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Title: Error in reflectivity due to wavelength shifts and width of the slitfunction
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History

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Version 2 of 31 May 2000 released during the 4th OMI Science Team Meeting of 13-15 June 2000.

Purpose

Closure of Action Items 10 and 16 of the 3rd Science Team Meeting: Investigate the effect of the spectral stability and width of the slitfunction on the error in the reflectivity using spline interpolation. The reflectivity is the Sun normalized Earth radiance. The radiances and irradiances measured with OMI are subject to a convolution with the slitfunction of the instrument and binning on a discrete wavelength grid. Because of the finite spectral stability of the instrument the discrete wavelength grids for the radiances and irradiances may differ so that the calculation of the reflectivity requires interpolation to a common wavelength grid. This interpolation introduces an error that needs to be evaluated. It is important to note even in case of an infinitely good spectral stability, with both the radiance and irradiance on an identical wavelength grid, an intrinsic error is introduced because of the convolution with the slitfunction. The OMI sun and earthshine measurements introduce an averaging by the slitfunction and the ratio of two averaged functions is not equal to the average of the ratio of these functions. This error has to be dealt with in the level 1b to 2 processing.

In this document we study the error due to interpolation to a common wavelength grid for shifted wavelength grids and compare these errors with the errors at zero shift.

Simulations

Using a high-resolution reference solar spectrum and a high-resolution MODTRAN reflectance calculation for a typical set of atmospheric and viewing parameters¹, a high-resolution earth spectrum is generated. From the high-resolution radiance and irradiance, spectra, as-would-be-measured-by-OMI, have been calculated using the OMI channel partition, resolution and spectral sampling. The wavelength grids have been chosen in such a way that the wavelength at the pixel-center is shifted for the sun spectrum with respect to the earth spectrum. Five values for this shift have been used: 0.1, 0.05, 0, -0.05 and -0.1 pixel (1/10th and 1/20th of a CCD-pixel). Also, the FWHM of the slitfunction (spectral resolution) of channel UV-1 has been varied: S-FWHM=1, 2, 3, 4 and 5 pixels. So, for the UV-1 channel, a total of 25 cases have been studied. For UV-2 and VIS the current OMI baseline is adopted with an S-FWHM equal to three pixels. The slitfunction is given by $S(?) = 2^{-(?/FWHM)^n}$ with $n=4$ for UV-1 and $n=8$ for UV-2 and VIS. However, in this study we took $n=4$ for all channels.

The reflectance has been calculated in two ways: i), a *correct value* and, ii), an *OMI-value* that is obtained if only the OMI spectra are available.

The *correct value* is based on the high-resolution reflectance only. The high resolution MODTRAN reflectance, at the wavelengths of the OMI sun spectrum, is convolved with the slitfunction. The resulting reflectance depends only on the width of the slitfunction.

The *OMI-value* has been calculated by interpolating the radiances of the OMI earthshine spectrum onto the wavelength grid of the OMI sun spectrum. A spline interpolation has been used. Thereupon, the reflectance is obtained by calculating the ratio. The high-resolution features in the solar spectrum do influence this reflectance, because the averaging is over different parts of the different high-resolution OMI-spectra due to the shift.

One way to interpret the deviation between the reflectance calculated by the two methods is that the *correct* reflectance would be obtained from the OMI-spectra if, either the solar spectrum, or the reflectance would be wavelength independent. The deviations are largest for those wavelengths where the solar spectrum as well as the reflectance spectrum shows some structure.

¹ Solar zenith angle = 20°, viewing angle = nadir, ground albedo = 0.05, standard MLS atmosphere.

Figure 1(abcde) shows the relative deviation between two reflectance-values for the three OMI channels for the five values of the relative shift. For this figure the channel UV-1 S-FWHM is three pixels. Figure 2 shows the relative deviation for channel UV-1 for the five values of the relative shift and the five values for the S-FWHM. The maximum deviation per channel for each shift is presented in Table 1. Also, for channel UV-1 the results for five values for the S-FWHM are shown.

