

Review of the manuscript „The TropoPause Composition TOWed Sensor Shuttle (TPC-TOSS): A new airborne dual platform approach for atmospheric composition measurements at the tropopause“

by Bozem et al.

Reply to editor

We appreciate further suggestions to improve the manuscript. We will answer to all comments of the editor below point by point. Editor comments are given in standard, answers in red, and changes to the manuscript in blue font.

The authors could resolve all questions by the reviewers and did adjust the manuscript accordingly.

This makes the manuscript almost ready for publication. To finalize, I have a short list of suggestions that came up when reading the revision. These may provide some improvements. The authors hopefully agree.

L 41: Instead of HALO-(AC)³ better use the ACLOUD campaign as a reference. During HALO-AC³ also the HALO aircraft was operated and flew in the tropopause for some time. That's why your statement on the the Polar 5/6 operation might be misleading. In the ACLOUD data paper, a discussion on the collocation of P5/P6 is given (<https://doi.org/10.5194/essd-11-1853-2019>).

Thank you very much for this suggestion. We changed the reference accordingly and rephrased L41 ff.:

One approach in former studies was to perform co-located measurements with two aircraft, for example during CRYSTAL-FACE (Cirrus Regional Study of Tropical Anvils and Cirrus Layers – Florida Area Cirrus Experiment) (Jensen et al., 2004) or with the *Polar 5* and *Polar 6* aircraft during ACLOUD (Ehrlich et al., 2019). The *Polar* aircraft are almost identical making them well suited for co-located measurements as shown by Maherndl et al., 2024. However, flights with *Polar 5* and *Polar 6* aircraft could only be performed below 5 km altitude due to aircraft performance capabilities. In general, coordinated measurements involving two different aircraft often suffer from difficulties of exact horizontal co-location at two different altitudes due to different aircraft speeds, as pointed out by Klingebiel et al. (2017, and references therein). Further, measurements at a vertical distance of just 100-200m are difficult to realize with two aircraft for safety reasons.

L41: The sentence on Polar 5/6 can also be misleading because readers might not know, that the two aircraft are twins with the same performance. The second part of the sentence may imply, that the collocated approach never worked at all. However, with Polar 5/6 being almost identical, the collocated approach worked quite well for some

applications. See Maherndl et al. 2024

(<https://acp.copernicus.org/articles/24/13935/2024/>)

See rephrased text above.

L56: The introduction ends a little plain. I'm missing a motivation why TPC-TOSS is needed. Any discussion on the requirements to study tropopause gradients?

- What vertical resolution do you need to study tropopause gradients? Or separation between the two payloads?

- What accuracies of tropopause measurements is needed to study the gradients/processes?

In this respect, what is the intended advantage of TPC-TOSS compared to previous approaches. Is the motivation to have the identical instrumentation in two altitudes at the same time?

We added a paragraph to the introduction addressing the suggestions above:

The new setup of the TPC-TOSS (TropoPause Composition TOWed Sensor Shuttle) includes measurements of ozone, GPS information, aerosol size distribution from 95-1000 nm as well as sensors for humidity and temperature, which are operated simultaneously on the Learjet.

This approach addresses the challenge of characterizing transient fine-scale structures and composition variability in the tropopause region. Such features are particularly associated with composition gradients and variations in temperature, humidity and ozone. To resolve these structures, simultaneous measurements typically require a vertical resolution of 100-150 m and accuracies better than about 0.2 K for temperature and a few percent for humidity and trace species measurements.

Notably, conventional in situ single-platform approaches cannot provide truly simultaneous observations of transient structures with a lifetime of less than a few minutes. The dual-platform concept combining TPC-TOSS and the Learjet directly addresses this gap by deploying two synchronized payloads at slightly different altitudes. This configuration provides co-located measurements within the tropopause region, minimizing calibration offsets and temporal mismatches. A vertical separation of 100-150 m allows instantaneous determination of gradients and mixing signatures that would otherwise be obscured by sequential profiling. Compared with previous approaches, TPC-TOSS thus offers a unique capability to quantify small-scale transport and mixing processes at the tropopause and to relate observed gradients to underlying dynamical mechanisms.

In the following sections we will present the new setup and will provide uncertainties and individual tests, as well as some examples demonstrating the agreement between

the two platforms. Additionally, we will showcase typical results achieved during the first field setup.

L108: I would further emphasize that you demonstrate here the potential of the identical payloads in TPC-TOSS and the Learjet. I would also explicitly state, that for all other instruments references are given (instruments that were operated on one platform only). Readers might have the question: why only describing this selection of instruments and not all. That's why the tandem analysis should be highlighted. Additionally, you may motivate what is needed to prove that the duplicated instruments can be analyzed jointly: comparability, cross calibration, identical performance of the twin instruments must be given and demonstrated as in your study.

Thank you very much for the suggestion. We modified L108 ff. as follows:

This synchronized payload with partly identical instrumentation on TPC-TOSS and Learjet in particular allows for the determination of gradients of different quantities which in turn are used to study the effect of small-scale transient features on the UTLS composition. Therefore, the focus of this paper is on the TPC-TOSS and the duplicated instrumentation on the Learjet as part of the dual platform approach. For all other instrumentation on the Learjet and in the underwing pod we provide references for characterization and application of the respective instrument in Table 2 and Table 3. In Sect. 4 we will describe the TPC-TOSS instrumentation in detail also demonstrating the comparability and similar performance of the instruments based on cross calibration in the laboratory, during the intensive operation period on ground and also during research flights. This is in particular essential to ensure that observed differences between the two payloads reflect true atmospheric gradients rather than instrumental offsets.

Table 2-4: All acronyms need to be explained. Maybe in the table caption or a footnote.

We added the explanation of the acronyms to the respective tables.

Fig. 2: I can not identify any instrument on this picture. I only see a metal frame and some cables. This makes the image useless. If there is any reason why you show this images, then make it clearer to the reader, use labels, add a scale, etc.. or simple remove it.

We removed Fig. 2.