CLH-2: Condensed Water Contents from the Gulfstream V aircraft during SOCRATES, Jan-Feb 2018 (February 2019 to accompany R1 data release)

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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 on the NSF Gulfstream V during the 2018 SOCRATES field campaign. The overall objectives were to provide CWC at in support of SOCRATES mission objectives, and to serve as a "backup" CWC measurement for the counterflow virtual impactor (CVI) measurements of CWCs. A particular emphasis for CWC measurements during SOCRATES was to observe in mixed-phase clouds.

These results cover the mission flights based in Hobart, Tasmania. The time period covered is January 15 to February 24, 2018. Data are available for all flights on the SOCRATES mission, with near 100% coverage, with an important update to issues discussed for the R0 data release.

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 binned averages. For SOCRATES, 15 spectra were averaged in real time and stored as a single spectrum every 1/3 second (i.e., 3 Hz native data rate). For this data release, we have further averaged three of these single spectra to produce a 1 Hz dataset. 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 H_2O to demonstrate accuracy of the fundamental observable quantity.

4.0 Data Format:

Data files are named “SOCRATES-CUTOTAL-H2O_GV_2018MMDD_R1_RFNN”, where MM and DD are month and date, respectively, and RF stands for “research flight.” NN is the sequential flight number (i.e., 00, 01, 02, etc.). Files 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 H_2O, a thorough analysis of a voltage offset of the flow controller used to maintain a known and stable flow of air through the inlet and detection volume, and assessment of accuracy specified in the “Specifications” Table above.

5.0 Data Remarks:

The CLH-2 measurements of CWC from SOCRATES are of good quality. There was an important instrument problem for all flights having to do with a shift in the calibration of the flow controller that was due to accumulation of small dust/sand grains in the flow-sensing element. The problem was identified in the field during SOCRATES during the second half of the campaign, and the error in flow was documented by testing against a known flow calibration source (good to 5%), but a final analysis and assessment required significant testing in the lab. This testing was, necessarily, destructive (requiring complete removal, disassembly, and forced damage to the sensor). However, it was successful in validating the field calibration of the flow voltage error. Intercomparing with CWCs measured by the NCAR CVI inlet and water instrument, which uses an analogous approach to CLH-2, we were able to demonstrate that the error occurred for the entire field campaign, and, presumably, for the ferry flights and evacuation flights to/from Hobart. Therefore, we have now applied a single slope, pressure-independent offset to the flow-versus-voltage calibration curve. This differs from the approach taken for the R0 release, which used a flight-by-flight assessment of the error based on additional factors (such as pressure and temperature) which turned out to be insignificant based on more carefully controlled tests in the laboratory.

We have also verified that there was a large leak in the sample cell during RF01, and one that was corrected before RF02 and did not reoccur for the remainder of the campaign. This is the only significant uncertainty remaining in the SOCRATES CLH-2 CWC data set, in terms of known instrument issues. We are in the process of comparing CWC results from multiple instruments to assess issues of inlet icing, hysteresis from melting, and evaporation, which are “normal” considerations for measurements in mix-phased clouds. The next release (R2) will include corrections for these issues that will be based on an empirical approach, since icing cannot be readily reproduced in the laboratory.

6.0 Missing data periods, known problems

Flight Number, Date	Known data issue	Comment
RF01, 2018-01-15	Leak in absorption cell affecting enhancement factor	CWCs are more noisy and uncertain as a result (+/- 50%)
RF02, 2018-01-19	none	
RF03, 2018-01-22	none	
RF04, 2018-01-23	none	
RF05, 2018-01-25	none	
RF06, 2018-01-28	none	
RF07, 2018-01-30	none	
RF08, 2018-02-03	none	
RF09, 2018-02-04	none	
RF10, 2018-02-07	none	
RF11, 2018-02-16	none	
RF12, 2018-02-17	none	
RF13, 2018-02-19	none	
RF14, 2018-02-21	none	
RF15, 2018-02-24	none	

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.