Remote Sensing of Stratospheric Vertical Concentration Profiles from TELIS

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7th Atmospheric Limb Conference LIMB-13
This presentation participates in the student award contest

DLR

Instrument Overview

TELIS (**TE**rahertz and submillimeter **LI**mb **S**ounder):

- Remote sensing in far infrared and microwave spectral range
- Deriving vertical gas profiles in the stratosphere (10–40 km)
- Three channel cryogenic heterodyne spectrometer

1.8 THz *DLR*

OH, HO_2, H_2O, $H_2{}^{18}O$, $H_2{}^{17}O$, HDO HCl, HOCl, NO, NO_2, CO, O_2, O_3

480 – 650 GHz *SRON*

BrO, ClO, HCl, HOCl, ClOOCl, NO, N_2O, HNO_3, HO_2, H_2O, $H_2{}^{18}O$, $H_2{}^{17}O$, HDO, CH_3Cl, HCN, CO, O_2, O_3

500 GHz *RAL*

BrO, ClO, N_2O, O_3

- Together with MIPAS-B and mini-DOAS on a balloon gondola
- Three campaigns in March 2009, January 2010, and March 2011

Inversion Methodology

- Forward model based on **GARLIC**
- Jacobians provided by automatic differentiation
- Nonlinear optimization solver
- Direct and iterative regularization methods
  - Tikhonov regularization (TR)

$$x_{i+1} = x_a + \left(K(x_i)^T K(x_i) + \lambda L^T L\right)^{-1} K(x_i)^T \left(y^\delta - F(x_i) + K(x_i)(x_i - x_a)\right)$$

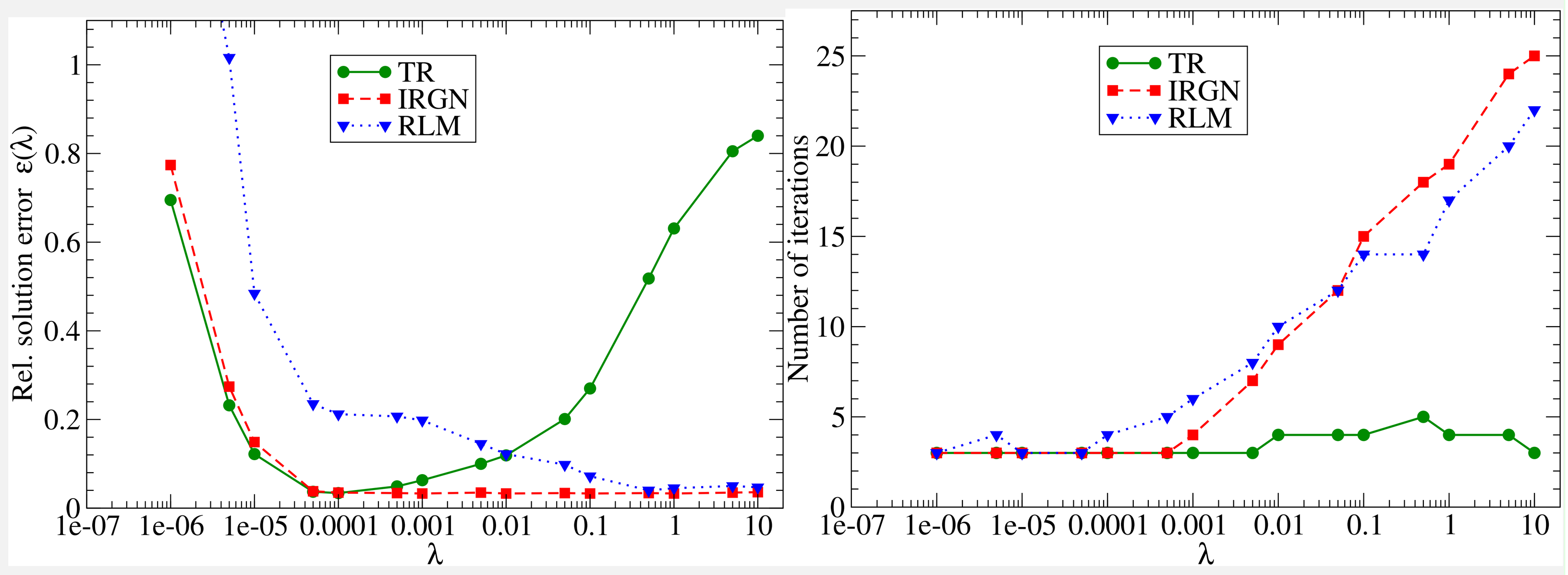
  - a priori knowledge x_a in penalty term
  - constant λ
- Iteratively Regularized Gauss–Newton Method (IRGN)

$$x_{i+1} = x_a + \left(K(x_i)^T K(x_i) + \lambda_i L^T L\right)^{-1} K(x_i)^T \left(y^\delta - F(x_i) + K(x_i)(x_i - x_a)\right)$$

