Toward CO_2 and CH_4 measurements by ground based observations of surface-scattered sunlight: Radiative transfer modeling

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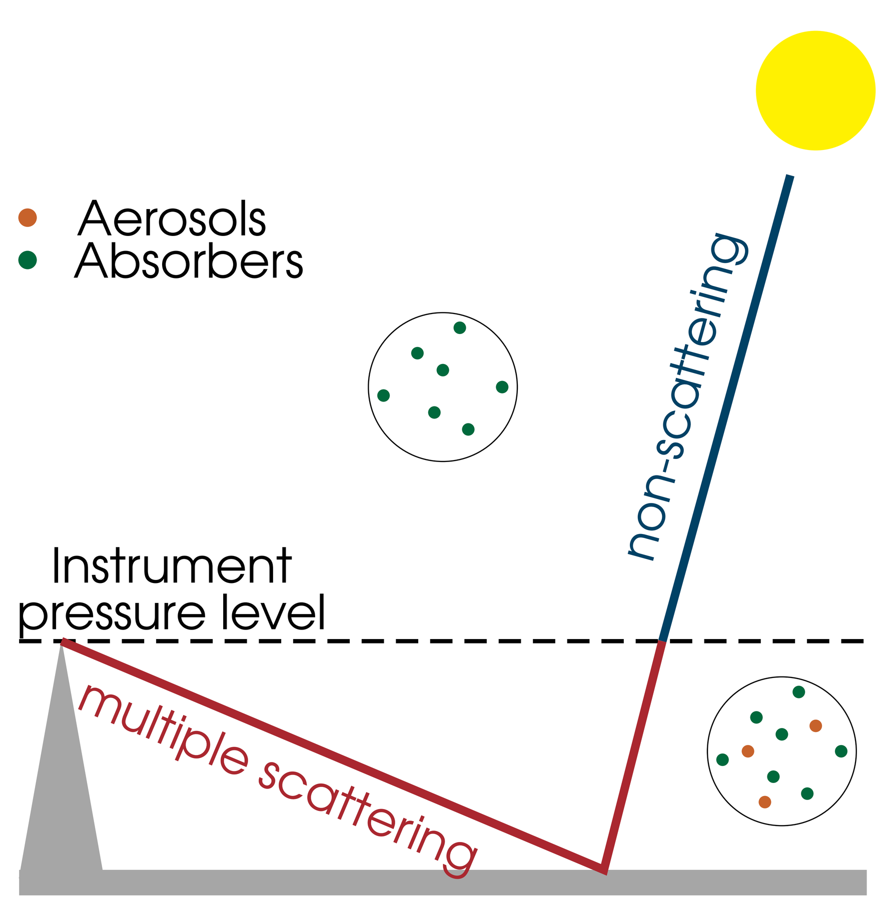
Introduction

A portable, field-deployable spectrometer for measurements of surface-scattered sunlight is under development and first results look promising (1). This relflected-sun observation geometry is highly sensitive to the atmospheric composition in the boundary layer due to the long horizontal path component. The pioneering reflected-sun experiment is CLARS-FTS (3) overlooking the Los Angeles basin from the top of Mt. Wilson. However, this measurements are also prone to aerosol scattering. Since retrieval methods rely on accurate knowledge of the actual lightpath, rigorous radiative transfer modeling is required to evaluate spectral measurements of surface-scattered sunlight with high accuracy (2).

