On a side note, I wonder what happens if you already have AOD "perfectly" measured (or retrieved), how will that influence the DFS?

- I did not check the equations related to Jacobians, so I have no comments in that section. Someone with the requisite background should check these equations.

- Could this retrieval be performed above a cloud? (say a boundary layer cloud, where $As \rightarrow 1.0$)?

- There is a mention about "measurement error of 0.05" (line 199). What does that mean?

- Related to measurement error, normally an instrument will have an expected accuracy for typical reflectance (e.g. 2% for something like MODIS) or polarization (expected 0.5% for APS). What are the tolerances that can be accepted here? Since the idea is to work in hyperspectral space, how accurate does the wavelength characterization need to be (for example, could instrument be wrong by 1 nm, or 0.1 nm?)

- I think the physics/intuition can be explained a little bit better. I provide some suggestions below.

Minor comments: Note line numbers - probably an AMT format issue, but the line numbers are only two digits. I do my best to guess the hundreds digit in my comments.

- All: Suggest writing as "O2-A" and "O2-B" bands, (without the "-" the A and B modifiers tend to dangle off by themselves in some sentences).

- Lines 29-32: Is a run-on sentence. Actually there are scattered run-on sentences throughout the manuscript. (e.g. line 93-98).

- Line 32: Is IPCC, 2014 the right reference? Usually people do IPCC, 2013 for the science, and 2014 for the policy.

- Line 42: Instead of "obtain the information", maybe "observe" (I could obtain the information from the model). I guess I could also propose a high-resolution network of ground/aircraft monitors, but probably would be super expensive!

- Lines 57-58. What is the O2-A band, anyway? Where is it (spectrum) and why is it called the O2-A band? (Same with O2-B band). Is it O2 absorption only, or is it also other constituents that absorb? (info later in paper, but could use a short description here).

- Line 99. Currently awkward. How about writing "Our study is different from past studies in two ways".

- Line 102-104. "potential of radiance in in O2 A…" is awkward. How about: "While Sanghavi et al. (2012) and Vasilkov et al. (2013) have demonstrated that measured radiance in O2 A and B can be used for retrieving aerosol profile over dark surfaces, ours is the first to test whether DOLP in these bands can add information."

- Lines 106-112- Another run-on (too many subjects in one sentence). And should be "Fourier".

- Lines 150-162: Suggest to use bullets for readability?

- Lines 199: I don't understand what is a "measurement error of 0.05". Are there units? Is this in reflectance, or in DOLP?

- Lines 205-ish (and Table 1). Normally, one reports the center radius and the variance to calculate the size distribution, drive a Mie code, and calculate the effective radius.

- Line 220 – What kind of aerosol has peak height of 16 km? Volcanic ash? While I am thinking about very high altitude aerosols, what about cirrus clouds? If they are present, what would happen to aerosol retrieval?

- Line 230: (and Figure 1). Misspelling of wavelength. I am curious if information would be more clear, if plotted panels A/B on same vertical scale, and C/D on same vertical scale. Also, I wonder if "penetration altitude" is the best term for the variable plotted in panels C/D. I find the term misleading. Unfortunately, I have no suggestions for a better term. This is for nadir (solar zenith angle = 0) ?

- Page 235: I am not following this logic: "Hence, the spectral contrast of reflected sunlight in terms of their intensity and polarization contains information of atmospheric scattering (including aerosol scattering) at different altitudes of the atmosphere (Figure 1 e-f)." The figures are as a function of absorption optical depth, so we need some sort of information about the scattering profile, (maybe it could be plotted on the same graph as a black dotted line?) And then this might help answer my next comment as well

- Lines 240-ish (and Figs 1-e/f) reads: "Figures 1 e–f the DOLP at the top of an aerosol-free atmosphere over various surface types (with reflectance from 0.05, 0.2 to 0.5) as a function of molecular absorption optical depth. It should be noted that the O2 absorption is much larger than the Rayleigh scattering optical depth in both bands." Molecular absorption refers to O2 only. Molecular scattering (Rayleigh) refers to other gases as well. What are typical values for scattering optical depth in these bands (how much larger is absorption than scattering?).

- Lines 245-258: I think the explanation mostly makes sense here. In a molecular scattering atmosphere above a black surface, the DOLP can attain its maximum value (For completeness, I would like to see a curve with As = 0.00 – analogous to an ocean scene?) As soon as one adds a surface target, the polarization signal gets muted. Hence, DOLP gets reduced. But I am having trouble understanding why as you add absorption to the path, why DOLP is increased? I guess what is happening is that the super thick absorption acts like a black surface?

- Lines 265-269 and Figures 2a-b: I am satisfied with the figures and explanations, except for the colors. In Fig 2a, Red, green, and blue curves are different Hpeak values, whereas in 2b, 2c, the same colors represent different As values. Suggest different colors, or at least different line styles for each set of figure panels.

- Figure 3: I would suggest making a Figure 3.5, which has the same panels, but for a continuum wavelength.

- Line 318: Why not perform a test for only radiance in the O2-B band? And then a part (e) would be radiances + DOLP in both bands. To make more readable, maybe could be written as bullets.

- Line 325 (and Fig 4): What do you mean by number of channels? I understand this is hyperspectral, but what are the channel widths? This information is stated more clearly later in the paper, but it could be useful here.