Retrieving CO_2 profiles from TCCON near-infrared spectra

Sébastien Roche (1), Kimberly Strong (1), Debra Wunch (1), Joseph Mendonca (1), Geoffrey C. Toon (2), and Brian J. Connor (3)

(1) Department of Physics, University of Toronto, Toronto, Canada
(2) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
(3) BC Consulting Limited., Martinborough, New Zealand

Contact: sebastien.roche@mail.utoronto.ca

Introduction

The Total Carbon Column Observing Network[1] (TCCON) is composed of high-resolution ground-based Fourier transform Infrared (FTIR) spectrometers that record solar absorption spectra. Column-averaged dry-air mole fractions of CO_2 (XCO_2) are retrieved from the recorded spectra and used to validate satellite observations of XCO_2 and to study the carbon cycle.

GFIT is a non-linear least-squares spectral fitting algorithm used for TCCON retrievals. Amongst other parameters, volume mixing ratio scale factors are retrieved for several gases. A single scale factor scales the a priori concentration profile of each fitted trace gas, thus it does not change the shape of the profile.

GFIT2[2] is a profile retrieval algorithm that allows the profile shape to vary during the retrieval process. The algorithm thus has more freedom to fit the observed spectra, but is also more sensitive to uncertainties in the forward model calculations such as spectroscopic errors and instrument misalignment, for example.

The purpose of this study is to investigate the feasibility of stable CO_2 profile retrievals.

Spectral windows

To add different sources of profile information, windows of various opacities are used (Fig. 1).
The strong band holds more information on concentrations at lower altitudes, the weak band is more sensitive to higher altitudes, and the usual TCCON bands are sensitive throughout the troposphere (Fig. 4, a).

