

Review of: "Accurate and high-resolution measurements of UTLS water vapor by balloon-borne laser absorption spectroscopy" by Brunamonti et al.

Content

The manuscript presents the first in-flight validation of ALBATROSS, a balloon-borne mid-infrared laser spectrometer for UTLS water vapour, based on seven soundings from Payerne and Lindenberg (2022-2026). Each flight carried the Vaisala RS41 and a CFH as reference instruments. The authors report tropospheric excellent agreement in comparison to the two reference instruments, and use two balloon-wake "spikes" to argue that ALBATROSS has a low response time of about 1s. A substantial part of the paper documents the identification and iterative mitigation of internal contamination pathways and the in-flight CO₂ purge system developed to suppress them.

Overall impression and rating

This is a valuable and timely contribution and, in my view should be clearly published in AMT. Independent, fast-response, spectroscopically traceable balloon hygrometer is exactly what the community needs given the phase-out of the cooling agent R23 for the CFH/FPH operation, the transition to new chilled-mirror concepts, and the limited future satellite coverage. The engineering work is careful and honestly reported and I particularly appreciate that the authors document the failures rather than only the successes. The F6 profiles are a genuinely impressive result. The manuscript is well written and well organised and I therefore recommend publication in AMT after some minor revisions stated below.

Main comments:

- Measurement technique: Which pressure and temperature are used to convert retrieved H₂O number density (or line area) to mixing ratio? RS41? An in-cell sensor? The SC-MPC body temperature? This is the single most consequential retrieval input and it is not stated. And on a related point: How homogeneous are the temperature and pressure fields in the Albatross inlet, since that also affects retrieval?
- Do corrected data enter the statistics? Table S1 lists the five F3 intervals as flagged ("partly corrected by diffusion model"), while Fig. 6 presents the cor-

rected points among "valid measurements". Section 4.4 defines flagged points as those excluded. Please state unambiguously whether the corrected points are included in Table 2 and Fig. 8, and report the statistics with and without them. As it stands, a reader cannot tell whether the stratospheric 3 +/- 10 % includes model-corrected data.

- Purging system: Does CO₂ reach the optical cell, and if so what does it do to the retrieval? The connectors are held at slight overpressure with CO₂. If CO₂ leaks into the cell, two possible effects could arise: first any absorption or continuum contribution near 1662 cm⁻¹ line, and second more importantly, a change in the collisional broadening of the H₂O line, since CO₂-broadening coefficients differ from air-broadening. Please comment on that, if this could be potentially affect the retrieval.
- Missing concentration dependence analysis: You have done a great job of illustrating the differences between the instruments on a height scale and thus also on a pressure scale, but in validation studies, a comparison as a function of H₂O is typically used as well. This can be done either with a regression of ALBATROSS against CFH (log-log or orthogonal regression, with slope, intercept and confidence intervals) over the full 5-5000 ppm range or just with the difference in H₂O (detlaH₂O) along the reference. A slope test is the standard way to demonstrate that agreement holds across three orders of magnitude in H₂O and a addition figure showing this would be a very good addition to the paper.

Further Specific comments/questions:

- Abstract, line. 30 and Sect. 5: Please state that valid stratospheric data were obtained in four of seven flights, and that the 12-28 km statistics rest on two independent profiles.
- Page 2, line 15: I think there are also satellite measurements with higher resolution. For example, ACE-MAESTRO provides an altitude resolution of about 1 km (e.g. Weaver et al. 2019). I would suggest expanding the range to 1-3 km and adding the phrase "depending on the satellite."
- Page 6, line 15-17: The purge budget doesn't close. 25g CO₂ = 0.568 mol approx. equals 12.7 sL which result in approx. 85-127 min at the stated 0.10-0.15 slpm, not the "about 3 hours" claimed. Can you please comment on it ?
- Page 7: Please state how ALBATROSS, CFH and RS41 time bases were synchronised, and the residual uncertainty as this is very essential for the later comparison.
- Page 8: Flight F2 used a dry-ice/alcohol cryogen mixture rather than R23 for the CFH. Since cryogen choice is one of the motivations for the paper, does F2's performance differ systematically from the R23 flights? Even a sentence would be of interest to GRUAN readers.
- Page 10, line 26: I guess the low ascent rate cannot be explained by the parachute. The drag by the balloon itself is much larger than the one of the parachute. For me it looks like the balloon had a small leakage and thus lost slowly helium this

would explain, why the ascent rate even further decrease with time (see your Fig. 2).

- Figure 4, Section 4.2: Is there a reason why the Albatross measurements in the troposphere don't start at higher pressures than about 750 hPa or lower? Is the selected water vapor line already visually dense due to the increased concentration? I think it would be good to at least mention this in this section.
- Figure 6a: Above approx. 30 hPa the corrected (turquoise) points scatter between roughly 8 and 20 ppm against CFH values of 6-7 ppm, which is more than the "slight moist bias of 1-2 ppm" stated in the text. Please reconcile the text with the figure, or restrict the statement to the altitude range where it holds.

Technical comments/questions:

- Page 8, lines 21-22: "European Centre for Medium-Range Weather Forecasts (ECMFW)" --> ECMWF.
- Page 12, line 31: "F3 reached an altitude of 35 km (approx. 6 mbar)"; Please use hPa consistently.
- Page 13, line 1: "flights F1 (Fig. 2i) and F4 (Fig. 2l)" should be Fig. 4i and Fig. 4l.
- Page 17, line 13: "wake of the ballon" --> balloon.
- Page 18, lines 1-2: "5 m for ALBATROSS and and 15-20 m for CFH", Please remove the duplicate.

References:

- Weaver, D., Strong, K., Walker, K. A., Sioris, C., Schneider, M., McElroy, C. T., Vömel, H., Sommer, M., Weigel, K., Rozanov, A., Burrows, J. P., Read, W. G., Fishbein, E., and Stiller, G.: Comparison of ground-based and satellite measurements of water vapour vertical profiles over Ellesmere Island, Nunavut, *Atmos. Meas. Tech.*, 12, 4039–4063, <https://doi.org/10.5194/amt-12-4039-2019>, 2019.