

## Interactive comment on "Improved slant column density retrieval of nitrogen dioxide and formaldehyde for OMI and GOME-2A from QA4ECV: intercomparison, uncertainty characterization, and trends" by Marina Zara et al.

Marina Zara et al.

zara@knmi.nl

Received and published: 8 June 2018

## Response to Anonymous Referee #2

We thank Anonymous Referee #2 for the evaluation and recommendations, which helped to improve the manuscript. In the following, a point-by-point reply is given. Page and line numbers in the replies refer to the marked-up version of the manuscript.

1. P1, L35, you may add something like "due to higher measurement signal to noise ratio" to explain it.

C1

Thank you. The sentence now is: We find that SCD uncertainties are smallest for high top-of-atmosphere reflectance levels with high measurement signal to noise ratios (P1, L34).

2. P5, L10, suggest changing the sentence "...is such that...is possible" to "...makes...possible..." to make it more readable.

We would like to keep the original expression because we feel it stresses the "causeeffect" type of relationship between the signal-to-noise ratio levels and achieving a spectral fit (P5 L14).

3. P6, L6, suggest changing "achromatic" to "wavelength independent" to make it easier to understand.

"Achromatic" is now replaced by "wavelength independent" (P6 L11).

4. P7, L1, you may add something like "improvement of cloud retrievals using measurements in O2 bands" before ", Additionally" as this is one of the main advantages.

This is a good remark, but we believe it does not fit in the section about the instrument and the quality of level-1 data.

5. P8, L13-14, it was mentioned that high-pass filter is applied. But it is not reflected in equations (1) and (2), probably omitted? Please also clarify if the high-pass filter is applied to the trace gas cross sections.

The polynomials  $P(\lambda)$  in Eq. (1) and  $P^*(\lambda)$  in Eq. (2) effectively act as high-pass filter (added in Line 31 P11). For the intensity fit, absolute cross sections are used. For the optical density fit, differential cross sections are used. They result from subtracting a polynomial (not the DOAS fit polynomial,  $P^*(\lambda)$ ) from the absolute cross sections.

6. In Tables 2 and 3, it might be useful to add the reference used in the fitting, e.g., average irradiance, monthly average irradiance, daily Earthshine radiance.

For Table 2: Done (see P10; footnotes); For OMNO2A v1&v2 and OMINO2-QA4ECV

the reference spectrum is the 2005-mean solar irradiance spectrum. For OMINO2-NASA, monthly averaged solar irradiance spectrum is used as reference. Lastly, for GONO2A-BIRA and GONO2A-QA4ECV daily solar irradiance spectrum is used as reference.

For Table 3: The reference spectrum used in each spectral fitting algorithm is already mentioned as footnote in Table 3 (P13).

7. P12, L20-25, although Sun et al. (2017) shows that the slit function is stable over time, it also shows that derived in-flight slit functions are quite different from pre-launch slit functions especially in terms of cross-track dependence. Has the use of derived slit functions prior to the fit been tested as implemented in the GOME2 algorithms used in this study?

We have done limited tests using the "stretched preflight slit function option" for the NO2 fit. As can be seen in Sun et al. 2017 (Fig.3), the impact in the VIS is small (405-465 nm), and the row dependence is very weak. The impact on the NO2 slant columns is almost zero.

8. P16, Figure 2, what causes the relatively large difference between statistical and DOAS uncertainty in Northern high altitude in OMI data and in Southern high data in GOME-2 data?

Figure 2 on Page 17 represents the differential HCHO slant columns themselves, not their respective statistical and DOAS uncertainties.

9. P17, L19, does A only include absorption cross sections? How about the Jacobian for other parameters like wavelength shift?

Matrix A is formed by the cross-sections and the measurements errors (which are largely random (noise)). Equation (4) does not take into account systematic errors, which are mainly dominated by slit function and wavelength calibration uncertainties, absorption cross-section uncertainties, by interferences with other species, or by un-

СЗ

corrected stray light effects (e.g. De Smedt et al., 2018). Uncertainties on estimated values of the nonlinear parameters (shift, stretch, intensity offset parameters) are not taken into account in the reported errors on the slant columns (Danckaert et al., 2017).

10. P17, L25, you may add examples of non-linear parameters in the parenthesis.

The shift, squeeze and intensity offset parameters are now added in the text as nonlinear parameters (P18 L12).

11. P19, L8, has V3.1 been released?

Not yet. NASA has advised users to not use the v3.0 SCD uncertainties.

12. P20, Figure 3d, why DOAS uncertainty for NASA algorithm does not change much with latitude? Have some of systematic uncertainties been removed in the fitting (e.g., destriping, common residuals) so that DOAS uncertainties are even smaller for 40S-40N?

NASA DOAS uncertainties have indeed been post-processed, accounting for systematic effects. NASA removes common residuals from the OMI reflectances during the SCD retrieval. Moreover, such residuals are treated as solar zenith angle (thus latitude) dependent. This tends to dampen the latitudinal dependence of NASA DOAS uncertainties. In the NASA approach the error estimates are based on the statistics (chi-square estimates around the optimal SCD solution) primarily driven by the 'quality' of the OMI reflectances. Such quality depends on the effectiveness of instrument noise suppression via the removal of the common wavelength-, latitude- and FOV- dependent residuals.

13. P25, L19, you may mention "cloud radiance fraction" typically larger than "cloud fraction" so that clear-sky values are still slightly larger than all-sky values.

Thank you for your suggestion. The sentence: "Cloud radiance fraction values are typically larger than cloud fraction values therefore SCD uncertainties for clear-sky conditions are still slightly larger than the all-sky ones." is now added (P25 L21).

14. P29, L6-11, it is interesting to note from Figure 8b that DOAS SCD uncertainties seem to be smaller for those extreme off-nadir pixels in OMINO2-QA4ECV product. Is this due to increasing viewing zenith angle that increases reflectance as a result of multiple scattering?

The OMI rows excluded from our analysis are 22-53 (0-based). Therefore, relative to the "gap" on the maps, the row right before the gap starts (left side of the gap) is row 21 which is close to the absolute nadir viewing angle and this row appears the bluest (low uncertainty), whereas the row right after the gap ends (right side of the gap) is row 54 which is extreme off-nadir pixels and appears greenish (i.e. higher uncertainty).

15. P32, L13-15, this sentence is not clear, suggest rephrasing it. For example, it is not clear whether using annual mean increases or decreases the strips by saying "it manifests".

Good point. We now clarify that the presence of stripes is what manifests when we use annual mean solar irradiance spectra as reference (P32 L13).

16. P39, L33-34, suggest rephrasing this sentence there is not cause-effect relationship between increasing SCD uncertainties and stability of stratospheric and tropospheric retrievals.

We understand 'stability' here as defined by GCOS: stability is a requirement on the extent to which the uncertainty of a measurement remains constant over a long period. So if the SCD uncertainties increase over time, this affects the stability of the retrievals.

Technical comments 1. P6, L11, change "absorption signature" to "absorption signatures"

Done (P5 L15 and P7 L12)

2. P7, L3, add "in" before "September"

Done (P7 L8)

C5

3. P11, L16, change the second "stretch" to "squeeze"
Done (P11 L25)
4. P14, L12, change "prior" to "prior to"
Done (P14 L12)
5. P19, L2, change "extend" to "extent"
Done (P19 L18)
6. P39, L27, add "those" before "over bright scenes"
Done (P40 L5)

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2017-453, 2018.