
Effects of Scrambler on NO₂ and BrO DOAS retrieval

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1. Introduction

The scrambler of OMI causes spectral structures in the radiance, which affect DOAS retrieval of gases. The largest errors in the retrieved vertical column density can be expected for NO₂ and BrO [R1, R2].

Results of the scrambler breadboard confirmed the spectral structures as expected by the TNO-TPD analytical model. The maximum amplitude of the structures for OMI were estimated as < 0.1% for the VIS, < 0.03% for UV-2, and < 0.01% for UV-1 [R3]. These results are used to estimate the error in NO₂ and BrO retrievals due to the scrambler effects. The errors due to scrambler effects are compared with errors due to noise.

2. OMI simulations

OMI measurements were simulated for wavelengths between 425 and 455 nm for NO₂ and between 340 and 365 nm for BrO. Radiative transfer computations were performed with the Doubling Adding KNMI (DAK) model. The DAK model was used to compute both the radiance and the linear polarization. The OMI instrument was simulated by accounting for scrambler effects, convolution with the slit function and spectral sampling.

Simulations were performed for 36 Sun/satellite geometry's and two values for the surface albedo: 0.0 and 0.8. The scrambler effects were accounted for by using the TNO-TPD analytical model, with an amplitude of 1E-3 (0.1%) in the VIS at 500 nm, and 3E-4 (0.03%) in UV-2 at 380 nm. To account for off axis effects, two versions were used for the scrambler effect function. For these functions, the phase of the rapid varying mode differs by $\frac{1}{2} \cdot \pi$, see Figure 1.

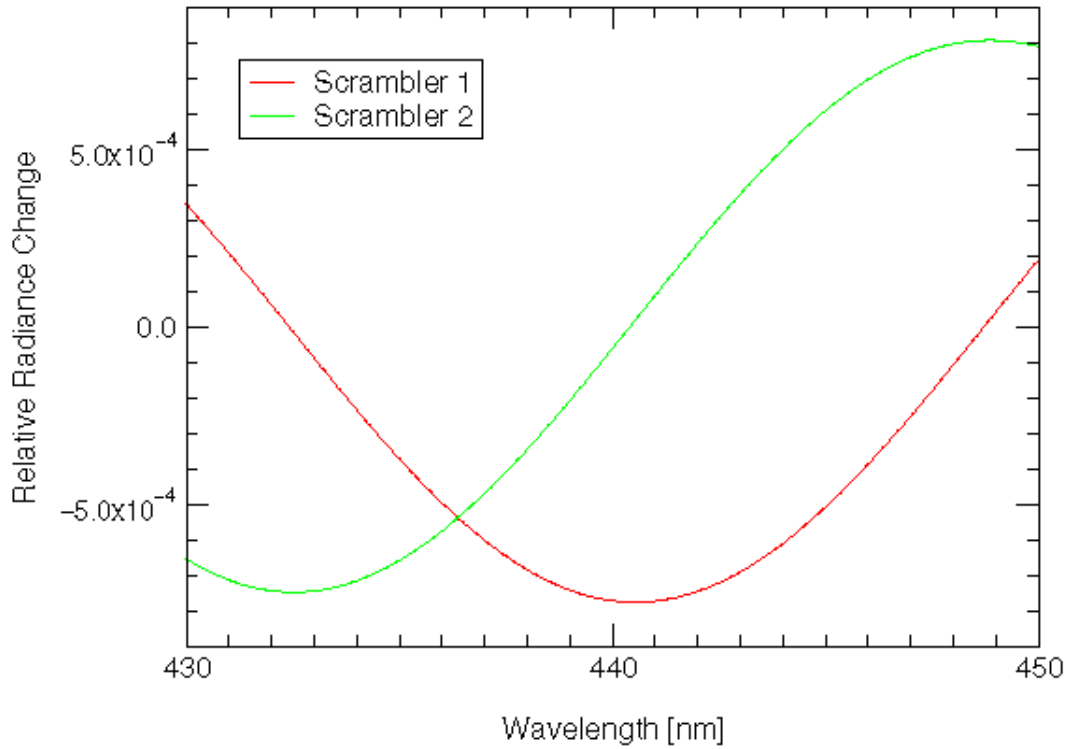


Figure 1. Scrambler effects on radiance as a function of wavelength for the VIS channel. Scrambler 1 and 2 differ by a phase shift of the rapid varying mode.

