

An RTTOV-type fast radiative transfer model has been developed for emitted clear-sky limb radiances from the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) onboard ESA's ENVISAT. MIPAS is an infrared sounder with very high spectral resolution (0.025 cm^{-1} , Table 1). It is designed to provide information on the thermal structure and chemical composition of the upper troposphere to lower mesosphere. The fast model is referred to as RTMIPAS, and it has been developed to directly assimilate limb radiances in a global variational data assimilation system (see separate poster for this).

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| Spectral resolution | 0.025 cm^{-1} unapodised (0.035 cm^{-1} apodised) |
| Spectral region | 685–2410 cm^{-1} in 5 bands |
| Nominal tangent altitudes in normal scanning mode | 6–42 km in 3 km steps; 47, 52, 60, 68 km |
| Field of view at tangent point (vertical x horizontal) | approx. 3 km x 30 km |
| Data coverage | September 2002–March 2004; one vertical scan every 5° |

Table 1 Main characteristics of MIPAS

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Methodology

The main characteristics of RTMIPAS follow RTTOV methodology (e.g., Saunders *et al.* 1999). Details can be found in Bormann *et al.* (2004, 2005).

- The atmosphere is represented on 81 fixed pressure levels (Figure 1).
- Convolved level-to-satellite transmittances are parametrized through regression models for the effective layer optical depths.
- The regressions are derived from results of line-by-line (LBL) computations for a sampled set of 46 ERA-40 profiles, using University of Oxford's RFM (Dudhia 2005). Horizontal homogeneity is assumed in these calculations.
- Humidity and ozone are treated as variable gases; for other contributing gases a fixed climatology is assumed.

The main differences and extensions to the nadir-RTTOV methodology are:

- Ray-tracing is required to determine the path conditions.
- The predictors have been revised for the limb-geometry; most fundamental change: replace secant of zenith angle with layer path length in the predictors.
- Field of view (FOV) convolution in the vertical is required. To do this, radiances are calculated for rays with tangent pressures at a subset of the fixed pressure levels (Figure 1). A cubic fit through these "pencil beam" radiances is used for the FOV convolution.