Setup

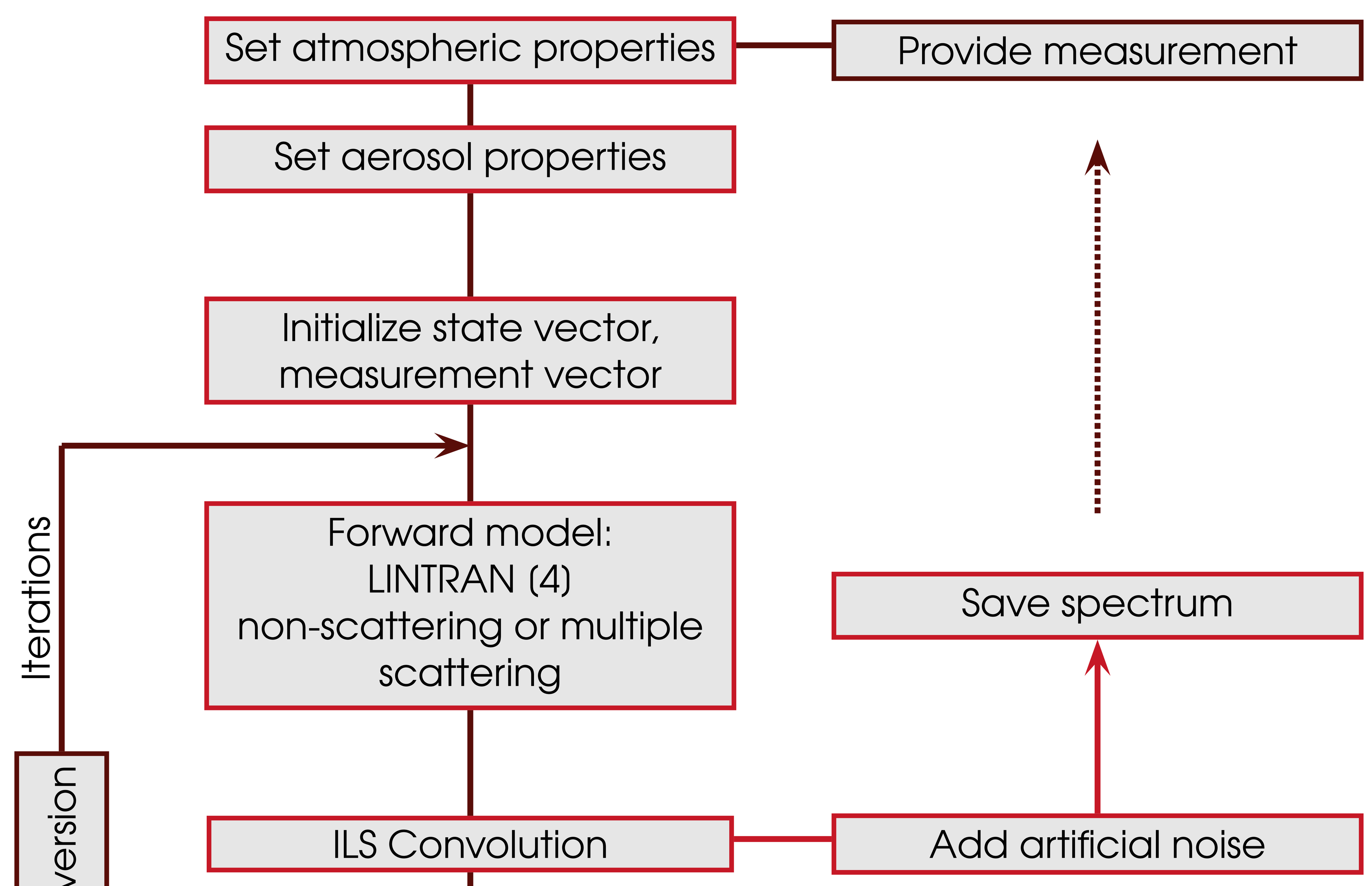
We start from the radiative transfer and retrieval software RemoTeC that has been applied to several satellite measurements for retrievals of dry air mole fractions of carbon dioxide and methane (XCO_2 and XCH_4, respectively) together with effective atmospheric scattering properties.