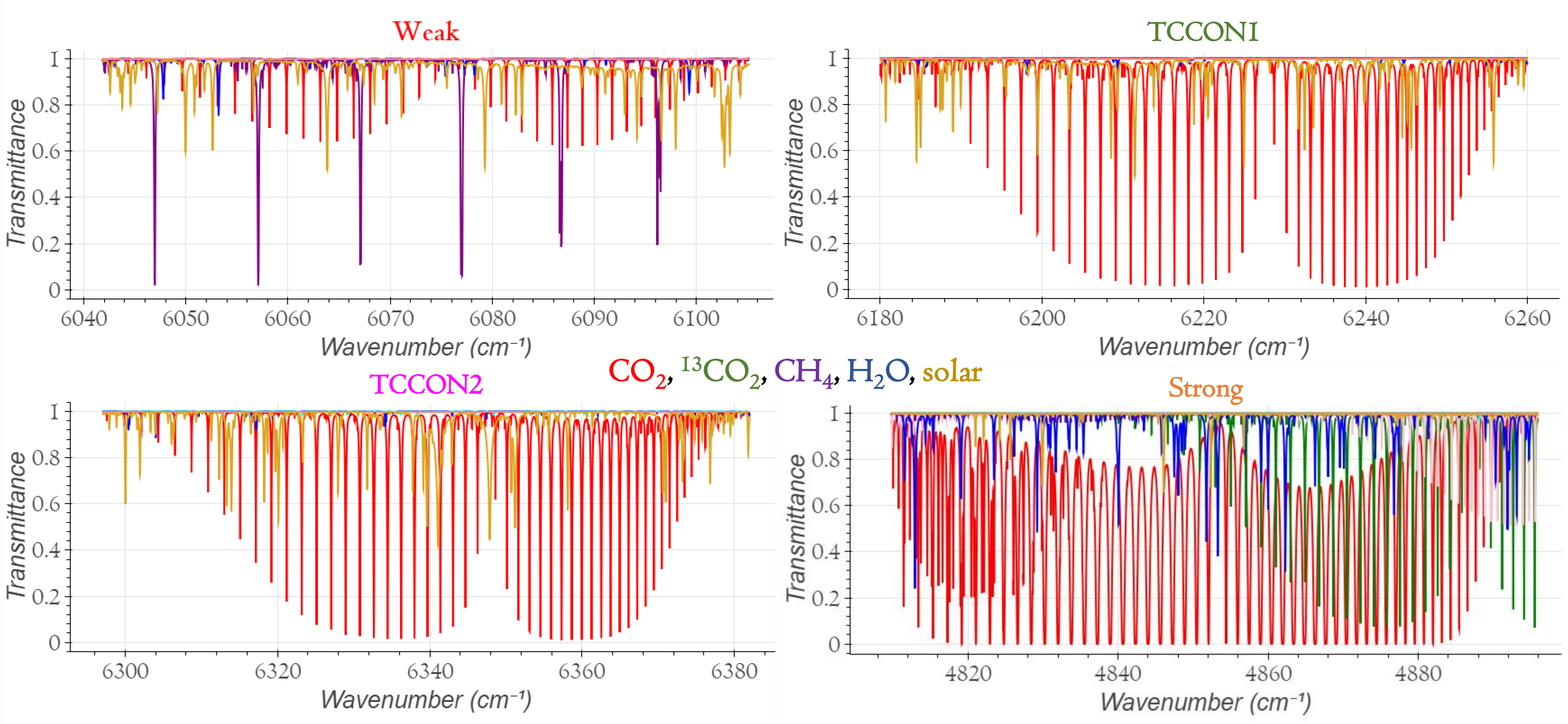

Figure 1: spectral windows used to retrieve CO_2, the weak band centered at 6073 cm^{-1} (top left), the standard TCCON bands centered at 6220 cm^{-1} (top right) and 6339 cm^{-1} (bottom left), and the strong band centered at 4852 cm^{-1} (bottom right).

Improved fits

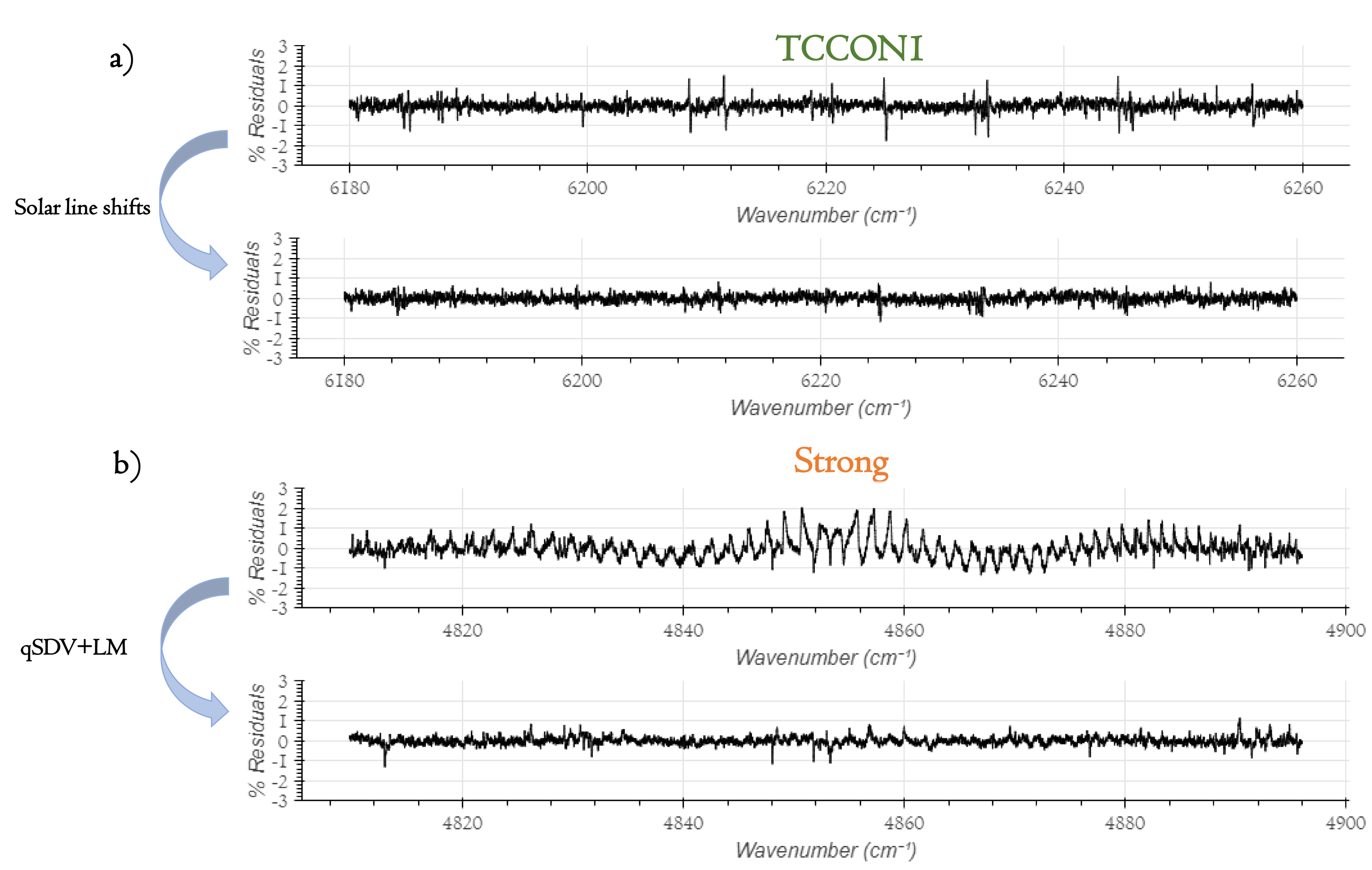

Figure 2: improved spectral fits due to (a) correction of solar line shifts in TCCON1 window, and due to (b) the addition of the quadratic speed-dependent Voigt profile with CO_2 line mixing[3] (qSDV+LM) in the strong window.