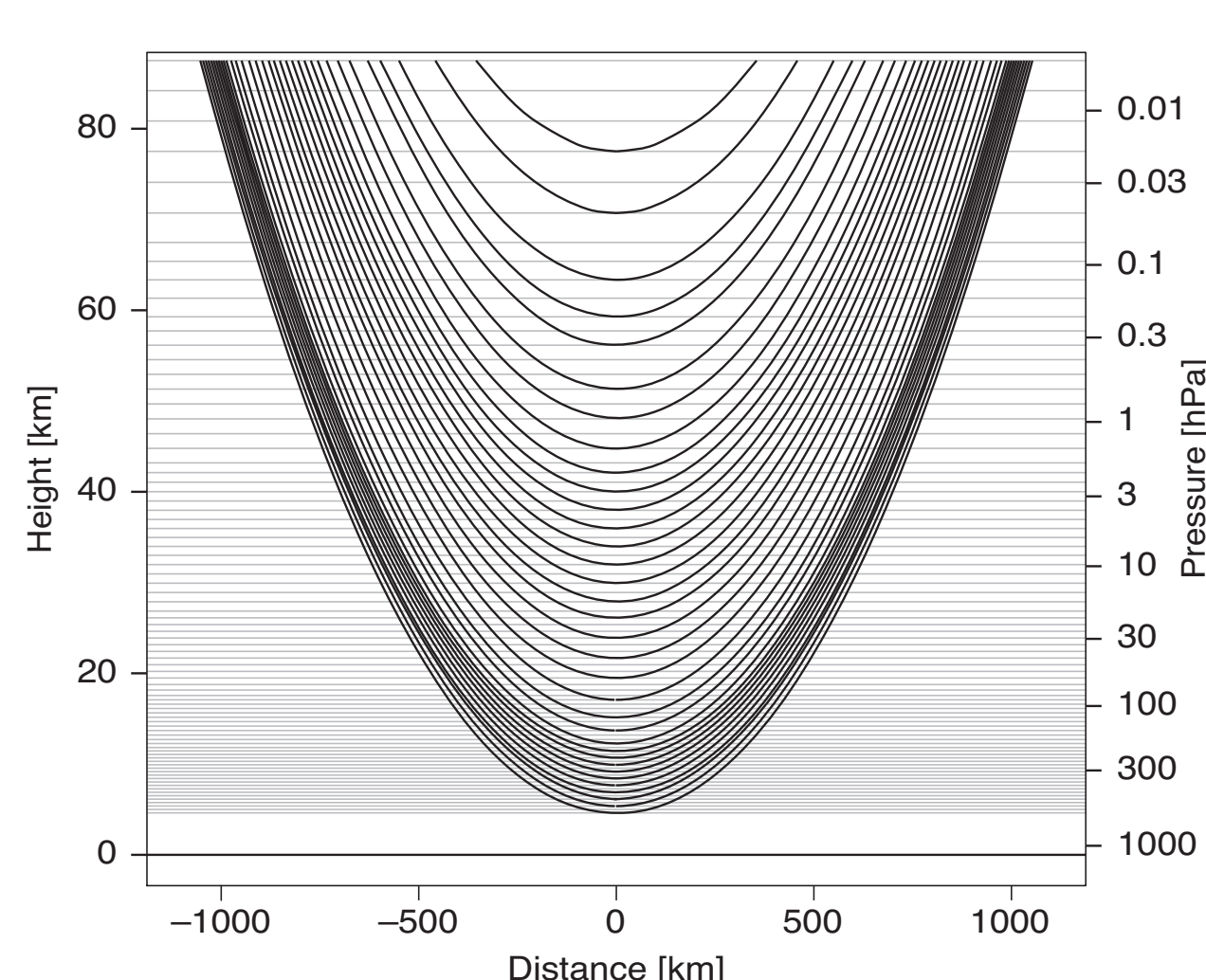


Figure 1 Schematic representation of the levels (horizontal lines) and pencil beams (curved lines) used in RTMIPAS, mapped into a plane-parallel view.

Conclusions

A regression-based fast radiative transfer model for emitted clear-sky radiances has been adapted to the limb geometry for the first time. The model can simulate radiances for all channels of the MIPAS instrument in the 685–2000 cm^{-1} wave number range, taking into account effects of variable humidity and ozone. Tangent linear and adjoint routines have also been developed.

The validation of RTMIPAS shows that for horizontally homogeneous atmospheres the error introduced through the fast parameterisation is below the instrument noise for most channels and tangent altitudes. This fast model error is expected to be smaller than errors introduced through uncertainties in the spectroscopy. RMS differences between RTMIPAS and LBL transmittances are typically around 10^{-4} – 10^{-5} , and the maximum RMS rarely exceeds 0.005. This indicates a performance comparable to RTIASI for the nadir geometry. The model extends well to atmospheres with horizontal gradients.

A separate poster summarises the first experiences with assimilation of MIPAS limb radiances in the ECMWF system.

The RTMIPAS method has recently been successfully adapted to the Microwave Limb Sounder (MLS) on EOS-Aura (Liang Feng 2005, personal communication).

Validation

The RTMIPAS radiances and transmittances have been compared to LBL equivalents for a set of 53 ERA-40 profiles not used in the training ("independent set"). This characterises the errors introduced through the fast parameterisation ("fast model errors"). Errors introduced through the spectroscopy or through neglecting the variability of gases other than humidity and ozone are not addressed here.

- RTMIPAS can reproduce LBL radiances to an accuracy that is below the noise level of the MIPAS instrument for most channels and tangent pressures (Figures 2 and 3).
- Fast model errors tend to be larger for the lower pencil beams.
- Fast model biases are small and mainly confined to lower pencil beams (Figure 4).
- Root mean squared (RMS) differences between RTMIPAS and LBL transmittances are typically around 10^{-4} – 10^{-5} , and the maximum RMS difference rarely exceeds 0.005 (not shown).

