Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Universität
Karlsruhe (TH)

Universität Karlsruhe/Forschungszentrum Karlsruhe GmbH, Institut für Meteorologie und Klimaforschung
Postfach 3640, D–76021 Karlsruhe, Germany. (e-mail: tilman.steck@imk.fzk.de)

T. Steck, M. Höpfner, T. von Clarmann, H. Fischer, B. Funke, N. Glatthor, U. Grabowski,
S. Kellmann, M. Kiefer, A. Linden, G. Mengistu Tsidu, M. Milz, G.P. Stiller, and D.Y. Wang

2D-retrieval approach and diagnostics for MIPAS-Envisat

1. Introduction

The advantages of a limb sounder are the possibility to provide vertically high resolved profiles and the sensitivity to species of low abundance. On the other hand, horizontal inhomogeneities (in particular of temperature), if not taken into account properly, can cause serious systematic errors within the retrieval. A dedicated method of taking full 2D fields of state parameters into account in the forward and retrieval model is presented and applied to simulated MIPAS-Envisat spectra.

2. Retrieval Concept

The basic idea is that the full 2D state vector $\mathbf{x}$ is updated per Newtonian iteration i (inner loop) and sequentially for each limb sequence l (outer loop) in the sense of sequential estimation [1]:

$$\mathbf{x}_{i+1,l} = \mathbf{x}_{i,l} + (\mathbf{K}_{i,l}^T \mathbf{S}_{\epsilon,l}^{-1} \mathbf{K}_{i,l} + \mathbf{S}_{a,l}^{-1})^{-1} \times [\mathbf{K}_{i,l}^T \mathbf{S}_{\epsilon,l}^{-1} (\mathbf{y}_l - \mathbf{F}(\mathbf{x}_{i,l})) - \mathbf{S}_{a,l}^{-1}(\mathbf{x}_{i,l} - \mathbf{x}_{a,l})],$$

where $\mathbf{y}$ is the measurement vector, $\mathbf{K}$ the Jacobian, $\mathbf{S}_\epsilon$ the measurement noise covariance, $\mathbf{x}_a$ the *a priori* state vector that is updated per limb sequence as $\mathbf{x}_{a,l+1} = \mathbf{x}_{0,l+1} = \mathbf{x}_l$, and $\mathbf{S}_a$ the *a priori* covariance: $\mathbf{S}_a$ is updated per limb sequence as $\mathbf{S}_{a,l+1} = (\mathbf{K}_l^T \mathbf{S}_\epsilon^{-1} \mathbf{K}_l + \mathbf{S}_{a,l}^{-1})^{-1}$, the initial *a priori* covariance $\mathbf{S}_{a,1} = \mathbf{S}_{ver} + \mathbf{R}_{hor}$ is a combination of a covariance with exponentially decaying off-diagonal elements for vertical regularization $\mathbf{S}_{ver}$ [2] and a first order Tikhonov smoothing constraint in horizontal direction $\mathbf{R}_{hor} = \alpha \mathbf{L}_1^T \mathbf{L}_1$. $\mathbf{y}_l$ contains only one limb sequence per iteration l, which saves a lot of memory in comparison to simultaneous analysis of several limb scans [3].

3. Diagnostics of 2D-retrieval

Simulations have been performed within an ESA study focusing on the UTLS region: spectral resolution is 0.1 cm^{-1}, number of tangent altitudes per limb sequence is 16 (distance: 2 km), 40 sequences in horizontal direction (distance: 155 km). This mode is similar to the special MIPAS mode S6. Retrieval grid: 2 km vertical spacing, 100 km horizontal spacing. The initial and *a priori* field is a horizontally homogeneous mid-latitude temperature field.

