

Interactive comment on “A fiber-coupled laser hygrometer for airborne total water measurement” by S. W. Dorsi et al.

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Reviewer #2 General Comments: The paper describes the development of a second generation of a fiber-coupled laser hygrometer (CLH-2) for airborne measurements. The instrument has a new and compact design to be installed and flown in a standard underwing canister of any aircraft in order to measure total water vapor in the range of 600–25000 ppmv at pressures of 200–1000 hPa. The instrument is a further development of the CLH-instrument as reported earlier by Hallar et al., 2004 and Davis et al., 2007b. In itself the CLH-2 hygrometer is a new design of a compact hygrometer and through its standardization also very suitable for different kind of airborne applications. In so far the present paper

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is certainly appropriate for publication in AMT. However, the real new contents are the parts describing the CLH-2 as an airborne water vapor detector. The parts on the total water vapor are not really new and more or less a repetition of earlier publications by Hallar et al., 2004 and Davis et al., 2007b. The authors have reported the instrumental design, calibration procedures and uncertainty estimations in a very good way. Therefore I would certainly rate the paper to be published in AMT but only after restructuring and reducing the rather large sections describing and discussing total water vapor content (TWVC) and cloud water vapor content (CWC) which actually don't add any new information and thus should not really be in the focus of the paper.

Authors: The authors would like to thank Reviewer #2 for their thoughtful and constructive recommendations. We recognize that our decision to emphasize the novel elements of the new instrument, which involves a new and improved approach to measuring water vapor in the CLH configuration, leaves an impression that the paper is about measuring water vapor. Rather, this new approach is better suited than its predecessor for measurements of total water from some aircraft, such as the Gulfstream V, yet it retains the important features that made the first generation instrument successful. We believe that removing material related to total water, including an overview of the nature of the ‘total water’ signal that is observed using this approach, will leave the reader with the impression that the instrument is, indeed, designed to measure water vapor, which is not the case. There are more precise ways of doing that (e.g., the Princeton VCSEL).

Consequently, we have made modifications to better present the total-water focused design of the CLH-2, in addition to addressing other Reviewer comments. Our changes are described below, alongside the Reviewer's specific comments. We refer to page and line numbers as they appeared in the original discussion paper.

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Reviewer #2 Specific Comments:

Reviewer #2: The real new content of the present manuscript is the further development of the CLH as a gaseous water vapor detector and therefore this should be the focus of the paper. Certainly the capabilities of the CLH-2 are to measure total water vapor when combined with a proper inlet system. But this option has been reported already before by Hallar et al., 2004 and Davis et al., 2007b such that it should only be a minor part of the paper. Therefore, I strongly recommend to omit or reduce most of the TWC, CWC etc. because it is adding nothing original or new to the paper. Examples are: Footnote 1 (Page 7357-7358), Page 7364, Restructurizing Chapter 4: uncertainty of CWC should only be short by just referencing to appropriate literature.

Authors: The CLH-2 is exclusively used for evaporative total-water measurement. In addition to the forward-facing, sub-isokinetic, heated inlet, the CLH-2 has been designed with total-water measurement features including heated sample lines, sharp bends in the sample flow path to encourage water particle impaction, and a VMR measurement range suited to the water concentrations encountered in clouds. Such a system has not previously been deployed in a standard wing canister, and documenting the total-water measurement capabilities of this system, though based on existing techniques, is an important role of this paper. To clarify the nature of the CLH-2 as a purpose-built total water instrument, and not simply a hygrometer with an evaporative inlet, several changes have been made. The section on instrument calibration (Sec. 3) explains the basis for using water vapor-only mixtures to calibrate a total-water instrument. The instrument diagram has been augmented to show an image of the CLH-2 with its forward-facing inlet (Fig. 1), a key aspect of the total-water measurement system and an integral instrument component. A new figure has been added (Fig. 6) that presents in-flight CWC observations from the CLH-2.

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Reviewer #2 notes correctly that the CLH-2 uses a measurement technique that has been previously described and demonstrated, and that the details of the technique need not be described in this manuscript. We share the reviewer's attitude that, aside for basic introductory material, the previously documented details of this technique can simply be included as references, rather than described in the text. Reflecting this, in preparing the original manuscript, we included only summary descriptions of the enhanced total water technique, and instead cited references for derivation of condensed-water content from enhanced total-water content (pp. 7363, line 3), use of computational fluid dynamics models for determining aspiration efficiency (pp. 7363, line 13) and details of a numerical model for particle vaporization times (pp. 7363, line 16). However, while existing methodology information can be cited and details excluded from this manuscript, we believe it is necessary to describe the performance of the CLH-2 instrument in its role as a total-water instrument. This includes the results of particle vaporization calculations for the purpose-built heated CLH-2 inlet and the analysis of uncertainty in CWC determined with the CLH-2, both of which have a significant impact on the interpretation of observations made with this new instrument. The equation used to remove the effect of sub-isokinetic sampling from CWC measurements (pp. 7363, eq. 3) was redundant with previous work and has been removed.

The material presented in this paper requires the clear and consistent use of terms to describe the mass concentration of water that occurs in solid, liquid, and vapor phases and that occurs in solid and liquid phases. Because the existing literature contains inconsistent or contradictory terms for these concepts, we believe it is necessary to identify the existing precedents that we follow and to include clear definitions, as done in Footnote 1.

Reviewer #2: The CLH-2 has been designed to measure direct absorption

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and not 2f-techniques. This immediately raise the question: In how far the CLH-2 can also be used as an absolute measuring hygrometer which don't need any calibration?. The authors should address this aspect and discuss it, whereby an uncertainty analysis in this perspective would be most appropriate.

Authors: In response to the reviewer's comment, we have added a discussion of the uncertainties involved in retrieving water vapor mixing ratio using the spectral parameters instead of a laboratory calibration (Section 3).

Reviewer #2: The authors reported that the CLH-2 has been flown on the NSF/NCAR Golfstream: Reporting of the results of the performance of the CLH-2 would contribute substantially to the present paper.

Authors: In response to the reviewer's suggestion, documentation of the CLH-2 in-flight performance onboard the NSF/NCAR GV has been included (new Section 5: Initial airborne deployment), along with a figure showing CWC observations during the deployment (Figure 6).

Reviewer #2: a) Change Title of the paper: "A fiber-coupled laser hygrometer designed for airborne measurements"

Authors: Because this instrument is uniquely equipped and operated for total-water measurement, and because these total-water-focused aspects of the design feature significantly in the presented manuscript, we believe that it is appropriate for the title to contain the phrase 'total-water'.

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Reviewer #2: b) Abstract (Page 7346), Line 4-5: "This compact instrument has been flown....." is misleading and should be omitted because nothing in the present manuscript reports on this.

Authors: Further information about instrument operations on the GV aircraft has been added (new Section 5: Initial airborne deployment).

Reviewer #2: In the abstract also more quantitative information on the performance characteristics of the new CLH-2: measurement range of water vapor, time response, pressure range.

Authors: We do not believe that these details are necessary in the abstract. Citing the water vapor measurement range in the abstract may mislead some readers, given that the CLH-2 is not designed as a vapor-only hygrometer. CWC range is strongly dependent on the particle enhancement factor and other deployment-specific conditions. Time response also varies with deployment conditions, including mass flow rate and altitude (pp. 7359, line 18). We include quantitative estimates of CWC uncertainty in the abstract text, but believe that additional details are better suited to the manuscript body.

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