Method

- Retrieve CO_2 from different spectral windows to exploit different sources of profile information.
- Improve the fitting algorithm.
- Use AirCore profiles as a priori. Those provide the "truth" as the prior, in this case the retrieved profiles should be equal to the prior. Discrepancies come from errors in the forward model.
- Correct those biases for each band.
- Combine retrievals from the different bands to produce a single profile.

Results

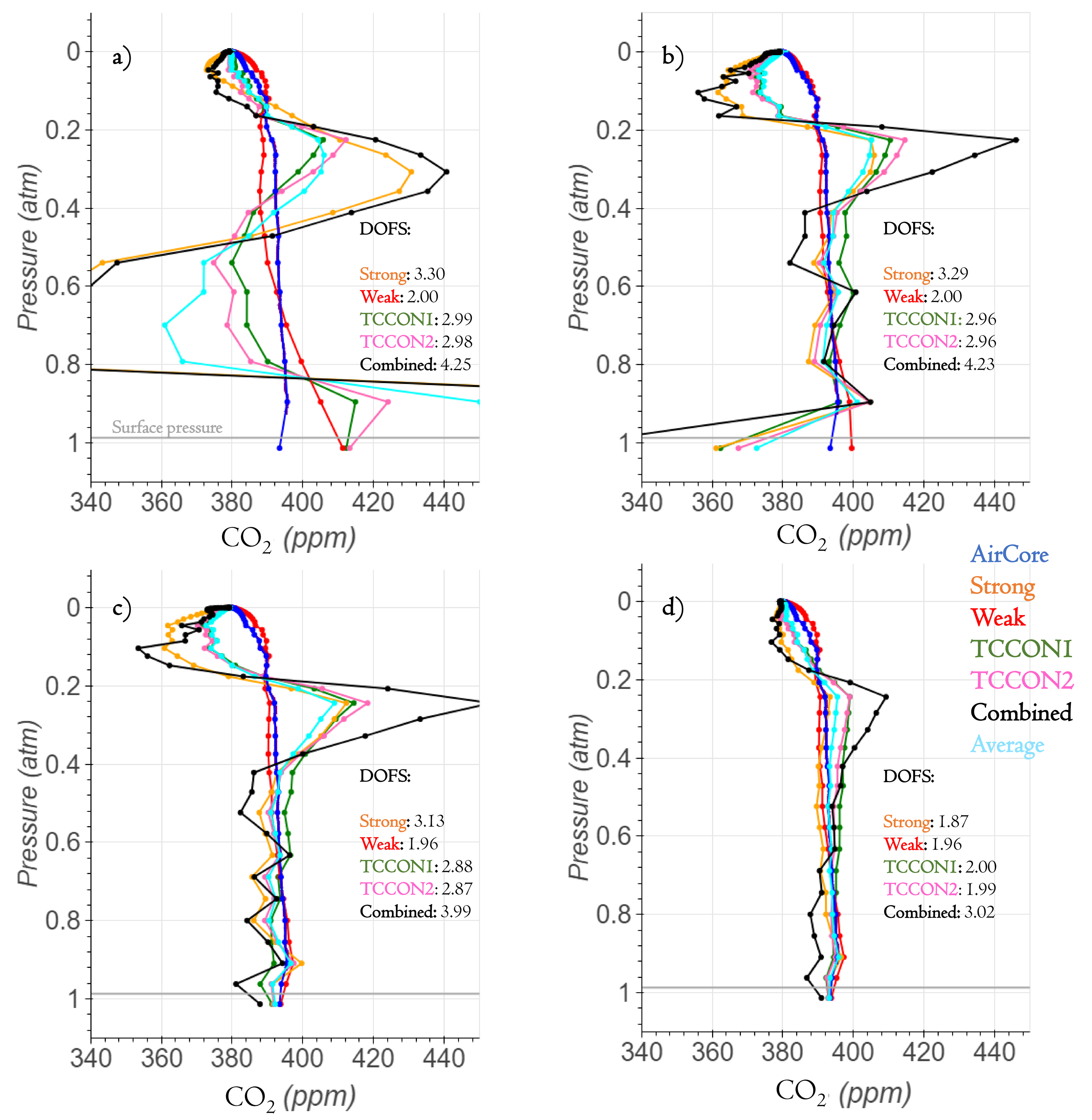

Figure 3: CO_2 profiles from each window retrieved with different setups (a) 71-level grid (1km spacing), Voigt line shape with no line mixing, (b) qSDV+LM, 71-level grid, (c) qSDV+LM, 51 levels grid, (d) qSDV+LM, 51-level grid, noise scale factor empirically adjusted to obtain dofs~2 in each window. The "Combined" profile is a weighted average of the profiles from the different windows using the retrieved covariance matrices as weights. The "Average" profile is the non-weighted average of the profiles from the different windows.

