Introduction

- Accurately forecasting UV dosage levels has become far more important as the rate of climate forcing has accelerated.
- The NRC Decadal Survey made clear that it is the irreversible nature of potential increases in water vapor in the stratosphere coupled with decreases in lower stratospheric temperatures resulting from CO₂ forcing and water vapor feedback will increase the catalytic destruction of ozone in the stratosphere.
- Unexpectedly high relative humidities observed in the cold tropopause region in clear air and cloudy challenge current microphysical and dehydration models.

Consequently, accurate or “benchmark” quality water vapor measurements are needed to:

- Maintain an accurate observational database for stratospheric trend measurements.
- Provide measurements in the TTL to help distinguish proposed stratospheric exchange mechanisms.
- Provide the accuracy necessary for categorizing relative humidity measurements in contrails, in the tropopause region and in the upper troposphere near and within cirrus clouds.
- Provide accurate water vapor measurements in polar regions where heterogeneous ozone loss critically depends on ambient water vapor.
- Provide “benchmark” quality water vapor data for model validation.

Intercomparison of water vapor measurements in the UT/LS have highlighted systematic instrument differences:

- Water vapor measurements as summarized in Figure 1 of SPARC 2000 illustrated significant differences between water vapor measurements in the UT/LS.
- We focus on systematic differences observed between Harvard Lyman α and AIDA TDL, first four with extensive UT/LS data; last 3 with extensive UT/LS data.
- Potential temperature (K)
- Mixing ratio (ppmv)

Intercomparison of water vapor measurements in Figure 2 illustrates significant differences between Harvard Lyman alpha and AIDA TDL, first four with extensive UT/LS data; last 3 with extensive UT/LS data.

Because typical laboratory calibrations are carried out at room temperature, their insensitivity to temperature must be established. We show an example of the calibration’s insensitivity to temperature in Figure 4.

So how do we resolve this systematic difference?

Foundation for measurement accuracy must be laboratory calibrations tied to SI traceable standards.

Harvard calibrations

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Vapor pressure of liquid water (Bubbler)</th>
<th>Liquid water droplet injector</th>
<th>121.6 nm Abs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lyman α</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>ICSF</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>AIDA TDL</td>
<td>X</td>
<td>X</td>
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<td>AIDA TDL</td>
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* Both ICOS (Integrated Cavity Absorption Spectrometer) and ICSF (Integrated Cavity Spectroscopy) instruments were developed at Harvard to measure water vapor Nurses and both laboratories in the laboratory under flight conditions.

We illustrate the Lyman alpha calibration setup in Figure 2.

In Figure 6 we show a detailed examination of agreement between Harvard water vapor instruments.

Key instrument of interest: Lyman α, CFHI, JLH, FISH2, AIDA TDL; first four with extensive UT/LS data; last AIDA reference instrument.

Our approach:

1. Use analysis to distinguish between calibration errors (directly resolvable in lab), offsets or artifacts at low water, and sampling errors.

Our approach:

- Agreement between Harvard, JLH and CFHI is excellent, not quite as good between Harvard and AIDA TDL, still poorer between Harvard and FISH2.
- Large differences between ICSF and FISH2 are resolvable in lab.
- Examine low water results on 3 days while taking into account calibration differences.
- Deltagap represents modeled correction to Lyman α data because of insufficient flow.

Intercomparison of water vapor measurements between Harvard instruments validate Lyman alpha:

- Laboratory calibrations apply in flight.
- Offset constrained to at most 0.1 ppmv in nitrogen corresponding to 0.2 ppmv in air.

Recent CRAYVIT intercomparison (see poster by Harold Saathoff et al. for further details)

So what can we learn from a carefully run laboratory intercomparison?

CONCLUSIONS:

- Lyman α measures about 0.30±0.05 ppmv higher than the AIDA TDL.
- Using the limited intercomparison data with CFHI on the 18th and 19th, Lyman α is about 0.35±0.05 ppmv higher than CFHI.
- The difference with JLH data is about 0.05-0.10 less than with AIDA TDL.
- The difference from FISH2 is slightly higher, about 0.40±0.10 ppmv.

MAJOR CONCLUSIONS from Aquavit:

- Observed differences at low water are small, and do not approach those observed in flight.
- Direct Laboratory intercomparisons under flight-equivalent conditions are needed for these instruments.