3. Results for NO₂

From the OMI VIS channel simulations the NO₂ slant column density (SCD) was computed in the wavelength region between 430 and 450 nm, using standard DOAS methods. The SCD was computed for simulations without scrambler effects, and for the two versions of the scrambler. The relative error due to scrambler effects was computed by comparing the SCD with and without scrambler effects.

The largest errors for three NO₂ concentrations are given in table 1 for vertical column densities of 2.0E15, 6.0E15 and 1.2E16 molec/cm². As expected, the largest error occurs for the smallest concentration. The error is almost linearly with the inverse of the concentration. For scrambler 2 the effect is larger than for scrambler 1. This illustrates the effect on DOAS retrieval of the exact shape of the perturbation.

Table 1. Maximum error on NO₂ SCD due to effects of the scrambler.

NO ₂ [molec/cm ²]	scrambler 1 [%]	scrambler 2 [%]
2.0E15	0.96	-2.5
6.0E15	0.32	-0.84
1.2E16	0.16	-0.42

An earlier study reported an error of maximum 4 % on NO₂ retrieval due to 1E-3 scrambler effects [R1]. This study used concentrations of 6.0E15, and 1.2E16 molec/cm² and assumed 100%

polarization of the incoming radiance. When in the present study the same assumption on the polarization is made, the maximum error in the SCD due to scrambler residual polarization is 2 %.

To assess the accuracy of the NO₂ slant column retrieval, the effect of the scrambler should be compared to errors due to signal to noise. Therefore, effects of signal-to-noise of 1000 were added to the OMI simulator described above. Simulations were performed for a vertical column density of 6.0E15 molec/cm² and a surface albedo of 0.0. Figure 2 shows the error due to scrambler effects alone and for the combined scrambler and noise effects. As can be seen in Figure 2, the effects of noise are generally larger than the effects of the scrambler. It should be noted that the scrambler errors are systematic (but vary over the swath), whereas noise causes random errors.

