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2D-retrieval approach applied to MIPAS-Envisat data

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 and real 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]:

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

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. Application to simulated spectra

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 scan is 16, tangent altitude distance is 2km. This mode is similar to the special MIPAS mode S6. Retrieval grid: 2 km vertical spacing for 1D and 2D, 100 km horizontal spacing for 2D.

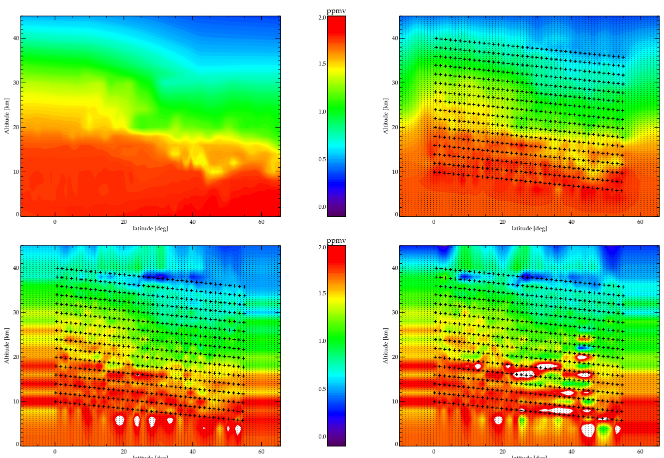

Figure 1: Upper left: Reference 2D methane field. Upper right: Retrieved 2D methane field assuming correct 2D temperature; horizontal grid is indicated by dotted lines, tangent points are marked by crosses. Lower left: Retrieved 1D methane assuming correct 2D temperature. Lower right: Retrieved 1D methane assuming correct 1D temperature.

The initial and *a priori* field is a horizontally homogeneous mid-latitude methane field.
Figure 1 shows the intercomparison of 2D and 1D retrieval of methane. 1D results show oscillations especially in the case of 1D temperature (lower right), and even some oscillations for true 2D temperature (lower left).

4. Application to measured spectra

2D and 1D temperature results are intercompared for real MIPAS measurements from September 26, 2002 of the southern polar vortex (orbit 3002, ZPD crossing time about 20:30). Figure 2 shows temperature results of 2D (upper left) and 1D (upper right). Differences between 2D and 1D (lower right) usually show values between -3 and 3 K with maximum values of ± 10 K (regions with strong horizontal gradients). Intercomparison of 2D retrieval and ECMWF analysis show good agreement with larger differences at higher altitudes.

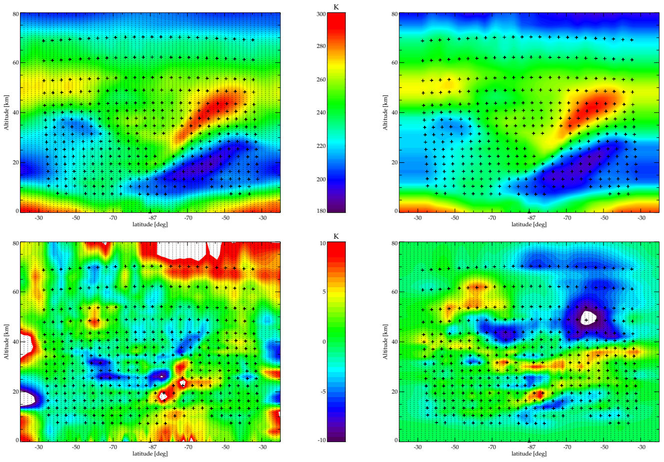

Figure 2: Results for orbit 3002. Upper left: Retrieved 2D temperature. Dots and crosses as in Figure 1. Upper right: Retrieved 1D temperature. Lower left: Difference between retrieved 2D and 1D temperature. Lower right: Difference between retrieved 2D and ECMWF temperature.

5. Summary and Outlook

- A robust method for retrieving 2D fields in case of limb sounding is presented.
- Sequential analysis of the measured limb scans saves considerable memory usage.
- 1D methane retrieval in the presence of horizontal temperature inhomogeneity shows strong oscillations.
- 2D temperature retrieval of real data works fine and preliminary results show some larger discrepancies to 1D retrieval (up to 10 K).
- Consideration of clouds in the line of sight will be included.

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References

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[3] M. Carlotti et al., Appl. Opt., 40 (2001), pp. 1872–1885.