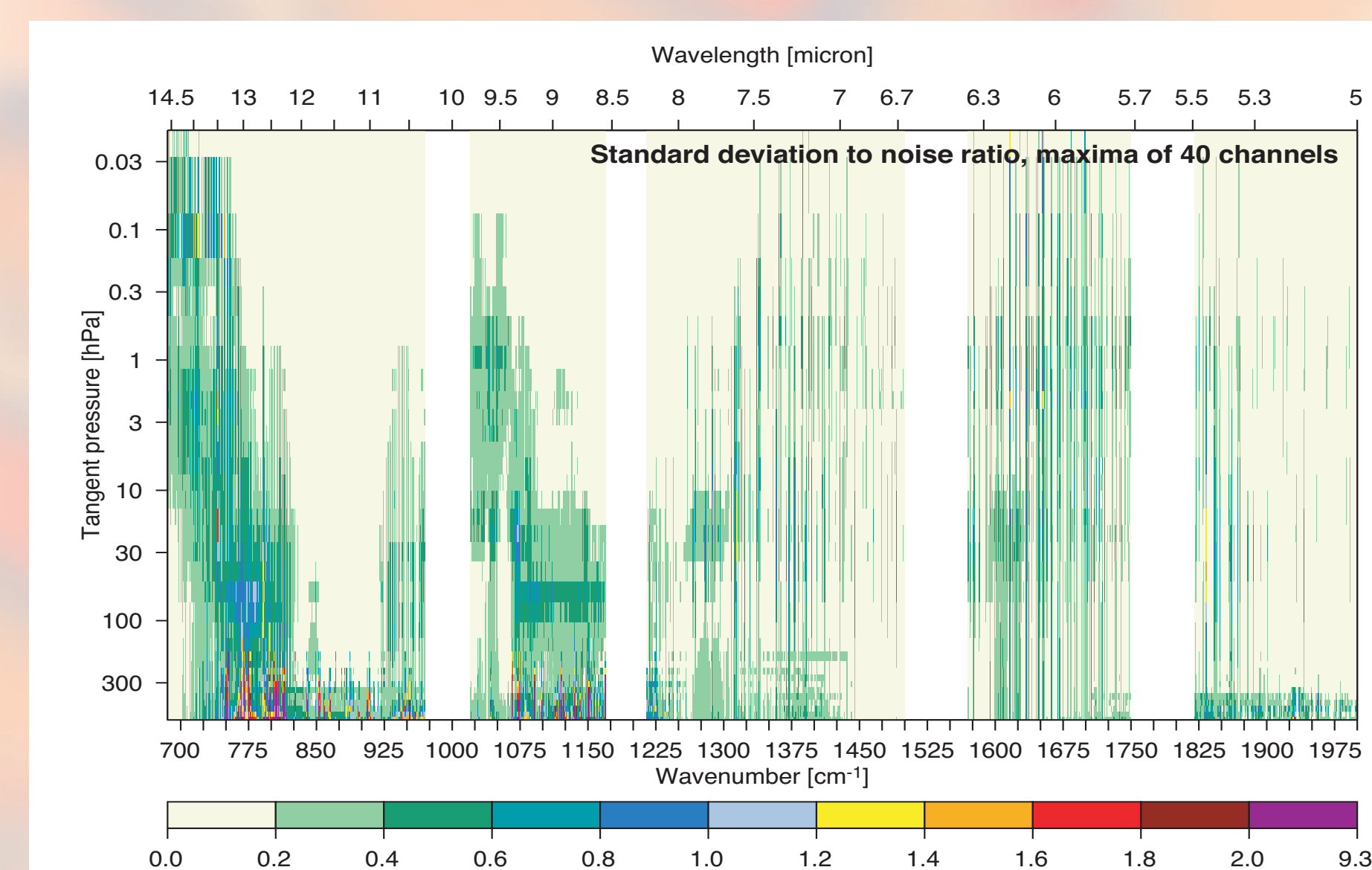


Figure 2 Maximum over 40 channels (i.e., 1 cm^{-1} intervals) of the standard deviation of the RTMIPAS-RFM radiance differences, scaled by the MIPAS noise. Note that this display emphasises the poorest performance of RTMIPAS per 1 cm^{-1} interval.