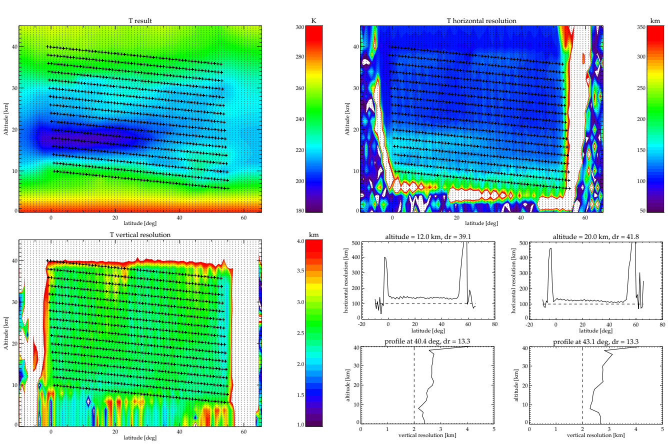

Figure 1: Upper left: Retrieved 2D temperature field; horizontal grid is indicated by dotted lines, tangent points are marked by crosses. Upper right: Horizontal resolution calculated from the 2D averaging kernel. Lower left: Vertical resolution calculated from the 2D averaging kernel. Lower right: Horizontal (top) and vertical (bottom) resolution for selected altitudes and latitudes with degrees of freedom d_r, which is calculated from the trace of the averaging kernel [4].

Figure 1 shows the result and diagnostics of a 2D temperature retrieval. The horizontal resolution (lower right (top)) in the stratosphere is even lower than the distance of the limb sequences (155 km) and gives more degrees of freedom than number of limb sequences (lower right (top)). The horizontal resolution (and therefore the sensitivity) in the stratosphere is slightly better than in the troposphere (upper right) and in the cold tropopause region. The vertical resolution (lower left) is larger than the tangent altitude spacing (2 km) but smaller than the field-of-view width ($\approx$ 3 km).

4. Intercomparison with 1D-retrieval

2D and 1D temperature results are intercompared for a field ranging from -10° to 65°N (Fig. 2 upper left) used to simulate spectra, where only random errors are added. Figure 2 show the differences between the true field (upper left) and the 2D results (upper right). The root-mean-square (rms) error is 0.82 K for the region where measurements are available (region with crosses). The rms error for 1D results (Fig. 2, lower left) is 2.45 K. Differences in the 1D case are largest (more than 4 K) mainly where strong horizontal gradients are present (12 km, 45°N; 32 km, 10°N).

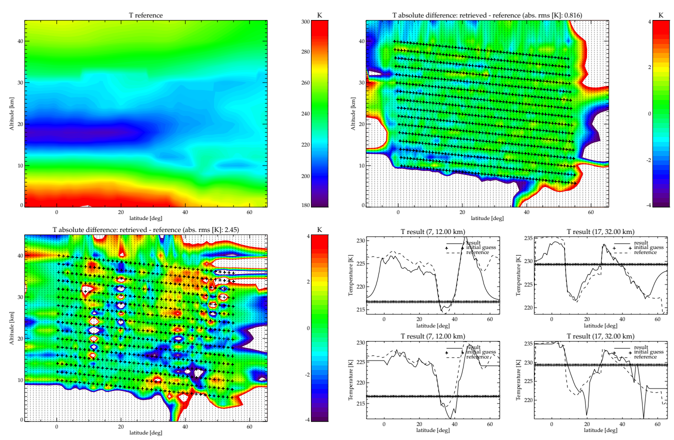

Figure 2: Upper left: Reference 2D temperature. Dots and crosses as in Figure 1. Upper right: Difference between reference and retrieved 2D temperature. Lower left: Difference between reference and retrieved 1D temperature. Lower right: Difference between reference and retrieved 2D (top) and 1D (bottom) temperature for selected altitudes.

5. Summary and Outlook

- A robust method for retrieving 2D fields in case of limb sounding is presented.
- 2D averaging kernels allow dedicated diagnostics of the result.
- 1D temperature retrieval show large errors (more than 4 K) especially where strong horizontal gradients are present.
- 2D errors are smaller than in 1D and usually do not exceed 1 K.
- Application to real MIPAS-Envisat data for case studies (strong horizontal gradients) and measurements in special mode S6.

Acknowledgments: This research was supported by ESA, contract no. 15457/01/NL/MM.

References

[1] C. D. Rodgers, Rev. Geophys. & Space Phys., 14 (1976), pp. 609–624.
[2] T. Steck and T. v. Clarmann, Appl. Opt., 40 (2001), pp. 3559–3571.
[3] M. Carlotti et al., Appl. Opt., 40 (2001), pp. 1872–1885.
[4] T. Steck, Appl. Opt., 41 (2002), pp. 1788–1797.