

Thank you very much for your thoughtful and detailed comments. We believe the changes we will make (as detailed below) will improve the manuscript substantially.

#### Referee #1 comment responses

The description of the instrument (response) model in Sect. 2.1.2 gives very little details and there is no reference to a more detailed description.

We will modify the first paragraph of this section so that it reads:

"The reference radiance spectra corresponding to the NO<sub>2</sub> reference amounts over water, rural and urban scenes were modified by applying the instrument model (for several US locations). The instrument response model was based on the TEMPO design, which consists of a reflective f/3 Schmidt-form telescope and a spectrometer assembly that utilizes a diffraction grating to form an image on CCD detector arrays (Zoogman et al. (2017)). The simulated radiance was modified by this instrument response model, which sampled the radiance at 0.2 nm wavelength steps with a resolution of 0.6 nm, and applied a PS response.<sup>125</sup> The PS response model was not specific to TEMPO as our goal was to understand the range of impacts associated with the ACX polarization requirements. The noise was also applied as defined by the ACX signal-to-noise (SNR) specification. Our instrument parameters from TEMPO were modified by assuming a sampling strategy or integration time modification that brought the noise in line with that specified by ACX. Table 2 shows the parameters included in this model."

Note that a reference was included that details the TEMPO design:  
Zoogman 2017 <https://doi.org/10.1016/j.jqsrt.2016.05.008>

How does polarization influence the measurement?

We will add more intuitive description of the influence of polarization before introducing the formalism: "If the instrument is sensitive to light with a certain polarization, this variation in degree of linear polarization translates to a variation in measured radiance throughout the day. Thus, limiting the PS of the satellite sensor can limit the radiometric uncertainty. "

What kind of spectrally-dependent polarization features may be expected? What knowledge is available from GEMS and TEMPO, instruments that do not have a polarization scrambler? Could a figure be provided showing polarization sensitivity (PS) vs. wavelength?

The expected polarization sensitivity spectrum will depend on the ACX architecture yet to be developed. Although we used TEMPO-like parameters for assessing noise impacts, we chose to keep the polarization analysis general to give early assessments without constraining to a particular architecture, since this can vary widely depending on the optical components in the optical path. As noted the Mueller Matrix will be used once it is modeled or measured to give a more accurate and complete description.

#### Minor comments

Page 1, line 5: Given the formulation of names and acronyms of the other instruments, it is more logical to write "... and OMI (Ozone Monitoring Instrument), ... "

Agreed. We will modify.

Page 2, line 26: Given the formulation of names and acronyms of the other instruments, it is more logical to write "... such as TROPOspheric Monitoring Instrument (TROPOMI), ... "

Agreed. We will modify.

Page 2, line 27{28: The "GEMS" discussed by Hollingsworth is an entirely different GEMS than the Korean geostationary spectrometer. Please add an appropriate reference for GEMS. The paper of Hollingsworth is more appropriate for line 30.

You are correct. The reference was not appropriate. We will substitute Kim et al 2020 (doi: 10.1175/bams-d-18-0013.1) and move Hollingsworth reference to line 30.

Page 2, line 35: The paper by van Geen et al. (2020) describes the TROPOMI NO<sub>2</sub> retrieval and is more appropriate in line 26.

We will substitute a different reference that we believe is more relevant (Crutzen et al. 1979)

Page 2, line 51: Since both GEO and LEO have been spelled out in line 25, the line can read "... in both GEO (...) and LEO, though ... "

Agreed. We will modify.

Page 3, line 62: For clarity please write "... its circular polarization through ... "

We will modify.

Page 4, Sect. 2.1.1: The light scattered by the surface may also become partly polarized. An example is the scattering by a water surface (e.g. principle behind Polaroid sun glasses). Is this taken into account, and could this affect the analysis?

This effect could be taken into account by specifying a bidirectional polarization distribution function. We have not yet implemented such a model in our simulations. These could have some affect – perhaps on the order of 1% difference in the degree of linear polarization. We chose to neglect this effect in the interest of simplicity but will consider including for future works.

(See Maignan et al. (<https://doi.org/10.1016/j.rse.2009.07.022>) and Litvinov et al. 2011 (<https://doi.org/10.1016/j.rse.2010.11.005>))

In the conclusion, we will add "In addition, the limited set of surface reflectance types that were used and the directional and polarization surface effects that were neglected, can be included in future work to improve the accuracy of the results."

Page 5, line 110: A space is missing in "shrubs(30%)"

A space will be inserted.

Page 5, Table 1: Please explain the parameters AOD and sigma. Are the aerosols a mix of scattering and absorbing aerosol types?

“Loading” will be replaced with “aerosol optical depth (AOD)” in the text and the acronym will also be defined in the footnote of the Table. We will also add the mean index of refraction for the aerosols to show their absorption properties.

Page 6, line 132: The second occurrence of "all" at the start of the line needs to be removed

Will be removed.

Page 7, line 145: Surely the cloudy radiance  $L_{\text{cld}}$  is meant here.

The symbol will be changed.

Are these radiances polarized, or unpolarized? Would that influence the result?

The predicted radiance terms are derived from the unpolarized component. This would only affect the result if the instrument were designed to measure the polarization state.

Page 7, line 150: A comma is missing in ". . . cloud radiance fraction,  $f_r$ , . . . "

We will insert a comma.

Page 8, lines 171{172: The "temperature correction" appears out of nowhere and it is not clear what it refers to. Is it related to the temperature dependence of the NO<sub>2</sub> cross sections, which is compensated by a temperature correction term in the AMF calculation in the NO<sub>2</sub> retrievals of e.g. OMI and TROPOMI?

Yes. This refers to empirical temperature correction coefficient accounting for the temperature dependence of the NO<sub>2</sub> absorption cross-section. We will add this description to the text. “A correction term,  $\alpha$ , is normally included in the AMF calculation to account for the temperature dependence of the NO<sub>2</sub> cross sections, though was neglected here by setting it to one”

Page 8, line 173: The sentence is a little difficult to follow; suggest to write "This error can be considered as the change in radiance the PS effect leads to, which . . . "

Agreed. We will change to “This error can be considered the effect of a change in detected radiance due to PS, which, in turn, leads to an error in the interpretation of the amount of clouds in the scene.”

Page 8, line 175: You write: "Note that this changes negligibly as a function of wavelength". Why? Could the instrument polarization response ( $m_{01}$ ,  $m_{02}$ ) not be strongly wavelength dependent?

The NO<sub>2</sub> retrieval errors could indeed vary if the PS changes as a function of wavelength. In this study, having no such information, we assume a constant PS parameters with wavelength. We will clarify “Note that assuming a constant polarization sensitivity over the wavelength range, this error will also change negligibly as a function of wavelength..”

Page 9, line 195: A comma is missing after "respectively"

Will change.

Page 9, line 199: You write that  $m_{01} = \_PS$ . Is PS a constant here, independent of wave-length. Why?

See the comment above.

Page 10, figure caption: For clarity suggest to write "(blue line and right axis)"

Will change.

Page 11, line 220: Parenthesis are missing around "Zoogman et al. (2017)"

Will change.

Page 11, line 224: The second occurrence of the word "cases" can be removed

Will remove.

Page 13, Fig. 8: These plots are not so easy to understand. Could you explain the shaded regions in more detail?

Will add the sentence "The shading is meant to emphasize the difference between the reference and retrieved amount."