A New Instrument For *In-situ* Measurement of Total Ice Water Content

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Abstract

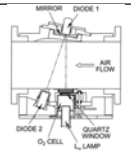
The recently developed Harvard Total Water (HTW) instrument measures the ice water content of cirrus, in conjunction with the Harvard Water Vapor (HWV) instrument. The instrument samples liquid and/or solid water particles without perturbing the ambient particle density, and uses the well-established Lyman-alpha photo-fragment fluorescence technique to make accurate and precise measurements of the total water content of the ambient air.

Data obtained aboard the WB-57 aircraft on flights out of Costa Rica (9ºN, 84ºW) during the summer of 2001 and out of Key West, Florida (24ºN, 81ºW) during the Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment, July 2002, show both agreement with the Harvard water vapor instrument in dry air, and sufficient sensitivity to detect sub-visible cirrus near the tropical tropopause.

The Total Water Instrument

Figure 1.

The total water instrument mounted in a WB-57 pallet.



A schematic of the total water detection axis.

The instrument consists of three primary subsystems:

1. An inlet through which liquid and/or solid water particles are brought into the instrument duct without perturbing the ambient particle density,
   - The inlet shape was designed to avoid flow separation.
   - The inlet is positioned 3 feet from the aircraft skin to sample unperturbed air.
   - Isokinetic flow at the inlet is maintained by controlling the RPM of a roots pump downstream of the detection axis. We continuously feedback on NAV Pressure, Temperature, and Air Speed data.

2. A 600 watt heater that efficiently evaporates the liquid/solid water before it reaches the detection axis,
   - The instrument utilizes a 600 watt heater array just downstream of the inlet with a feedback thermistor to vaporize particles.
   - Flow temperatures just downstream of the heater are ~30ºC.
   - The tubing between the inlet and the detection axis is glass coated and heated to minimize wall effects.
   - Temperatures at the detection axis are typically between ~0-10ºC.

3. A water vapor detection axis that accurately and precisely measures the total water content of the ambient air.
   - We measure water vapor mixing ratios by lyman-α photo-fragment fluorescence.
   - The detection axis is identical to that of the Harvard Water Vapor instrument (HWV).

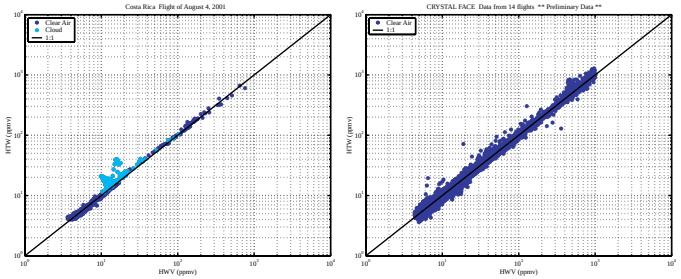
Instrument Calibration & Validation

- We calibrate over a range of pressures (15 – 400 mbar) and water vapor mixing ratios (10 – 300 ppmv).
- We routinely perform calibrations of both instruments before and after field missions to monitor changes in optical sensitivity.
- During CRYSTAL-FACE, we ran calibrations in the field.
- Consistency between lab calibrations and field calibrations showed agreement to within 5% for HTW, giving us confidence both in our ability to run calibrations in the field, and in the absolute numbers.
- Based on preliminary calibrations, the agreement between Harvard Total Water and Harvard Water Vapor during the CRYSTAL-FACE mission was ~+/-5%.
- The calibration of the HTW instrument was stable over the course of the mission.

HTW data, obtained aboard the WB-57 aircraft on flights out of a) San Jose, Costa Rica during the summer of 2001, and b) out of Key West, Florida during the summer of 2002, show agreement with HWV data in clear air (Figure 2).

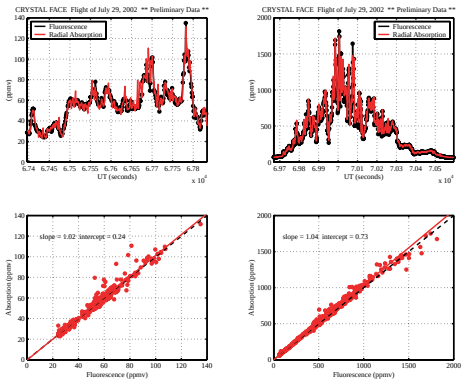
Figure 2. HTV and HWV agree in cloud free air over three orders of magnitude.

a) **b)**



Furthermore, the HTW instrument is ideally suited to in flight comparison of two measurement methods: photo-fragment fluorescence and direct absorption.

Figure 3. Water vapor measured by direct absorption is plotted versus water vapor measured by fluorescence for cloud events during the flight of July 29th, 2002. The agreement is good to <5%, and substantiates the fluorescence calibration. These are just two examples out of twenty or more for the mission.

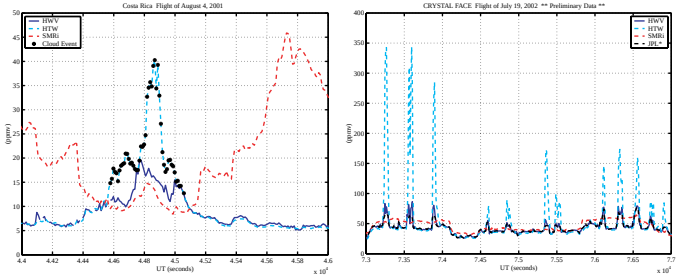


Ice Water Content of Cirrus

The HTW instrument makes accurate IWC measurements for a full range of cirrus in the upper troposphere, from the sub-visible (~1 ppmv) to the optically thick (> 1000 ppmv).

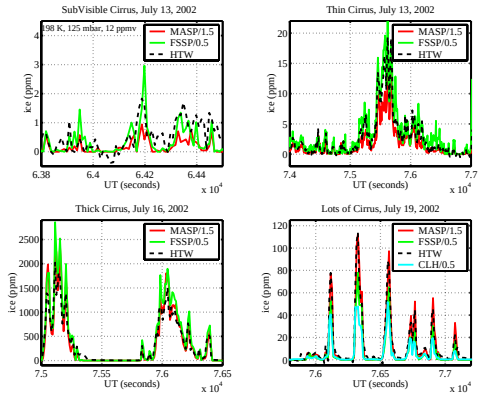
Figure 4. Cloud events during select flights out of a) Costa Rica and b) Key West during CRYSTAL-FACE, demonstrate the HTW instrument's sensitivity to cirrus.

a) **b)**



Subtraction of measured water vapor from measured total water yields the ice water content (IWC) of the cloud.

Figure 5. This figure shows the agreement between instruments measuring ice water content aboard the WB-57 during the CRYSTAL-FACE mission for a wide range of cirrus encounters. (The scale factors in the figure legends below represent the best fit for each instrument with respect to HTW and were evaluated using data from the entire mission. Significant variability in the agreement between the instruments is evident.)



Acknowledgements

We thank NASA for supporting the CRYSTAL-FACE campaign; the pilots, crew and managers of the WB-57 program; and researchers Darrel Baumgardner, Paul Lawson, and Linnea Avallone for the use of their data in the intercomparison.