Table 1: The maximum deviation [in %] between the ‘correct’ and the ‘OMI’ reflectance, per channel, for each of the five values for the relative shift between the OMI -sun and -earthshine spectrum and, for channel UV-1, for each of the five values for the S-FWHM.

Shift [pixel]	UV-1					UV-2	VIS
	S-FWHM = 1 pixel	S-FWHM = 2 pixels	S-FWHM = 3 pixels	S-FWHM = 4 pixels	S-FWHM = 5 pixels	S-FWHM = 3 pixels	S-FWHM = 3 pixels
0.10	4.4%	1.6%	2.7%	3.7%	4.2%	1.7%	0.5%
0.05	2.7%	1.7%	2.8%	3.7%	4.2%	1.7%	0.3%
0.00	1.4%	1.8%	2.8%	3.7%	4.2%	1.7%	0.1%
-0.05	1.8%	2.1%	2.8%	3.7%	4.2%	1.7%	0.3%
-0.10	3.4%	2.5%	2.8%	4.2%	4.2%	1.7%	0.5%

From the figures in Table 1 a few observations can be made:

- (i) The error in the reflectance introduced by the degrading of the physical sun and earthshine spectra by OMI is non-negligible for a zero relative shift. This is due to the fact that “the ratio of two averages is generally not equal to the average of the ratio”. This is an intrinsic error that cannot be avoided.
- (ii) The errors are largest in channel UV-1, smaller in channel UV-2 and smallest in channel VIS. This is caused by differences in the structure in the atmospheric reflectance spectrum and by the different amount of averaging in the channels. The larger errors in channel UV-1 are mainly due to the larger sampling per pixel (0.32 nm versus 0.15 nm in UV-2 and 0.21 in VIS), while the smaller errors in the VIS channel are due to the small amount of structure in the reflectance spectrum.
- (iii) The three channels show a different sensitivity to the amount of shift between the sun and earthshine spectra. Restricted to the case where for all channels S-FWHM = 3 pixels, the maximum error is relatively insensitive to the amount of shift for channels UV-1 and 2, while for channel VIS there is a clear increase with increasing shift. It is not clear why this is so. Note that the error in the window [340-350 nm] in channel UV-2 does depend on the shift and the error is small for zero shift.
- (iv) Since the error can be large in the vicinity of strong lines in the solar spectrum, the retrieval of cloud-top-height, using the Ring effect at the Calcium lines at 395 nm in the VIS, will be affected by this error. It is therefore advisable not to use the reflectance obtained from the OMI sun and earthshine spectra, but instead make use of a high-resolution sun spectrum.
- (v) The large values of the error (even at zero shift) in channel UV-2 between 310 and 320 nm can affect the DOAS retrieval of SO₂ in this window.
- (vi) The effect of the error in channel UV-2 between 325 and 335 nm on the DOAS retrieval of ozone should be looked into, in view of the strict requirement of 2% on the accuracy of the ozone column. Currently this effect is, partly, accounted for by the Ring spectrum. However, since the error depends on the amount of structure in the reflectance, it depends on the ozone column.

Conclusions

- (i) The magnitude of a relative wavelength shift between the sun and the earthshine OMI-spectra affects the error on the reflectance in the visual channel and the large-wavelength side of channel UV-2. A shift of 1/10th of a pixel gives an error of 0.5%, 1/20th gives an error of 0.3%, and a zero shift gives an error of 0.1%.
- (ii) For channel UV-1 the value of the IRF-FWHM affects the dependence of the error in the reflectance on the shift: undersampling (IRF-FWHM = 1 pixel) results in a large sensitivity of the error on the shift; increasing the sampling suppresses this.
- (iii) The error in the reflectivity for a zero shift has to be dealt with in the level 1b to 2 retrievals.
- (iv) For channel UV-1 larger values of the IRF-FWHM lead to larger errors on the reflectivity at zero shift.