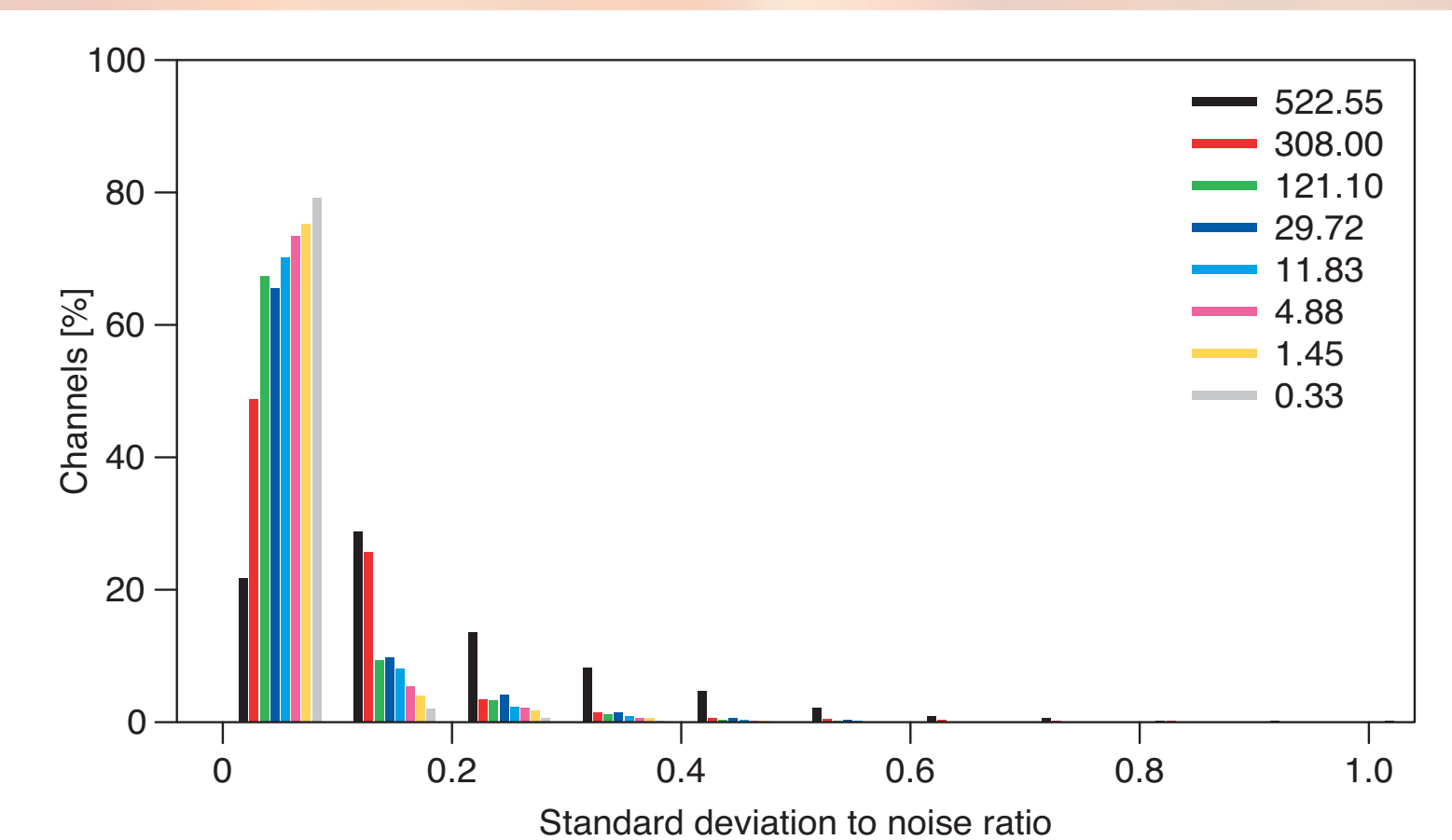


Figure 3 Distribution of the number of channels (%) versus the standard deviation of the RTMIPAS-RFM radiance differences, scaled by the MIPAS noise. Results for 8 selected pencil beams are shown, with their tangent pressures (hPa) indicated in the legend.