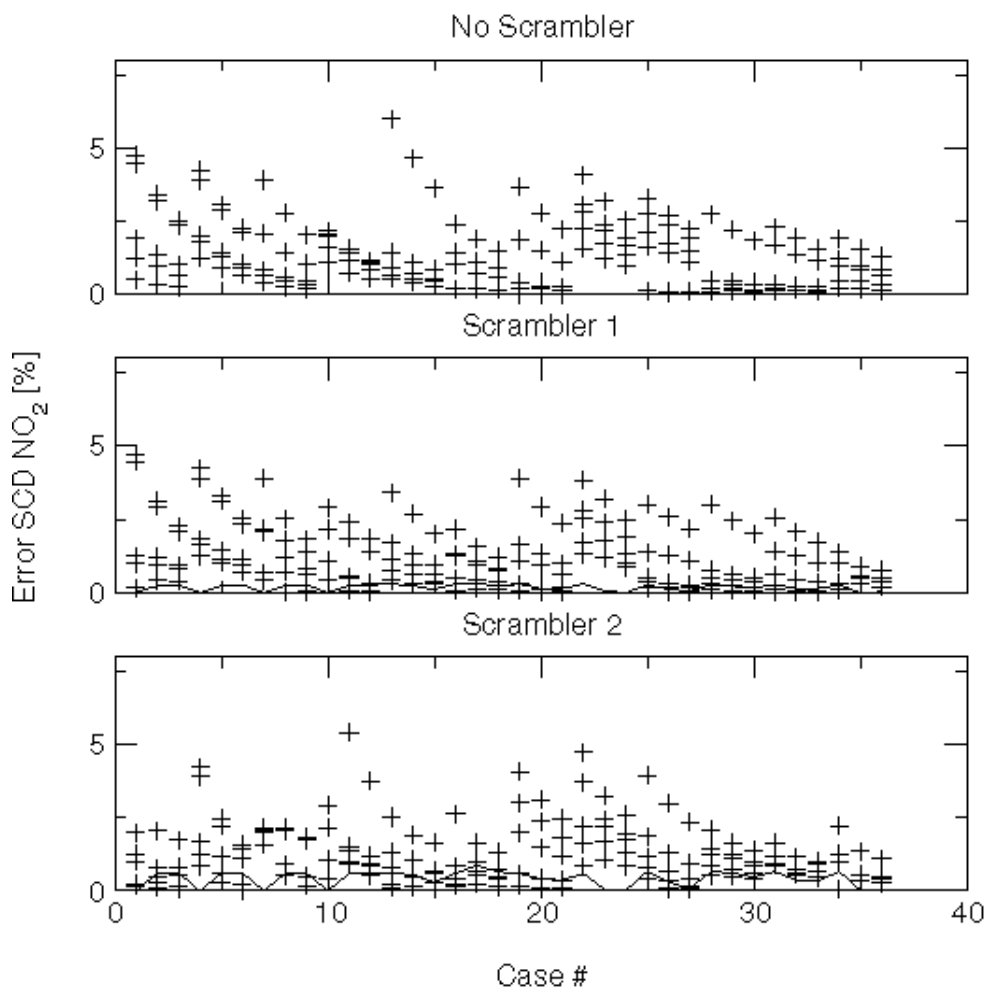


Figure 2. Error due to scrambler effects (line) and due to combined scrambler and noise effects (plusses), for no scrambler (upper plot), scrambler 1 (middle plot), and scrambler 2 (lower plot). For each case 5 simulations with (random) noise were performed.

4. Results for BrO

The SCD of BrO was computed from the simulated spectra between 345 and 360 nm, using a standard DOAS method. The error due to the scrambler was determined from the simulations with and without the scrambler effects. The vertical column density was 4.0E13 molec/cm². The scrambler effects were -1.1 and -1.5 %, for scrambler 1 and 2, respectively.

An earlier study [R2] reported errors in the VCD of $< 5\%$ for 100% polarized light and a VCD of $6.3E13$ molec/cm². For simulations using these assumptions the maximum error is 4%.

To assess the effects of noise, the simulations were repeated with a signal-to-noise level of 1200. Figure 3 shows the effects of the scrambler and the effect of the combined scrambler and noise effects. As can be seen in Figure 3, the effects of the scrambler are much smaller than the noise effects.