  - a priori knowledge x_a in penalty term
  - $\lambda_k = q\lambda_{k-1}$ with $0 < q < 1$
- Regularizing Levenberg–Marquardt Method (RLM)

$$x_{i+1} = x_i + \left(K(x_i)^T K(x_i) + \lambda_i L^T L\right)^{-1} K(x_i)^T \left(y^\delta - F(x_i)\right)$$

  - previous iterate x_i in penalty term
  - $\lambda_k = q\lambda_{k-1}$ with $0 < q < 1$



Retrieval Setup

- TELIS-DLR 1.8 THz channel data
- Measuring date: 24 January 2010
- A single segment (500 MHz) used for each retrieval
- Fitting parameters
  - Target molecule(s)
  - Altitude-dependent "greybody" fitting
  - Tangent-dependent baseline offset fitting
- Temperature: MIPAS-B retrieval
- Pressure: ECMWF data
- Angular pointing bias 3.4 arcmin upwards
- Atmospheric refraction considered

Acknowledgements

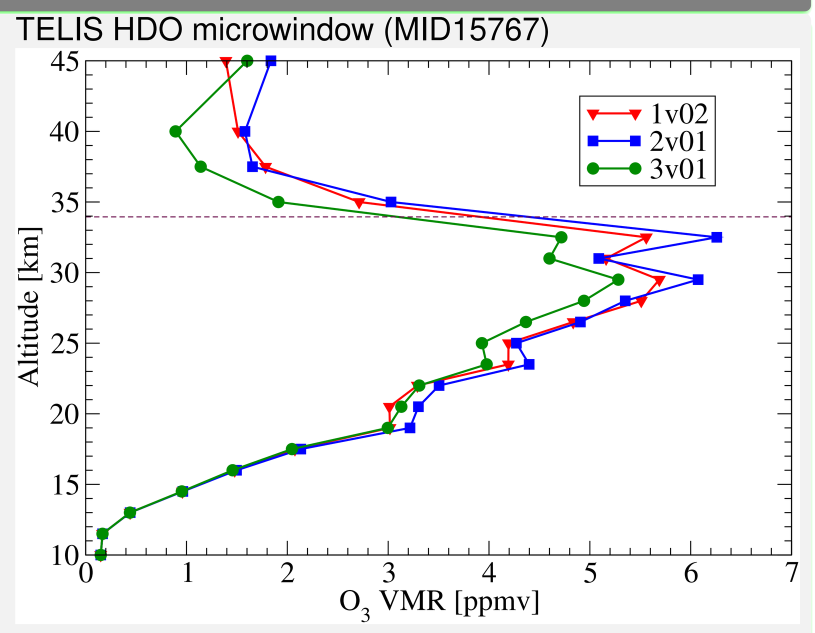
The authors would like to thank A. Doicu from DLR, A. de Lange and J. Landgraf from SRON, Y. Kasai, H. Sagawa, and P. Baron from NICT for many collaborations and fruitful discussions. We also appreciate G. Wetzel and H. Oelhaf providing temperature profiles from the MIPAS-B retrievals.

Level-1b Updates

- Major improvements
  - Measurement noise reduction (2v01)
  - Sideband ratio consolidation (3v01)
  - Nonlinearity correction (3v01)
- Intercomparison of O_3

