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First Results of Inversion for Far Infrared Limb Sounding

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A number of new generation instruments for remote sensing of the stratosphere have recently been launched in order to measure emission from space in the infrared (IR) and microwave spectral range to map atmospheric species. IR/microwave limb sounding is a well established technique for the observation of stratospheric trace gas species and has several advantages of meeting the research requirements that make the observations preferable.

With support from SRON in the Netherlands and RAL in UK, the Remote Sensing Technology Institute (IMF) at the German Aerospace Center (DLR) has developed a new stratospheric balloon-borne submillimeter limb sounder, so-called TELIS (**T**erahertz and submillimeter **LI**mb **S**ounder), which can be regarded as the successor of the THOMAS heterodyne instrument that has successfully been operated on DLR's FALCON research aircraft. Together with MIPAS-B instrument TELIS is acting as a precursor of further space-borne instruments for IR/microwave limb sounding. SMILES (**S**uperconducting sub**MI**llimeter-wave **L**imb-**E**mission Sounder), a joint space-borne mission between JAXA and NICT in Japan, aims to demonstrate highly sensitive submillimeter-wave soundings and to monitor global distributions of the stratospheric trace gases. Future missions will obviously utilize the millimeter and submillimeter waves that enable simultaneous observations of many trace species. High sensitivity is particularly essential for these missions to clarify trends of trace gases in mid-latitudes and to detect dynamical features of the atmosphere. Therefore, the development of instruments contributes to an increased interest and demand in high resolution radiative transfer modeling and advanced inversion strategy for better understanding of atmospheric environment by analyzing the recent limb sounding measurements.

The goal of our data analysis is to determine the atmospheric profile $\vec{x}$ with the data vector $\vec{y}$ comprising the signal measured by the instrument. Thus, we have to solve a minimization problem

$$\min_{\vec{x}} \;=\; \|\vec{F}(\vec{x}) - \vec{y}\|^2 \,, \tag{1}$$

which leads to an iterative solution by applying the Gauss–Newton method

$$\delta\vec{x} = \left[\mathbf{A}(\vec{x}_0)^{\mathrm{T}}\mathbf{A}(\vec{x}_0)\right]^{-1} \mathbf{A}(\vec{x}_0)^{\mathrm{T}}\,\delta\vec{y}\,. \tag{2}$$

Here, $\vec{F}$ and $\mathbf{A}$ denote the analytical measurements (model spectra) generated by the forward model, and the Jacobian matrix (first-order partial derivatives of function), respectively.

A new code PILS (**P**rofile **I**nversion for **L**imb **S**ounding), whose forward model is built on the Line-by-Line code GARLIC/MIRART, has been developed by DLR-IMF for solving the nonlinear inverse problems arising in the analysis of atmospheric measurements by recent limb sounders. This program emphasizes efficient and reliable algorithms and techniques for the computation of radiance and transmission, the Jacobian matrix evaluation, and constrained nonlinear least squares optimization.

In this work we present first results of retrieval of the gas concentration profiles as well as sensitivity studies from the far infrared limb sounding observations. In particular, automatic differentiation techniques and numerical regularization schemes shall be studied.