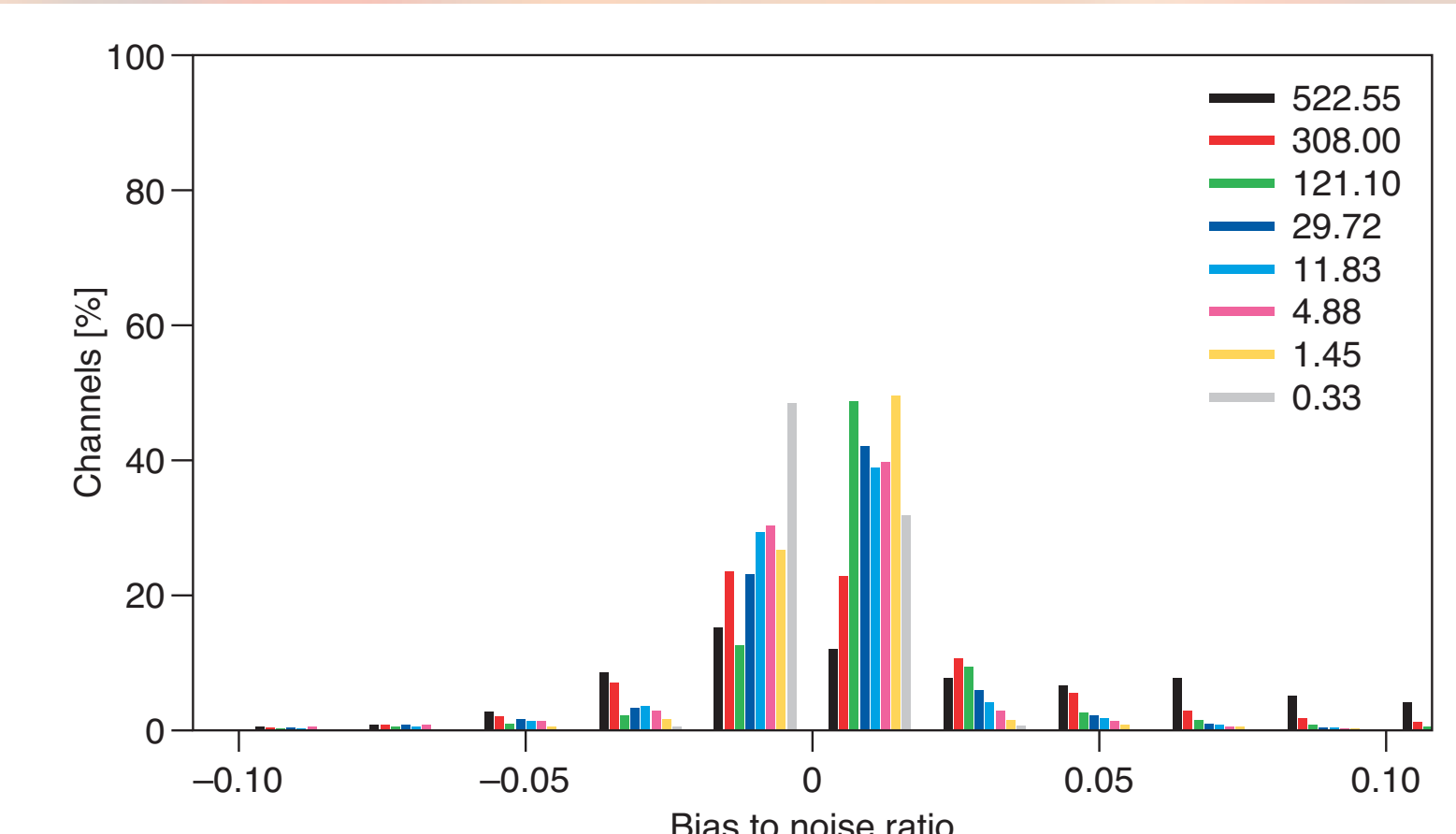


Figure 4 As Figure 3, but for the number of channels (%) versus the mean RTMIPAS-RFM radiance differences, scaled by the MIPAS noise.

RTMIPAS for vertical cross-sections

Limb radiances are sensitive to the vertical and the horizontal structure of the atmosphere. Neglecting horizontal gradients and assuming horizontal homogeneity, as done in the above calculations, can introduce large errors in the radiance simulation for lower FOVs, and these errors can exceed by far the noise level of the instrument (Figure 5).

RTMIPAS has been adapted to calculate radiances for a given atmospheric cross-section ("RTMIPAS-2d"). To avoid the costly retraining of the regression coefficients, we employ the same regression coefficients calculated under the assumption of horizontal homogeneity. The hypothesis is that the regression coefficients are adequate as long as the atmospheric variability on both sides of the tangent point is captured in the initial set of training profiles.

