EGUsphere, referee comment RC2
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Comment on egusphere-2022-207

Anonymous Referee #2

Referee comment on "Polarization performance simulation for the GeoXO atmospheric composition instrument: NO_2 retrieval impacts" by Aaron Pearlman et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-207-RC2, 2022

The authors present a closed-loop simulation study on the sensitivity of NO2 retrieval on instrument polarisation, for a future hyperspectral instrument with a small polarisation sensitivity of 5%.
This study is significant to give orientation in the definition/verification of instrument requirements for future missions.
The paper is generally well-written, but a few details are sloppy. There is a large amount of back-and-forth information, which sometimes makes it confusing for the reader, and this could be structured better.

General comments:

- In section 2, several simulation methods are given, which include a multitude of parameters.
  In section 3, the results of these simulations are presented. Here, the references to simulation parameters are given by (only) partly repeating these from section 2. At initial reading, this causes difficulty and a lot of back-and-forth reading in relating the results to the simulation parameters. And I still have to guess.
  I strongly suggest to make this more structured, by clearly itemizing in section 2, like "simulation A: ...", "simulation B: ..."
  and then referring to these cases in section 3
- It is shown in the paper that instrument polarisation sensitivity mainly affects the AMF retrieval, not the NO2 slant columns.
  In this study, the polarisation sensitivity enters NO2 vertical column through the retrieval of cloud fraction.
  But in operational retrievals, also the cloud altitude and(or) cloud optical thickness must be derived.
  Especially for cloud retrieval that uses information from polarised radiance (e.g. rotational raman scattering or deep absorption bands of O2) it may be expected that instrument polarisation plays a role. It is understood that the cloud retrieval algorithm for an instrument in initial development is TBD and simulations are premature. Nevertheless this should be mentioned explicitly.

Specific comments:

- Figure 2: Surface spectra are shown here from ~400 to 3000+ nm. But the NO2 retrieval window is 420-455 nm and from these figures it is impossible to see any spectral structure there. Please reduce the spectral range of the figure and comment on the surface spectral resolution.
- lines 160-175: here the description becomes confusing/sloppy:
  AMF in line 163 seems to be the height-dependent box-AMF which in Eq.(10) should be written as function of *z*.
  What is the relation between AMF_tot in Eq.(7) and AMF_total in Eq.(10) ? Meant is probably that Eq.(7) in incorporated in Eq.(10). I suggest to write this out in Eq.(10).
  In order to explain the alpha in Eq.(10) I suggest to say beforehand that the formulation follows Kuhlmann 2015.
  In line 175, should not ∂AMF_tot be ∂AMF_total, and is its only dependence on PS through Eq.(8) ? Please rewrite to make that explicit.
- section 2.2.2:
  - were the same aerosol parameters as for clear sky used? or no aerosol at all?
  - it is tacitly assumed that cloudy pixels have unpolarised radiance. Please mention/explain this explicitly.
- line 208: "other retrieval techniques that do not use a spectral fitting approach" should be
  "other retrieval techniques that do not use a polynomial correction term in the spectral fitting approach"
- Figure 5b. Why is the standard deviation over Water so much smaller than over Land? Usually the reflectances over water are smaller so S/N should be worse, unless you force S/N to be constant (as suggested in the text). Or is something else the case like an aerosol effect or a spectral surface effect? Please explain.
- section 3.2 . Confusing: which simulation from section 2.2.2 was used to generate Figure 7 and which one for Figure 9 ?
  See my general comment.
  Figure 7 has fixed surface type thus seems to be the second simulation from section 2.2.2. Figure 9 uses GEOS-5 data thus also seems to be the second simulation ??
  What means " water, rural, urban scene covers CONUS [...] for each surface? use for each grid cell the most abundant type?
  What means "with a fixed scene type over the CONUS grid" ? use 1 type for all grid cells?
  Please provide a bit less condensed description.
- line 220: parenthesis typo in Zoogman reference
- Retrieval results for Figure 6: Is it correct that these simulations were done with a small (<0.04) cloud fraction? "Cloud radiance fraction" refers to the retrieved result (doesn't it ?). Please specify which cloud fraction was used in the forward simulation for this figure.
- Figure 8: data for NO2 amounts 0f 5.0E+15 and 8.6E+15 are difficult to read in this figure. Is the relative error ("percent error") approximately equal for all three NO2 amounts? Please adjust figure or mention in the text.
- Retrieval results for Figure 9: are these retrievals with "fixed scene type" as suggested for the scenario with GEOS profiles in line 181? That would not be very realistic. If water is used for the extreme East/West (Atlantic/Pacific) why are the errors so much smaller than in fig 7c? Your text says "The higher cloud fraction decrease the retrieval errors" but also clear scenes at high solar zenith angle have much smaller errors. Is this because of the NO2 amounts? It would be useful to show a figure with NO2 input

column.