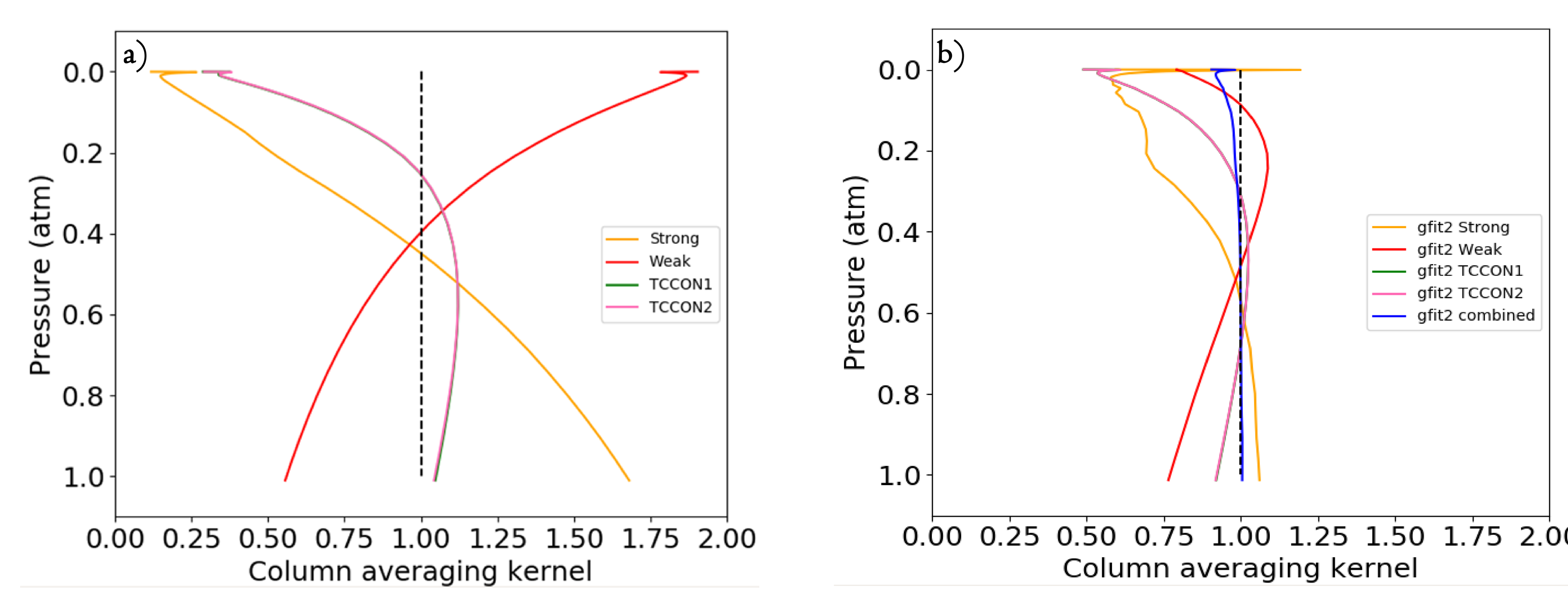

Figure 4: column averaging kernel for (a) GFIT scaling retrievals, and (b) GFIT2 profile retrievals.

Conclusions

Improvements to the fitting algorithm and prior constraints significantly reduce oscillations in retrieved profiles. However CO_2 profiles retrieved from the different bands remain inconsistent.

GFIT scaling retrievals lead to degrees of freedom for signal (DOFS) ~1.
GFIT2 profile retrievals have DOFS that can reach ~3-3.5.
Large oscillations can be smoothed empirically by applying a scaling factor to the measurement noise and still obtain DOFS ~ 2 (Fig. 3, d).

Profile retrieval has more uniform sensitivity to CO_2 with altitude (Fig. 4).

Acknowledgments

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