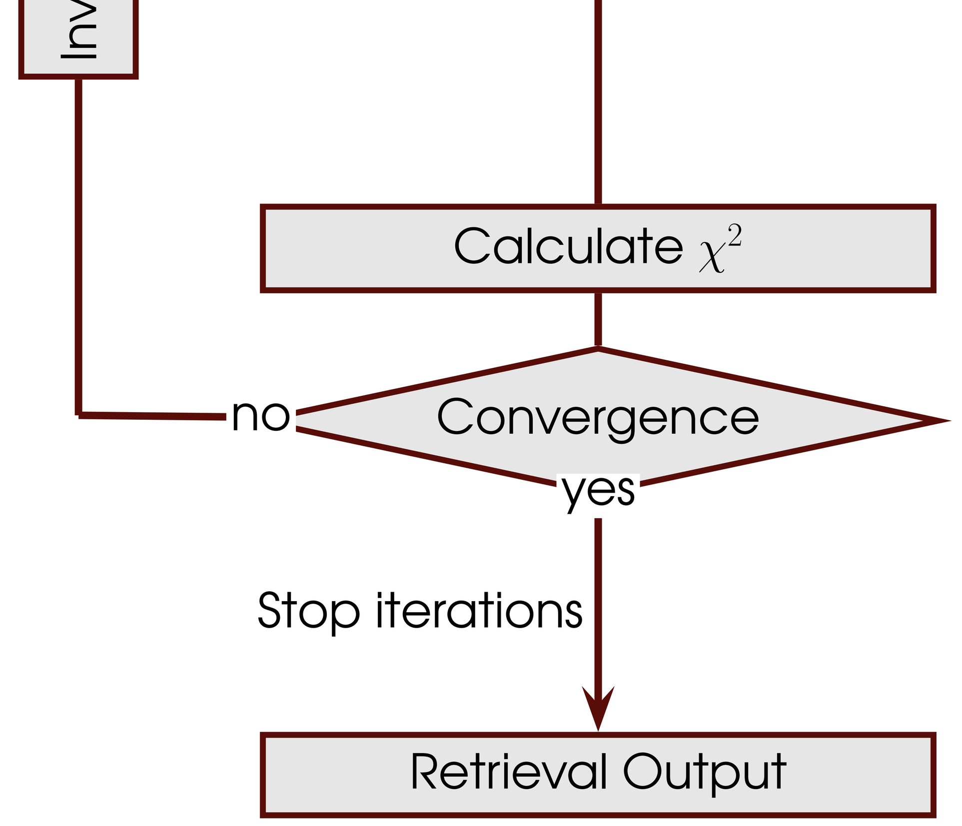


For the reflected-sun approach we divide the atmosphere in two parts at the pressure level of the instrument which is located above the planetary boundary layer. Above the instrument the atmosphere contains only absorbers. Below the instrument also aerosols are present. Since aerosols are produced primarily within the planetary boundary layer this assumption is reasonable.