Fig. 1a The relative deviation between two reflectance-values for the three OMI channels for a relative **shift of -0.10**

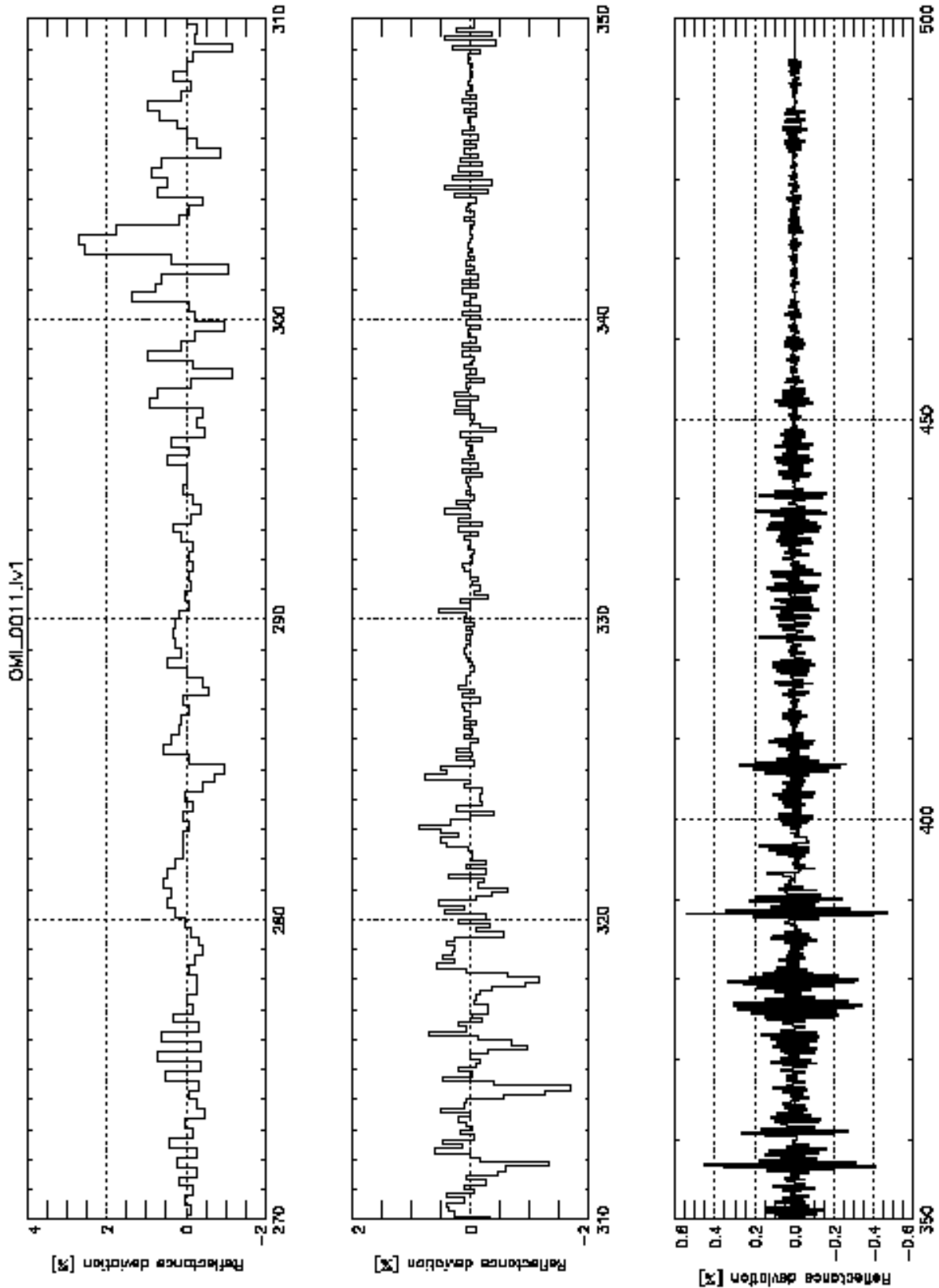


Fig. 1b The relative deviation between two reflectance-values for the three OMI channels for a relative **shift of -0.05**