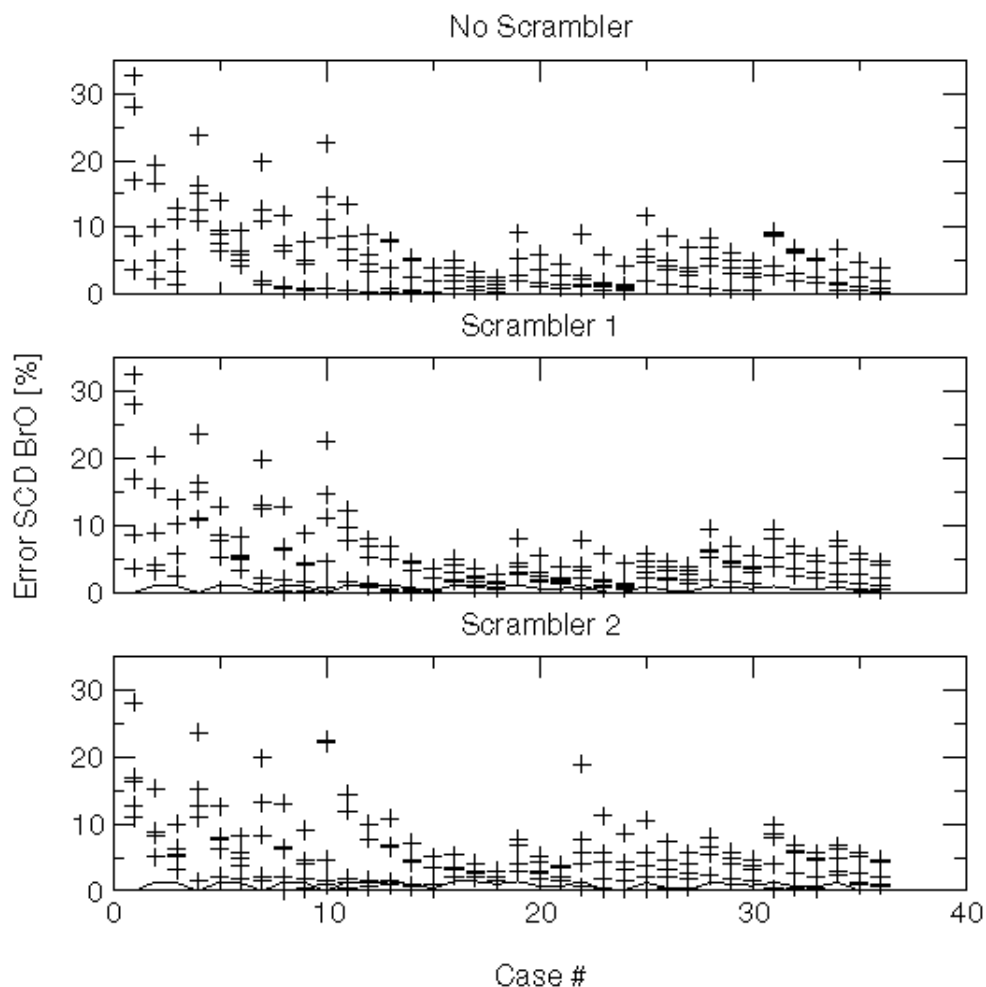


Figure 3. Error due to scrambler effects (line) and due to combined scrambler and noise effects (plusses), for no scrambler (upper plot), scrambler 1 (middle plot), and scrambler 2 (lower plot). For each case 5 simulations with (random) noise were performed.

5. Conclusions

Simulations were performed to assess the error in NO₂ and BrO DOAS retrievals due to the scrambler residual polarization effects. Radiative transfer calculations included linear polarization. For the scrambler effects the expected amplitudes from the breadboard results were used [R3]. Errors due to the scrambler were compared to errors due to noise. The following is concluded from the simulations:

1. For a NO₂ vertical column density of $6.0E15$ molec/cm² the error in the SCD is $< 1\%$.

Scrambler effects were found to be smaller than effects of noise for a signal-to-noise value of 1000.

2. For a BrO vertical column density of $4.0E13$ molec/cm² the scrambler error in the SCD was < 1.5 %. The error due to the scrambler is smaller than due to noise for a signal-to-noise level of 1200.
3. Including realistic values for the degree of polarization, strongly reduces the error due to the scrambler.

6. References

R1. Spectral structures similar to absorption features + optical test scrambler: consequences for DOAS column retrievals of ozone and trace gases and ozone profile retrieval. R van Oss, KNMI, 23-07-1999.

R2. Effects of scrambler distortions of $10E-3$ on DOAS retrieval. J.P. Veefkind and R. van Oss, KNMI, 29-07-1999.

R3. Proposal for requirement specifications on the polarization sensitivity of the OMI signal levels. H. Visser, TNO-TPD, 8-12-1999.
