

Atmos. Meas. Tech. Discuss., referee comment RC2
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Comment on amt-2022-322

Anonymous Referee #2

Referee comment on "Inferring the vertical distribution of CO and CO₂ from TCCON total column values using the TARDISS algorithm" by Harrison A. Parker et al., Atmos. Meas. Tech. Discuss., <https://doi.org/10.5194/amt-2022-322-RC2>, 2023

Review of Parker et al. (AMT-2022-322)

Retrieving vertical information, particularly boundary layer/upper tropospheric amounts, from TCCON observations, and potentially from spectrally similar satellite observations, has long been recognized as theoretically possible and valuable for insight into surface flux of the measured species. But it has been a very difficult practical problem, for reasons described in the subject paper (though I don't believe Doppler width is important in the troposphere).

There has been an ongoing effort to use multiple spectral windows of CO₂ for this purpose, especially the 4 windows used here, because of their widely different vertical sensitivities (resulting from their widely different optical depths). This effort has concentrated on detailed, iterative spectral calculations, and has not resulted to date in an operationally useful algorithm.

The current paper presents a very much simpler approach to using the same measured spectra. Its authors include several of the key figures from the earlier efforts, who necessarily are aware of the difficulties. The new approach is by further analyzing the column density results produced routinely from the TCCON observations of the several spectral bands. The paper proposes a novel use of the well-known MAP algorithm, applied to this problem by unique definitions of the fundamental quantities in the basic matrix equation $\mathbf{y} = \mathbf{Kx}$. The newer approach is orders of magnitude faster than iterative spectral calculations (though less general).

Thus the paper is potentially a very valuable step forward in this work, which may finally lead to that long-sought-after operational algorithm. That said, I have a number of serious reservations about it in its present form, and think it needs major revision.

Reading the subject of this paper, the first thing I wanted to see was the comparison between validation data and TCCON partial column results (P1) vs the (presumably improved) comparison to TARDISS, but no such comparison is ever made. I have no basis to judge how much (or indeed if) the algorithm succeeds.

Section 2.2 is the heart of the formulation. It is more difficult to read than it needs to be. Many of the symbols need more precise explanation, and sometimes have inconsistent descriptions. A few examples (not an exhaustive list) follow. In eq. (2), $\mathbf{x}_{a,p1}$ is called a 'profile' while \mathbf{x}_{part} is a 'partial column'; a study of eq. (3) is needed to understand the symbols in (2) (they are both profiles). In another case, eq. (17) is presented without justification and the actual meaning of \mathbf{A}_{vert} is opaque.

In eq.(1), $z_{a,p1}$ is said to be the median value of the TCCON-retrieved scale factor in the set of windows used, times the original a priori column (L. 226). Twelve pages later (L. 501-2) it turns out to be the *daily* median for CO₂, and equal to 1 for CO, which modified my understanding of the intervening material, and required re-reading. Also in eq.(1) \mathbf{x}_{part} is called 'partial column' while $\mathbf{x}_{a,p1}$ is called the 'profile.'

More generally, the authors have clearly made extensive analyses of the algorithm for various choices of input and data from various sites, which is commendable, and report these results in exhaustive detail in tables and figures. Unfortunately, descriptions in the text of the results shown in the tables and figures are more detailed and extensive than is useful, and inhibit identification and understanding of the key results.

Finally, there are a number of typos and careless errors. As examples (again, not an exhaustive list):

-L.174 'United States' includes a site in Saskatchewan!

-Fig. 3 caption: 'The profile above 6 km not shown' does not seem to refer to anything.

-L.527 contains 'of the' twice

-P.36 ends in the middle of a sentence which is not continued on the next page.

-Connor et al., 2008 is cited (it's the first citation in the text) but it's not in the reference list

-L.990 'Fig. B'; which one?