

CLH-2: Condensed Water Contents from the Gulfstream V aircraft during ORCAS, Jan-Feb 2016 (updated February 2017 to accompany R1 final data release)

Darin W. Toohey, University of Colorado Boulder
4001 Discovery Drive, University of Colorado, Boulder, CO, 80303;
(303) 735-0002 (phone); N/A (fax)
toohey@colorado.edu; <http://storm.colorado.edu/~toohey>

1.0 Data Set Overview:

This document is a summary of issues related to in situ measurements of condensed water contents (CWC) using the University of Colorado Closed-Path Hygrometer (CLH-2), an instrument that was flown piggy-back on the NSF Gulfstream V during the 2016 ORCAS field campaign. The overall objectives were to continue to obtain observations of CWC at various altitudes and atmospheric conditions to build up a statistical data base for interpreting the microphysical processes that are important for clouds. A particular emphasis for CWC measurements during ORCAS was to observe in mixed-phase clouds, as well as to determine the appearance of low-altitude clouds as a function of supersaturation.

These results cover the test flights from Broomfield, CO in December 2015, transit flights to/from Punta Arenas, Chile, and all mission flights from Chile. The time period covered is January 5 to March 1, 2016. Data are available for all flights on the ORCAS mission, with near 100% coverage, except for several flights as noted below.

2.0 Instrument Description:

The second-generation University of Colorado closed-path tunable-diode laser hygrometer (CLH-2) is an instrument for the airborne in situ measurement of total water content – the sum of vapor-, liquid- and ice-phase water – in clouds. This compact instrument is integrated onto the Gulfstream V aircraft in an underwing canister. It operates autonomously and uses fiber-coupled optics to eliminate the need for a supply of dry compressed gas. In operation, sample air is ingested into a forward-facing sub-isokinetic inlet; this sampling configuration results in particle concentrations that are enhanced relative to ambient and causes greater instrument sensitivity to condensed water particles. Heaters within the inlet vaporize the ingested water particles, and the resulting augmented water vapor mixing ratio is measured by absorption of near-infrared light in a single-pass optical cell. The condensed water content is then determined by subtracting the ambient water vapor content from the total and by accounting for the inertial enhancement of particles into the sampling inlet. The CLH-2 is calibrated in the laboratory over a range of pressures and water vapor mixing ratios.

Specifications

Accuracy	Precision	Measurement frequency	Horizontal resolution
15%	5% or 500 ppm	1 hz	200 m

3.0 Data Collection and Processing:

CLH-2 is an autonomous instrument, with all data stored in real time as raw absorption spectra taken at approximately 45 Hz, stored as 4.5 Hz averages, and processed into total water contents at 1 Hz. The main quantity derived is total water, representing the sum of water vapor and enhanced condensed water. Using a separate measurement of water vapor, enhanced total water is calculated

and this quantity is then normalized by the enhancement factor of the inlet, usually around 20-50, a quantity that is determined from detailed fluid dynamics calculations and empirically validated by comparing to other measurements of CWC when available. There are multiple quality assurance steps that involve validation of spectral accuracy (e.g., position of the water line center in the laser scan window), determination of line shape and comparison to a standard, which as the HiTran spectral data base, and comparison to other measurements related to total water, when available. In addition, water vapor measurements obtained in cloud-free air masses are compared to other measurements of H₂O to demonstrate accuracy of the fundamental observable quantity.

4.0 Data Format:

Data files are named "orcas-CUTOTAL-H2O_GV_2016MMDD_RA_XYNN", where MM and DD are month and date, respectively, and XY = TF, FF, and RF for "test flight," "ferry flight," and "research flight," respectively. NN is the sequential flight number (i.e., 00, 01, 02, etc.). Fines are currently comma delimited, with UTC as the first column and condensed water content, in grams per cubic meter, in the second column.

Additional details can be found in the text header that accompanies each file. Data are reported at 1 second intervals, with missing or erroneous results labeled "-9999."

The most recent version number is "R1", representing the best results obtained using post-mission calibrations of H₂O, validated to the accuracy specified in the "Specifications" Table above following the mission.

5.0 Data Remarks:

The CLH-2 measurements of CWC from ORCAS are of high quality. There were few instrument problems to report, except for several flights when the computer storage disk was becoming close-to-full, and the instrument suspended recording of data to protect from overwriting. This error was intermittent on several flights, and appears as a minutes-long segment of data with "-9999." These results are irretrievable.

We are still working to address a known timing error with our system clock, due to an aging battery that lost CMOS time between flights. Usually, this resulted in a 2-minute offset at the start of flights, while the aircraft was still on the ground, and by the time the plane was airborne, the system clock was set to true GPS time. But on several flights, when the system needed to be restarted to clean up the filling solid state storage disk, there are periods when our data are offset by upwards of 2 minutes. These periods have not been fixed in this "R1-labelled" version of the data, but are thought to be minor.

6.0 Missing data periods, known problems

Flight Number, Date	Known data issue	Comment
TF01, 2016-01-05	none	Complete set
TF02, 2016-01-07	data missing after 24:00:00 UTC	Files from end of flight dated 2016-01-08 were inadvertently deleted by an automated code before being archived
FF01, 2016-01-11/12	none	Complete set
FF02, 2016-01-12	none	Complete set
RF01, 2016-01-15	none	Complete set

RF02, 2016-01-18	none	Complete set
RF03, 2016-01-21	none	Complete set
RF04, 2016-01-23	Data missing 19:43 – 20:06 UTC	System reboot due to full disk
RF05, 2016-01-25	none	Complete set
RF06, 2016-01-25	none	Complete set
RF07, 2016-01-30	none	Complete set
RF08, 2016-02-05	Data missing: 17:10-17:27 18:44-19:10 19:41-20:37	System reboots multiple times due to full disk
RF09, 2016-02-08	none	Complete set
RF10, 2016-02-10	none	Complete set
RF11, 2016-02-11	none	Complete set
RF12, 2016-02-15	No CWC results	Missing H2O vapor due to server time synch error
RF13, 2016-02-17	No CWC until 14:24	Missing H2O vapor due to server time synch error
RF14, 2016-02-18	none	Complete set
RF15, 2016-02-19	none	Complete set
RF16, 2016-02-22	none	Complete set
RF17, 2016-02-24	none	Complete set
RF18, 2016-02-25	none	Complete set
RF19, 2016-02-29	none	Complete set
FF03, 2016-03-01	none	Complete set

7.0 Software compatibility (i.e., list of existing software to view/manipulate the data)

Any text reader/plotter

6.0 References:

Dorsi, S. W., Kalnajs, L. E., Toohey, D. W., and Avallone, L. M.: A fiber-coupled laser hygrometer for airborne total water measurement, *Atmos. Meas. Tech.*, 7, 215-223, doi:10.5194/amt-7-215-2014, 2014.