Level-1b version	Residual
1v02	1.510
2v01	1.466
3v01	0.8571

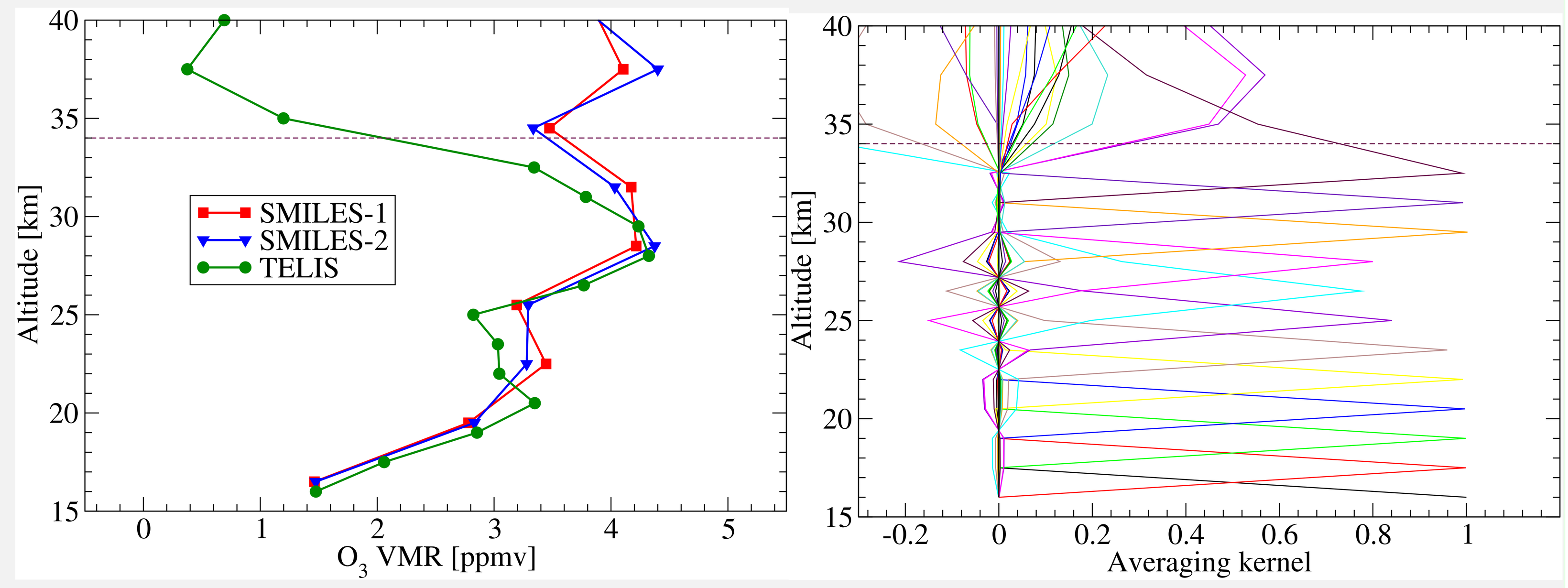
TELIS HDO microwindow (MID15767)



SMILES O_3 Validation

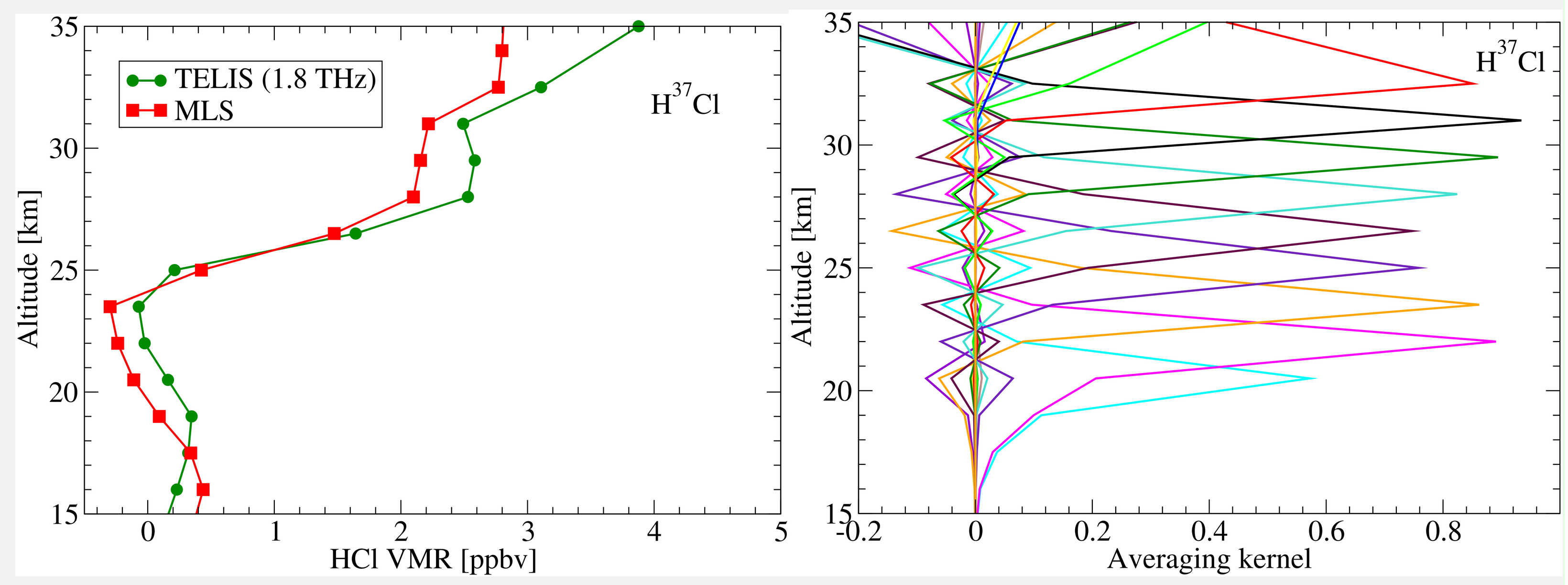
Y. Kasai et al. AMT 2013 (accepted subject to minor revision)

