

# A Laboratory Intercomparison of the Harvard University Lyman-alpha and JPL Tunable Diode Laser Hygrometers

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## GOALS

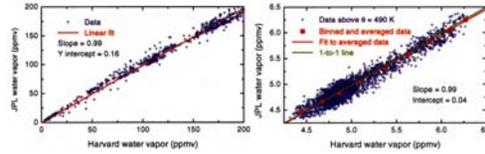
- To investigate the cause of differences observed between water vapor measured by the JPL laser hygrometer (JLH) and the Harvard hygrometers during the CRYSTAL FACE campaign.
- To provide additional calibration data for the JLH over a wide range of pressures and water vapor mixing ratios.
- To consider these laboratory calibrations runs as a first step toward the establishment of a long-term plan to maximize the accuracy and precision of *in situ* water vapor instruments.
- To promote opportunities for laboratory intercomparisons of all *in situ* water vapor instruments, independent of platform.
- To promote opportunities for instrument flight intercomparisons after laboratory intercomparisons have illustrated acceptable agreement based on criteria established by the community.
- As part of that plan develop a protocol for calibrations in the field that establish and/or validate instrument agreement on the ground during a mission.

## WHY THIS IS CRITICALLY IMPORTANT

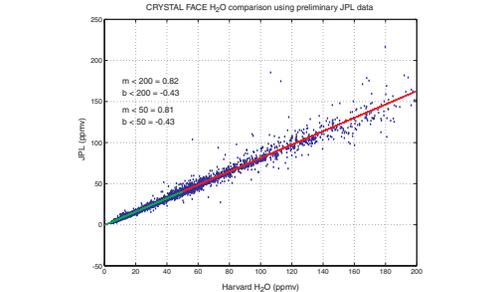
- A growing body of evidence derived from measurements of water vapor, total water, temperature and pressure in clear air, in cirrus clouds, and in contrails in 2001 over Costa Rica and in 2002 during CRYSTAL FACE exhibit supersaturations much larger than previously expected.
- This suggests large uncertainties exist surrounding the microphysics of cloud particles, especially regarding how the vapor pressure of water vapor over these particles depends on their size, shape, and chemical composition.
- These uncertainties have significant implications for strat-trop exchange, the water vapor budget of the atmosphere, understanding factors controlling the lifetime of cirrus clouds, and their ultimate impact on the radiative properties of the tropopause region and upper troposphere.

## HISTORY

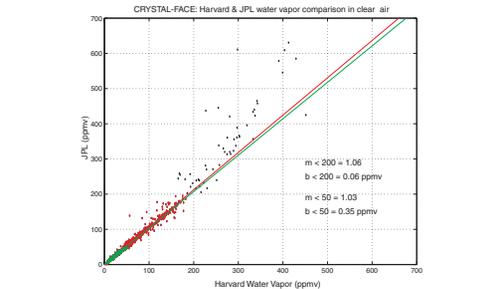
- Previous intercomparisons between Harvard Lyman-alpha hygrometer and JLH typically showed agreement of 5% or better in the stratosphere during both the POLARIS and SOLVE missions. The measurements diverged somewhat with increasing pressure in the tropopause region and below, as described by Hintsa *et al.*, J. Geophys. Res. **104**, 8183-8189, 1999.
- Based on preliminary calibrations the data archived in the field during the CRYSTAL FACE campaign exhibited a 25-35% difference between the Harvard and JPL water instruments with Harvard measuring higher and the largest disagreement occurring for ambient pressures below 130 mbar.
- Because of the previous excellent agreement of the two instruments, we suspected that the differences manifested in flight most likely result from laboratory calibration errors.
- A laser failure in the JLH during May 2002 WB-57F test flights required a new laser and completely new calibration in June 2002, prior to the field mission. The laser overheated in these preliminary calibrations and thus gave significantly different results than in flight (see Bob Herman's poster).
- Because the Harvard University calibration facility could provide known water vapor mixing ratios under a wide range of pressures and flow conditions, it was decided that checking the JLH calibration at Harvard would provide an excellent opportunity to resolve the differences observed in flight and tie the JLH measurements to the Harvard measurements.



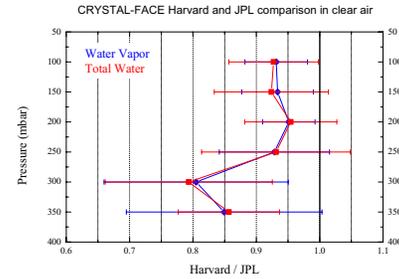
**Figure 1.** (top left) Regression of Harvard and JPL water vapor data for the second POLARIS deployment, including data up to 200 ppmv in the troposphere and stratosphere. (top right) Comparison of Harvard and JPL data between 490 and 540 K potential temperature during the second POLARIS deployment. (right) Percent difference between the JPL TDL and Harvard Lyman-alpha instruments flying on the ER-2 during POLARIS in 1997. Data from 0 to 200 ppmv H<sub>2</sub>O from all flights are included in this calculation, with the mean shown for each deployment. The standard deviation (1-sigma) is denoted by the horizontal lines.