To evaluate the performance of RTMIPAS-2d we compare radiances simulated with RTMIPAS-2d and the RFM for a set of 40 diverse cross-sections sampled from ECMWF model fields (Fig. 6):

- For tangent pressures of less than 300 hPa RTMIPAS-2d performs similarly well as RTMIPAS in the horizontally homogeneous case. This suggests little benefit from retraining the regression coefficients on the basis of diverse cross-sections.
- For tangent pressures larger than 300 hPa, RTMIPAS-2d shows larger deviations from the LBL calculations than in the horizontally homogeneous case. This suggests some benefit from retraining the regression coefficients on the basis of diverse cross-sections for these tangent pressures.
- Even without retraining of the regression coefficients the fast model errors in RTMIPAS-2d are much smaller than the large error introduced for lower pencil beams by neglecting the horizontal gradients in the atmosphere (cf, Figures 5 and 6).

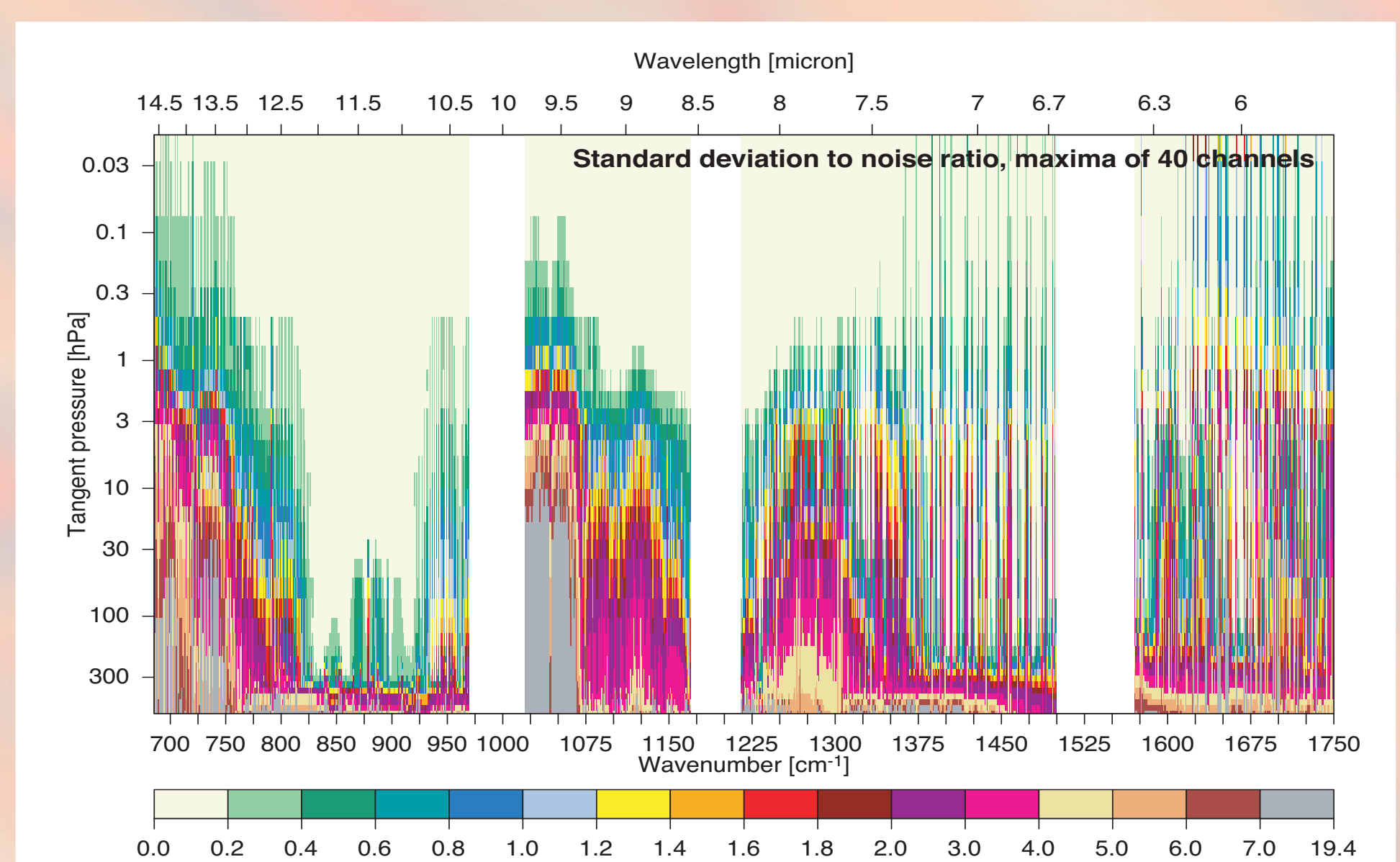


Figure 5 Error introduced by neglecting horizontal gradients for a sample of 40 cross-sections taken from ECMWF model fields. The plot shows the maximum over 40 channels (i.e., 1 cm^{-1} intervals) of the standard deviation of the RTMIPAS-1d-RFM-2d radiance differences, scaled by the MIPAS noise.