Method

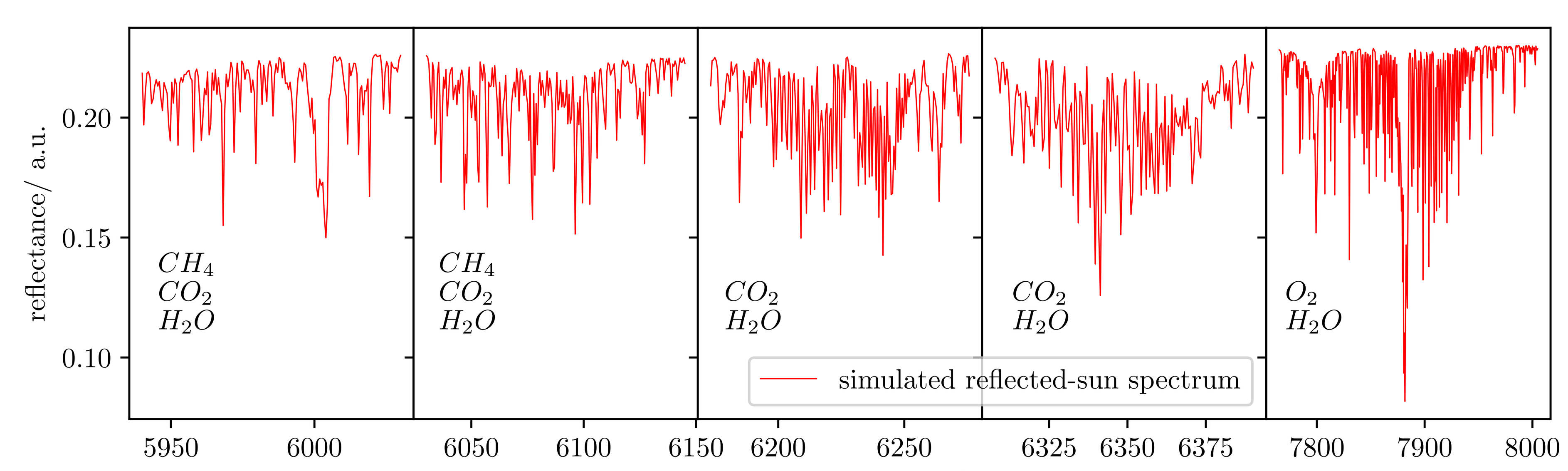
The radiative transfer and retrieval software RemoTeC retrieves XCO_2 and XCH_4 together with atmospheric scattering properties (2). Reusing modules and routines from the RemoTeC retrieval tool (dark red line) we build a simulation environment (highlighted in brighter red) for radiative transfer calculations.