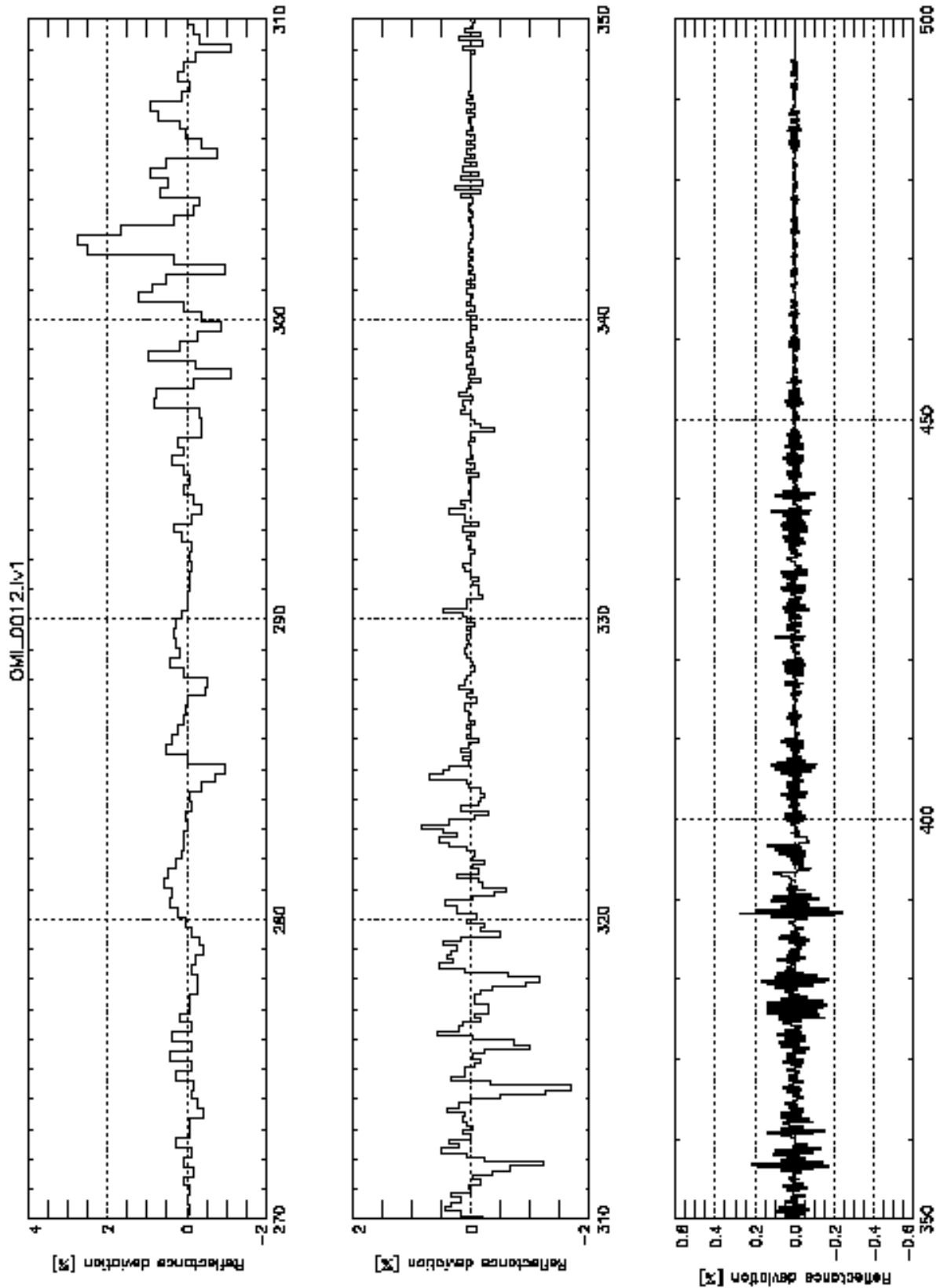


Fig. 1c The relative deviation between two reflectance-values for the three OMI channels for a relative **shift of 0.0**

