Aircraft Measurements of H$_2$O(v), N$_2$O, CH$_4$, and CO in support of the Second SAGE III Ozone Loss Validation Experiment

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Outline of Presentation

• Brief description of DLH and DACOM instruments
• New improvements for SOLVE-2
• Summary of data products, comparisons from SOLVE
• SOLVE objectives supported
DLH: the NASA Langley / Ames Diode Laser Hygrometer

- Tunable diode laser hygrometer operating in the 1.4 μm NIR spectral region
- Wavelength modulation at 4 kHz; 2F detection
- Line-locked to absorption line in low-pressure reference cell
- Uses one of two absorption lines, depending on conditions
- Double-pass external path configuration
  - “mirror” is panel of retroreflecting roadsign material, mounted on the outboard engine
  - sample volume is outside of aircraft boundary layer
  - no inlet effects, such as condensation, evaporation, interaction with walls
  - long path-length (28.5 m on DC-8), combined with line-locked, second harmonic detection allow good sensitivity and rapid time response
- Shares operator and data collection with DACOM instrument

New and Improved for SOLVE-2!

- Bandwidth improved to 15 Hz
- Improved, automated in-flight calibration procedures
- Preliminary values for water vapor concentration will be reported on the aircraft
- Additional high data-rate, high bandwidth data system added in parallel to existing system
DACOM - Differential Absorption Carbon Monoxide Measurement

- Mid InfraRed diode laser instrument
  - lead salt diode lasers; liquid nitrogen cooled
  - $N_2O$ at $4.5 \mu m$; $CH_4$ at $7.6 \mu m$; CO at $4.7 \mu m$
- Wavelength modulation at ~10 kHz; 2F detection normalized by chopped DC
- Line-locked to absorption lines in low-pressure reference cell
- Outside air ingested through Rosemont probe, through 36 m, 0.3 liter Herriott cell
- Response time approximately 1 sec
- Periodic in-flight calibration events using calibrated Niwot Ridge air

New and Improved for SOLVE-2!
- Improved data acquisition system and software
- Equipment weight and size drastically reduced
  - now fits in single rack with DLH
<table>
<thead>
<tr>
<th>Instrument</th>
<th>Species</th>
<th>Priority</th>
<th>Time Response</th>
<th>Precision ((1\sigma))</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diode Laser Hygrometer</td>
<td>H(_2)O(v)</td>
<td>1</td>
<td>50 msec</td>
<td>1% or 0.1 ppmv</td>
<td>10% or 1 ppmv</td>
</tr>
<tr>
<td>Diode Laser In-Situ</td>
<td>N(_2)O</td>
<td>2</td>
<td>1 sec</td>
<td>0.1%</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>CH(_4)</td>
<td>2</td>
<td>1 sec</td>
<td>0.1%</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>2</td>
<td>1 sec</td>
<td>1% or 1 ppbv</td>
<td>2%</td>
</tr>
</tbody>
</table>
Location of the DLH External Path on the DC-8 Research Aircraft

- Laser Transceiver at Station 530
- DLH Optical Path ~24 meters round trip
- Retroreflecting Panel on Engine #4
CAD Perspective of DLH Transceiver

1.4 µm Laser, Reference Cell

Alignment Laser

Solar Filter Fresnel Lens Detector
Bird’s-Eye View of DLH Mounted in DC-8 Window

- Solar-Blocking Filter
- Shutter
- Laser, Collimating Lens
- Alignment Laser
View from inside the DC-8 showing Alignment Laser on Retroreflecting Panel

- Retroreflector
- Visible Alignment Laser
- Outboard Engine
Transmission Spectrum in Region of DLH Absorption Lines

T = -50 deg C; Tdf = -60 deg C; p = 0.25 atm; p_{H2O} = 0.0108 mbar
Scan of Laser Current over Weak Line
Showing Assessment of 2F Baseline 'Zero'
Data Retrieval
- combining calibration with measurements -

• Calibration Data used to determine linestrength (S) and modulation depth (m)
• Analytical model gives, for a matrix of \( p, T \):
  \[
  \frac{2F}{DC} \bigg|_{\lambda_i, L} = f_i(\chi[H_2O(v)], p, T)
  \]
• Polynomial fit to \( f_i \)
• Polynomial inverted to give:
  \[
  \chi[H_2O(v)] = g_i(2F/DC, p, T, \lambda_i, L)
  \]
• DLH provides DC, 2F at 20/sec
• Aircraft data system provides \( p, T \) at 1/sec
• Measured 2F, DC, \( p, T \) combined to yield \( \chi[H_2O(v)] \)
Comparison among DC-8 Water Vapor Sensors during SOLVE

SOLVE Flight: January 23, 2000
NASA Langley/Ames DLH
Cryogenic Hygrometer
JPL Laser Hygrometer

Water Vapor volume mixing ratio

Time, UT

08:00 09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00
Comparison among Water Vapor Sensors during SOLVE
Sensors Aboard DC-8 and ER-2 Aircraft

SOLVE Flight: January 23, 2000
- Cryogenic Hygrometer (on DC8)
- Harvard (on ER2)
- JPL Laser Hygrometer (on DC8)
- JPL (on ER2)
- NASA Langley/Ames DLH (on DC8)
N$_2$O (ppbv)

DC-8 Time, UT

DACOM N$_2$O (DC-8)
ACATS N$_2$O (ER-2)
ALIAS N$_2$O (ER-2)
SOLVE objectives supported

• DLH Water Vapor measurements
  - SAGE-III validation
  - in-situ reference for remote measurements and balloon-borne sensors
  - intercomparison with instruments on Geophysica
  - photochemistry
  - tracer

• DACOM measurements
  - long lived tracers provide information about stratospheric air and thus context in which to interpret other measurements
  - comparison with other instruments on DC-8 and instruments on Geophysica
  - linkage to first SOLVE measurements, historical record

• Both instruments are being downsized and automated with a goal of providing data at lower deployment burden