Diode Laser Hygrometer Measurements of $\text{H}_2\text{O}(v)$
During INTEX-A

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Outline

• DLH Instrument
  – Operation
  – Status during INTEX-A
  – Calibration

• DLH Intercomparisons
  – P3 Intercomparisons
  – DC-8 Project Water

• Data Status
DLH Instrument Overview

Schematic from Inside DC-8

- NASA DC-8
- Laser Transceiver
- 28.5 m Optical Path
- Retroreflecting Panel

DLH Transceiver From Outside DC-8

- Retroreflector Panel on Engine

Schematic from Inside DC-8
DLH: the NASA Langley / Ames Diode Laser Hygrometer

- Tunable diode laser hygrometer operating in the 1.4 \( \mu \text{m} \) spectral region
- Wavelength modulation at \( \sim 3 \text{ kHz} \)
  - data analysis based on 2F demodulation, normalized by signal power
- Line-locked to absorption line in low-pressure reference cell
- Uses one of three absorption lines, depending on conditions (primarily altitude)
- Double-pass external path configuration
  - “mirror” is panel of retroreflecting roadsign material, mounted on the outboard engine
  - sample volume is primarily outside of aircraft boundary layer
  - Internal optical path is purged with dry air
  - no inlet effects, such as condensation, evaporation, etc.
  - long path-length (28.5 m on DC-8), combined with line-locked, second harmonic detection allow good sensitivity and rapid time response
  - normalization by return power allows measurements to be made within clouds
New and Improved for INTEX-A!

- DLH operation, in-flight calibrations, and data acquisition controlled by 2U Windows/LabVIEW system
- Analog Lock-In Amplifier replaced by computer-based digital Lock-In
  - Full absorption lineshape available for post-mission analysis
- Data rate: 100 independent samples/sec
  - 1 second data submitted to archive; higher rate available on request
  - System bandwidth limited to ~20/sec by volume of sampled external path
- Better solar background rejection using frequent offset measurement
- Preliminary values of water vapor concentration reported in-flight
Instrument Status during INTEX-A

- DLH operational on every flight
- Data provided:
  - 95.5% of 1 second periods
  - 96.6% of 10 second periods
  - 97.5% of 1 minute periods

- Currently analyzing return signal power variations during mission
  - Measurement of attenuation by clouds at 1.4 µm
  - Hope to extend this to visible wavelengths and fly prototype during INTEX-B
Instrument Status, continued

- DLH data header contains an error
  
  INSTRUMENT_INFO: Diode Laser Hygrometer - external path in-situ water vapor  
  DATA_INFO: Water Vapor **Dry** Mixing Ratio in ppmv  
  UNCERTAINTY: H2O(ν) = 5%

- Header should read:
  
  INSTRUMENT_INFO: Diode Laser Hygrometer - external path in-situ water vapor  
  DATA_INFO: Water Vapor **Wet** Mixing Ratio in ppmv  
  UNCERTAINTY: H2O(ν) = 5%

We report \( p_{\text{H2O}}/p_{\text{air}} \times 10^6 \), rather than \( p_{\text{H2O}}/(p_{\text{air}} - p_{\text{H2O}}) \times 10^6 \)

- Update will be made to archived data this week
Laboratory Calibration of DLH
DLH Calibration Methodology

• External path prevents calibration of installed instrument, except at ‘nature’s choice’ conditions
• Lab calibrations conducted at several values of pressure and water vapor concentration, to quantify laser characteristics and absorption line parameters
  – NIST-traceable chilled mirror hygrometer samples calibration mixture
• Spectral model developed which predicts harmonic lineshape
• Project-supplied static temperature and pressure are used convert measured signal into mixing ratio
H$_2$O Comparison

R$^2$ values: 0.99
DC-8 DLH vs. WP-3D Slope: 0.70 – 0.97
DC-8 Project vs. WP-3D Slope: 0.84 – 1.05
Altitude-Specific Histograms of DLH/Project Water Vapor Ratio
DLH vs. Project Water Vapor Comparison
Low Altitude, DLH using Weak Absorption Line
Examination of DLH Data

- DLH vs Project Water Vapor shows consistent trend at low altitudes / high water vapor concentrations
- DLH tends to be ~6% lower than project water at low altitudes, the difference decreasing as altitude increases
- For altitude < 20 kft, most DLH data taken using (new) weak absorption line
- Examination of flight data does not show any line-specific bias
- Examination of calibration data has not yet yielded any inconsistency within the weak line sets, or between the weak line and stronger line sets
- We will continue to examine our calibration and data analysis methodologies
Summary

- DLH performed successfully during entire INTEX-A mission
- DLH mixing ratio compared very well with P-3 and DC-8 project water during two of the three intercomparisons, less well during the July 22 intercomparison
- DLH and DC-8 project water mixing ratios differ by ~6% at the lowest altitudes; cause as yet undetermined
- DLH data file header contains definition error; will be fixed soon!