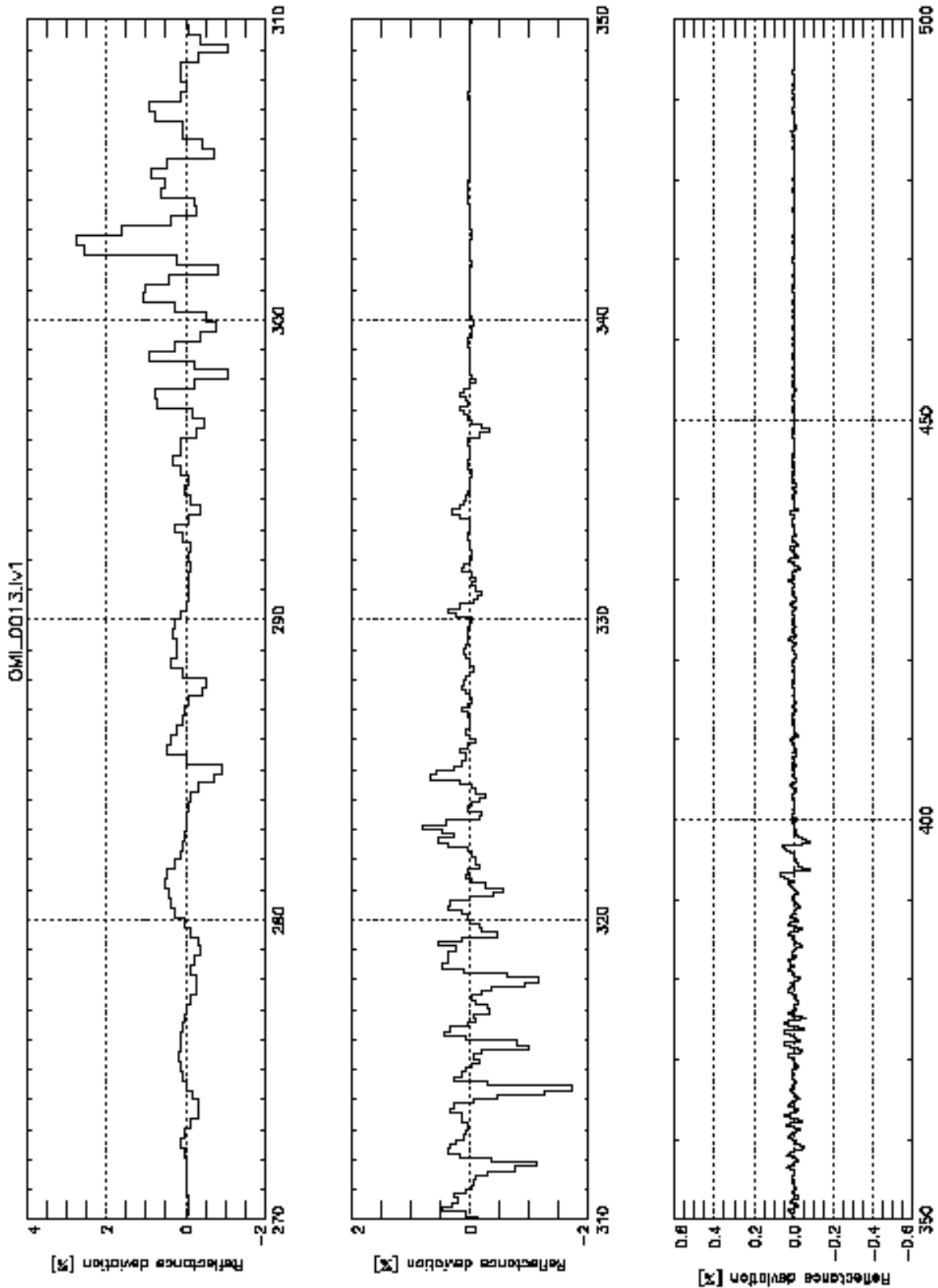


Fig. 1d The relative deviation between two reflectance-values for the three OMI channels for a relative **shift of + 0.05**