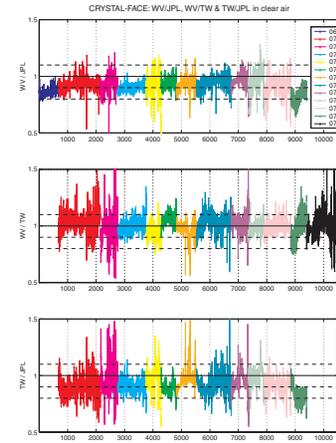
**Figure 2.** Intercomparison in clear air during CRYSTAL FACE between Harvard and JLH (based on June 2002 premission laboratory calibrations). Fit to the data is shown for data less than 200 and 50 ppmv respectively.



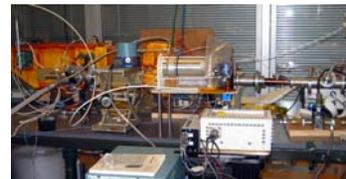
**Figure 3.** Plot of water vapor measurements in clear air during the CRYSTAL FACE mission. JPL mixing ratios derived using calibration data taken at Harvard University. Fit to the data is shown for data less than 200 and 50 ppmv respectively.



**Figure 4.** Plot of ratio of Harvard water vapor and total water vs JPL water vapor binned by pressure.



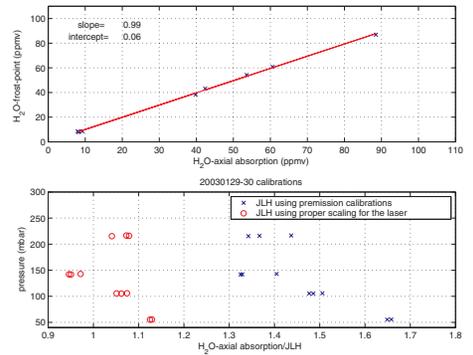
**Figure 5.** Plot of ratio of water vapor instruments in clear air during the mission. Data is color-coded by flight. The horizontal dashed lines represent changes of 0.1 in the measured ratios. With further analysis the existence of three instruments will allow a more detailed understanding of what atmospheric conditions cause one of the instruments to deviate from the other two. We could then identify regions where for example total water exhibits hysteresis (positive or negative), or where the JPL laser line might drift, or when pressure and temperature under the aircraft wing might change relative to reported T<sub>amb</sub> and P<sub>amb</sub>.



**Figure 6.**

Calibration setup at Harvard University as used with the JLH, shown here plumbed in parallel with the calibration flow system. Wet or dry air enters the flow system through 3/4" od teflon tubing and proceeds through a large ball valve that is used to adjust the relative flow through the two instruments. Immediately to the left of the inlet is an EMR, solar-blind PMT with a KBr photocathode and a narrow bandpass Lyman-alpha optical filter, which serves as the detector for an axial absorption measurement. To the right is the Lyman-alpha photofragment detection axis that flows as part of the total water instrument, mounted such that it samples air that is an integral part of the absorption axis. Adjacent to that detection axis is the Lyman-alpha light source used for the absorption measurement but hidden by the JLH. Both the light source and the KBr PMT are equipped with filter cells containing air at 1 atmosphere, which removes unwanted vacuum ultraviolet radiation.

**Figure 7.** Pictured here is the water vapor source. The 2-stage bubbler is shown here at the bottom, where the air is humidified based on the vapor pressure of water at the measured temperature and pressure. This flow, constituting about 25-1% of the total flow, is fed through a flow controller and then into a mixing chamber where it mixes with a main flow of dry air, also regulated by a flow controller, and then on to the main flow system.



**Figure 8.** (top) Plot of water vapor mixing ratio measured by absorption vs. measured by a laboratory frost-point hygrometer, the General Eastern 1311DR dewpoint sensor. Data are taken at pressures of about 700 and 850 mbar measured at the frost-point hygrometer. (bottom) Plot of ratio of water vapor measured by the JLH and by axial absorption vs. pressure.

## CONCLUSIONS

- The results of the laboratory intercomparison between the Harvard and JPL hygrometers verify that the large disagreements in the preliminary data between the instruments were primarily caused by uncertainties in the preliminary calibrations. The typical agreement exhibited between the two instruments is now 5-10%, consistent with the previous agreement exhibited during the POLARIS and SOLVE campaigns.
- These results, along with the agreement in the two independent temperature measurements on the WB-57F aircraft, validate the high relative humidity measurements observed in clear air, cirrus clouds, and contrails during CRYSTAL FACE, and suggest that our understanding of cloud microphysics and what controls the formation, growth rate, and evaporation of ice particles in the real atmosphere has a long way to go.
- The pressure dependence exhibited in figure 4 suggest more calibration work is necessary.
- We hope that this poster, and interactions generated during this meeting regarding the results presented here, constitute a first step in promoting additional laboratory intercomparisons as well as generating standards for a field calibration station.