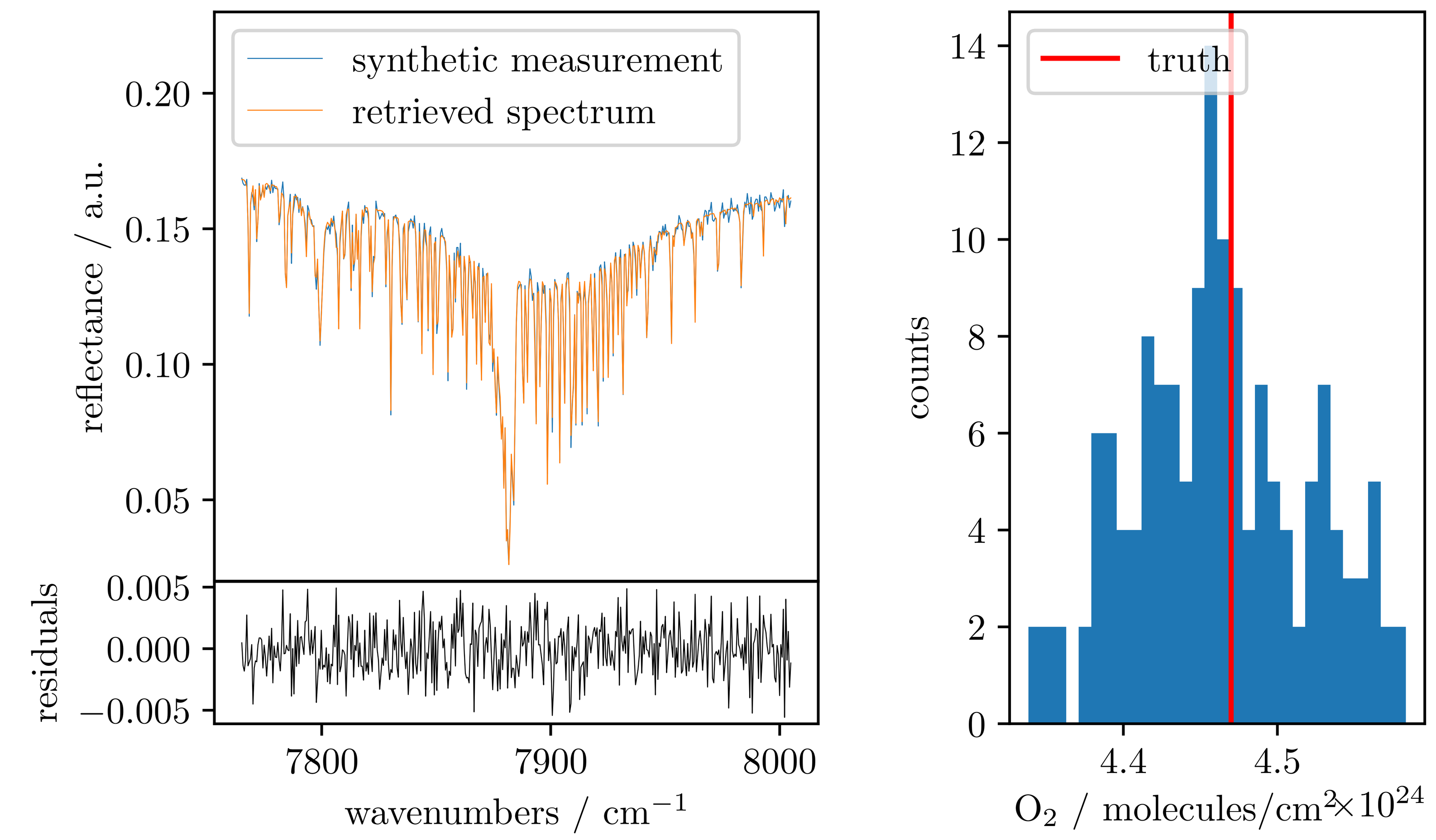


Current state

To simulate reflected-sun spectra, the forward model is called twice. First in non-scattering mode for the lightpath above instrument level. Next in multiple-scattering mode for the lightpath below instrument level.
The figure shows simulated reflected-sun spectra for 5 spectral windows.



Consistency



We retrieve 150 simulated multiple-scattering spectra and keep all settings constant. Then we compare the scatter of all retrieved quantities with their retrieval errors and with the noise level of the synthetic measurement. Exemplary plots are shown for O_2. The standard deviation of retrieved is O_2 $\sigma_{O_{2,retr}} = 5.61 \cdot 10^{22}\ 1/cm^2$ and mean of retrieval errors is $\mu_{\Delta O_2} = 6.04 \cdot 10^{22}\ 1/cm^2$. The same validation holds for the other retrieved quantities. Therefore, in the range of the error bars the retrieval represents the simulation truth.

Forthgoing research

In the next step we will adapt the inversion to the reflected-sun lightpath and repeat consistency checks. Once this is done, we want to use this promising tool to investigate and improve on the accuracy of radiative transfer modeling for reflected-sun measurements. We will calculate simulation studies to quantify errors of the retrieval tool, evaluate information content of reflected-sun measurements and investigate on the accuracy of the lightpath-proxy approach. The final goal will be to develop a refined approach for the evaluation of reflected-sun measurements based on these studies.

References

(1) Benedikt Hemmer. Toward ground-scattered sunlight measurements of carbon dioxide and methane. Master thesis, Heidelberg University, 2019.

(2) André Butz, Otto P. Hasekamp, Christian Frankenberg, and Ilse Aben. Retrievals of atmospheric CO_2 from simulated space-borne measurements of backscattered near-infrared sunlight: accounting for aerosol effects. *Appl. Opt.*, 48(18):3322–3336, Jun 2009.

(3) D. Fu, T. J. Pongetti, J.-F. L. Blavier, T. J. Crawford, K. S. Manatt, G. C. Toon, K. W. Wong, and S. P. Sander. Near-infrared remote sensing of los angeles trace gas distributions from a mountaintop site. *Atmospheric Measurement Techniques*, 7(3):713–729, 2014.

(4) D. Schepers, J.M.J. aan de Brugh, Ph. Hahne, A. Butz, O.P. Hasekamp, and J. Landgraf. Lintran v2.0: A linearised vector radiative transfer model for efficient simulation of satellite-born nadir-viewing reflection measurements of cloudy atmospheres. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 149:347 – 359, 2014.