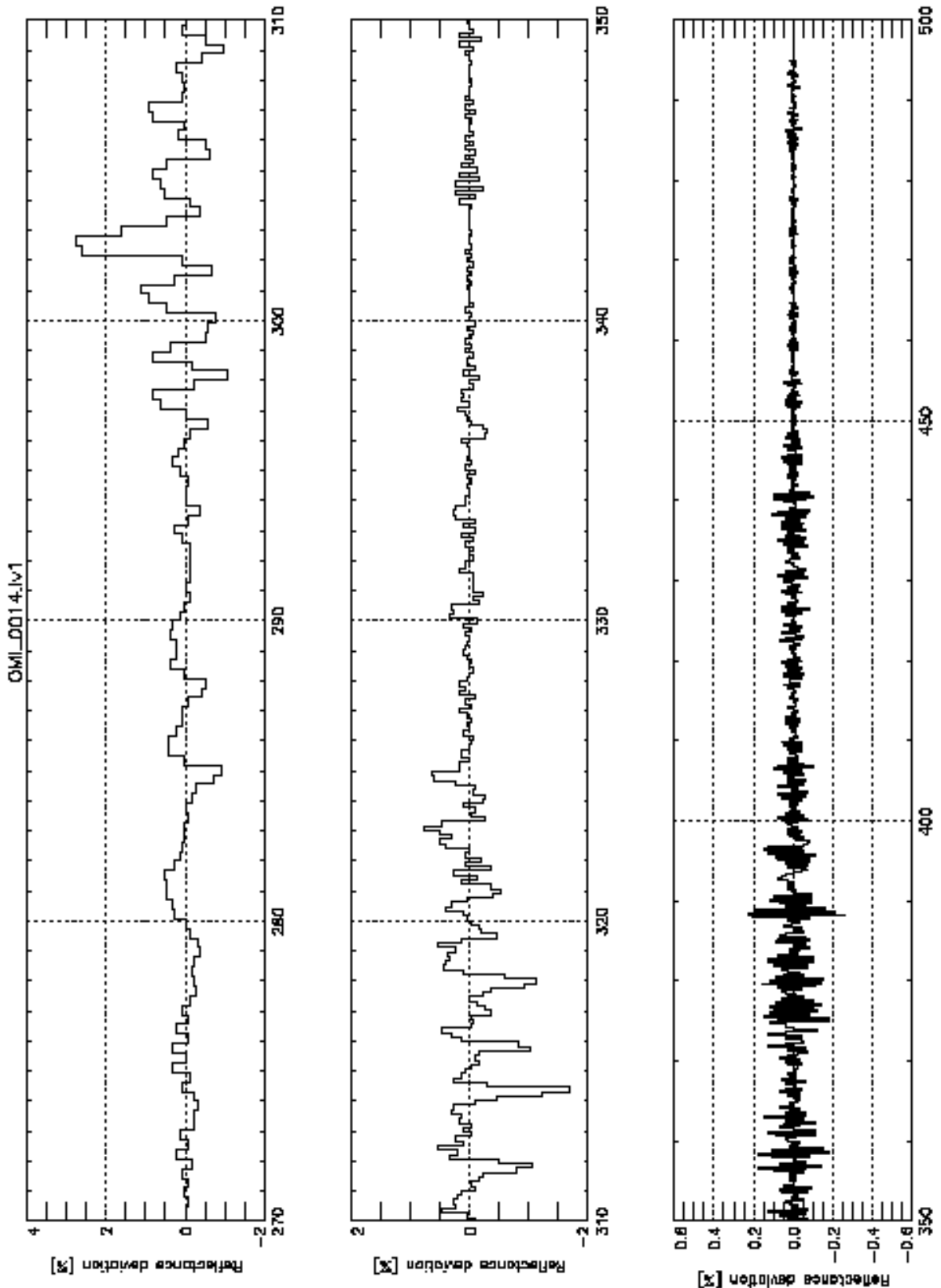


Fig. 1e The relative deviation between two reflectance-values for the three OMI channels for a relative **shift of + 0.10**