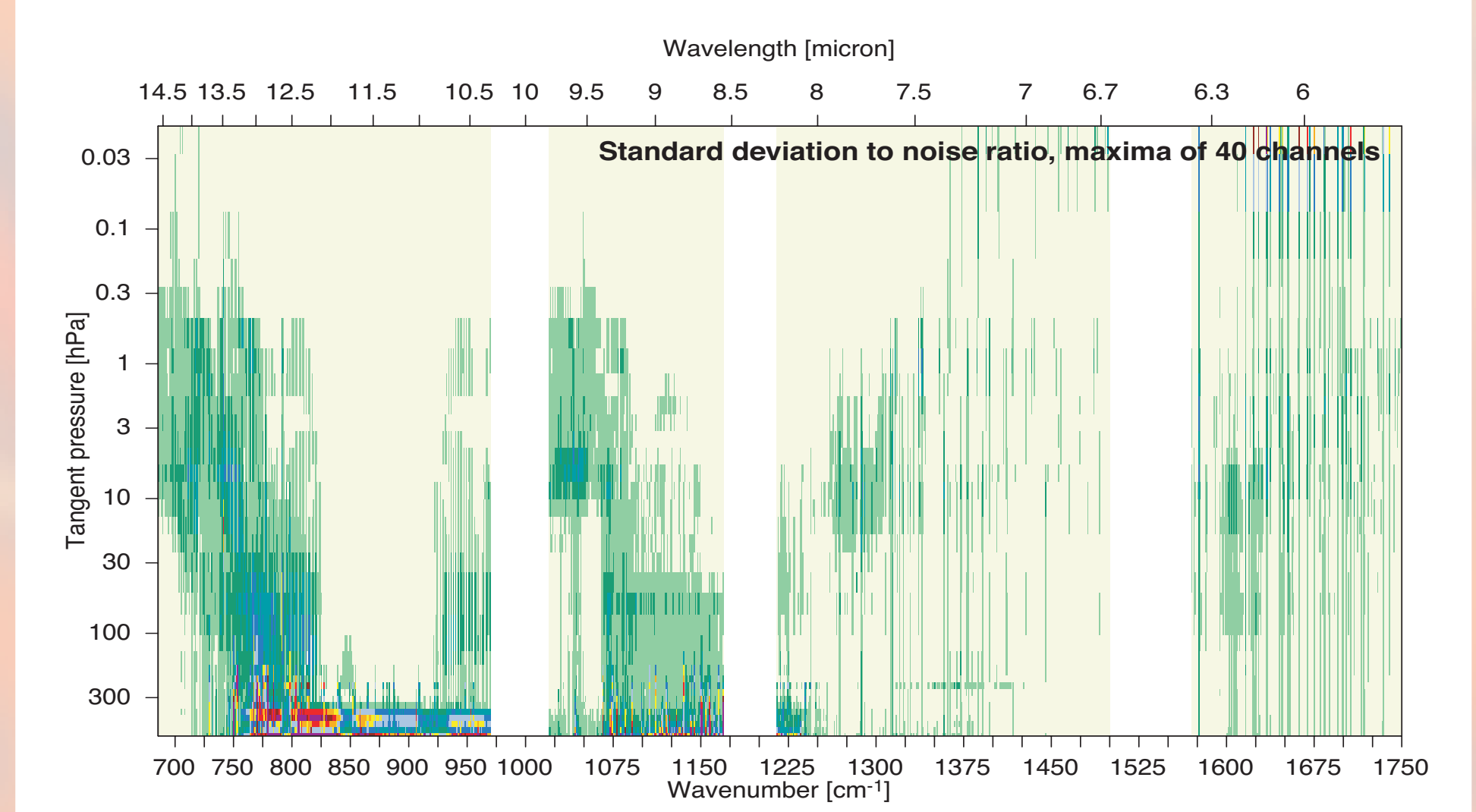


Figure 6 As Figure 2, but for a set of 40 cross-sections.

References

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