- **S**uperconducting sub**MI**llimeter-wave **L**imb-**E**mission **S**ounder
- Available observations 12 October 2009 — 21 April 2011
- NICT L2r product (version 2.1.5)
- Criteria: ±1 h, ±200 km
- Compare with TELIS CO microwindow (MID20864)



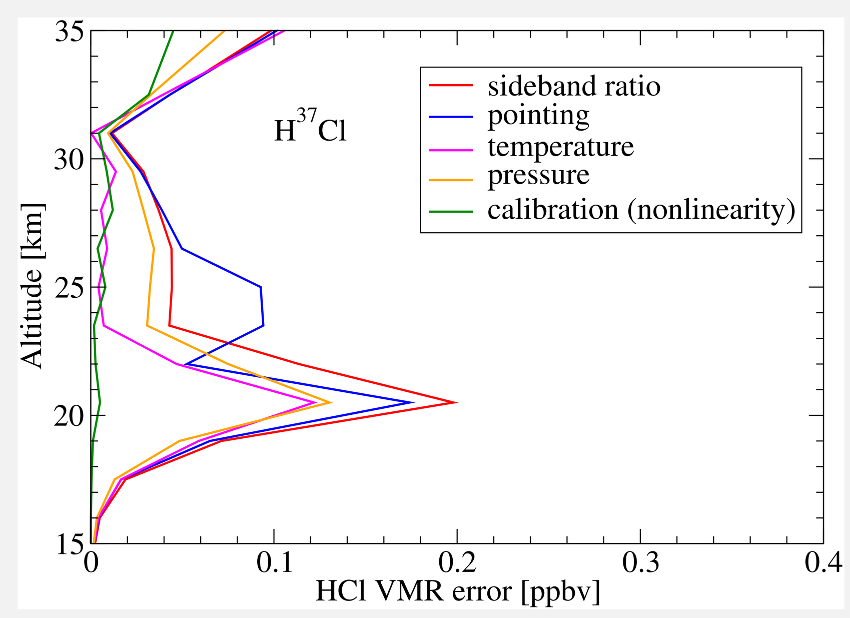
First Result of HCl Retrieval

- TELIS $H^{37}Cl$ microwindow (MID20044)

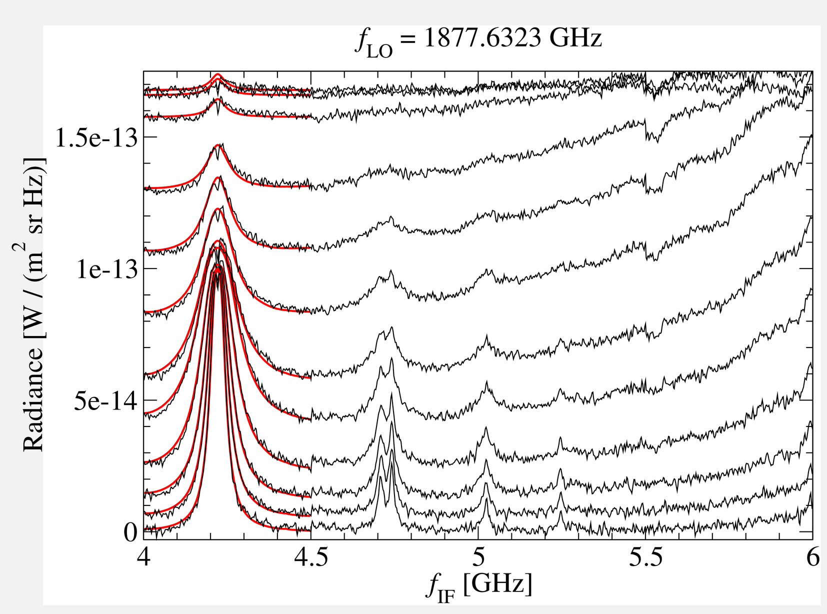


- Error analysis

Error source	Uncertainty
Sideband ratio	0.05
Pointing	0.5 arcmin
Temperature	1 K
Pressure	1 %
Nonlinearity	5 % compression



- Model spectra versus measurements at final iteration (segment 1)



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