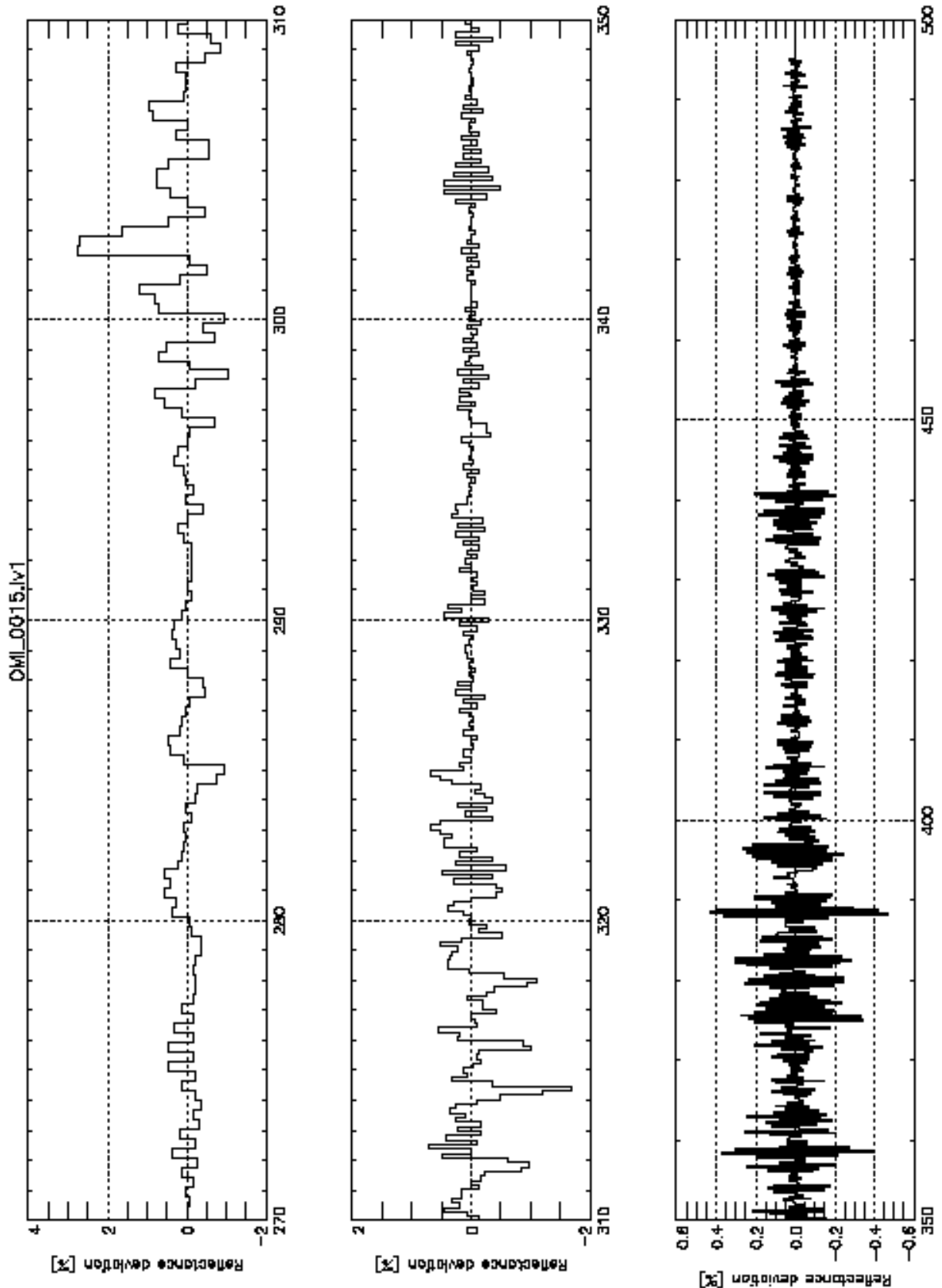


Fig. 2 The relative deviation for channel UV-1 for the five values of the relative shift (from left to right, $+0.1 \rightarrow -0.1$) and the five values for the S-FWHM (from top to bottom, $S=1 \rightarrow 5$).

