VCSEL Data Status in HIPPO

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NSF AGS-1036275
NASA NNX09AO51H

HIPPO Science Team Meeting
March 12, 2012

Photo: Minghui Diao, Batteny Islands, Antarctica, H5

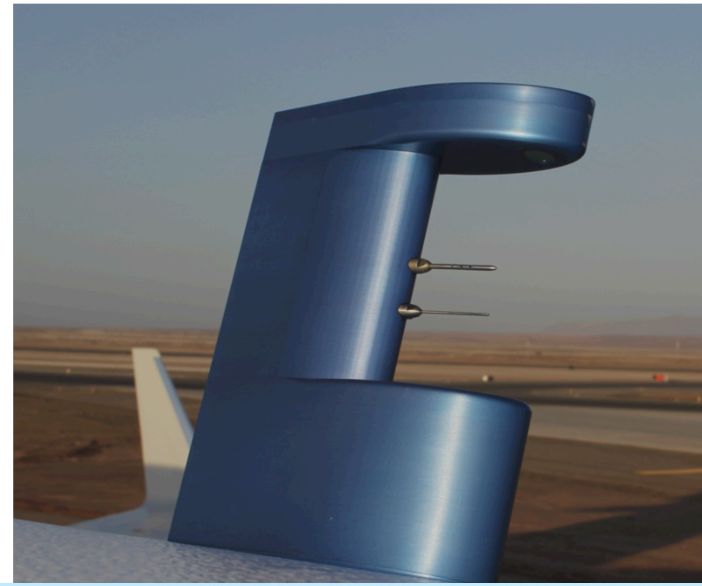
Experimental: NSF Gulfstream-V VCSEL hygrometer

VCSEL = vertical cavity surface emitting laser hygrometer for NSF G-V aircraft

(Zondlo et al., 2010)

Open-path configuration minimizes sampling artifacts

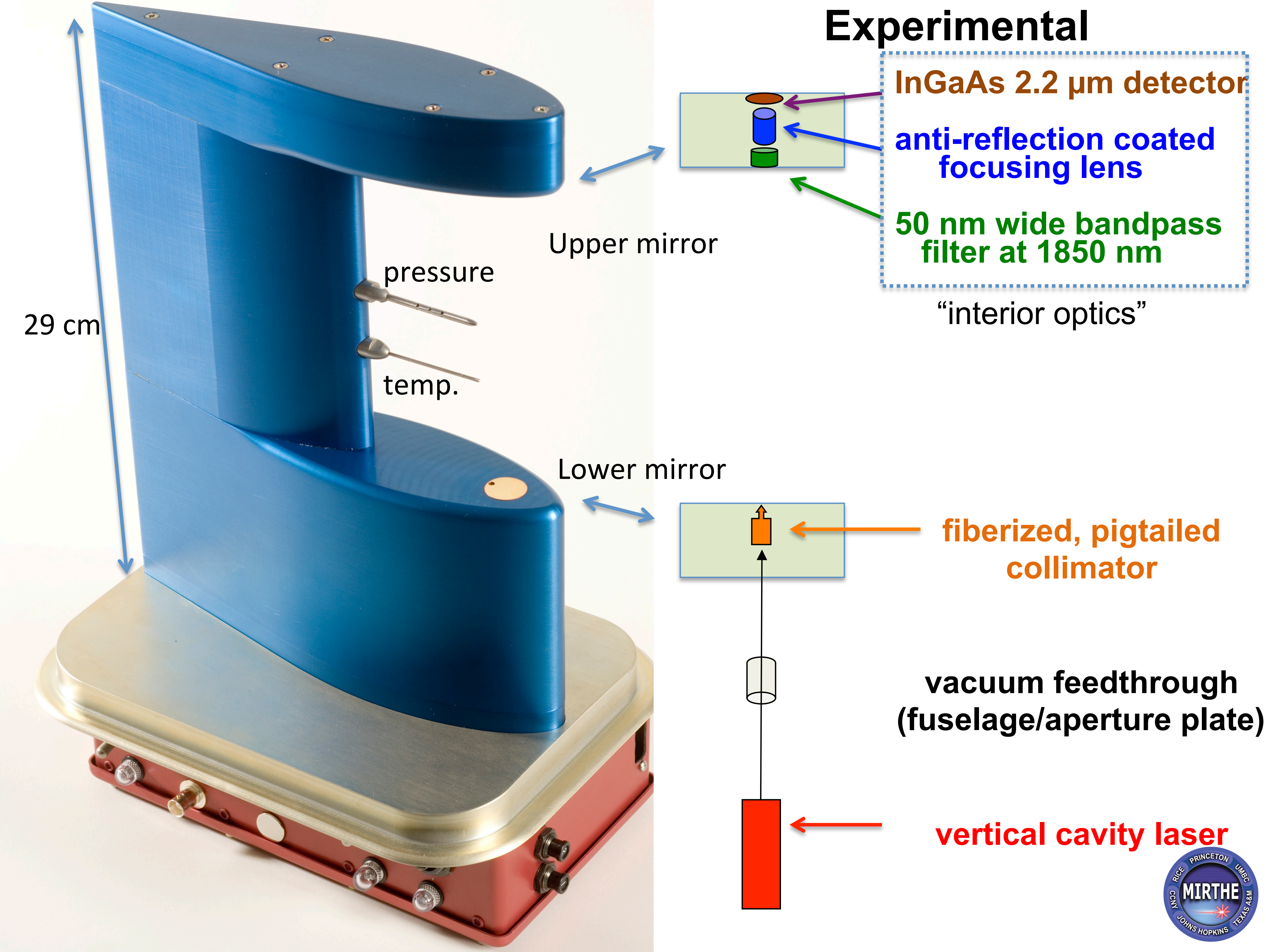
1854 nm fiberized VCSEL controlled by DSPs



Parameter	Specifications
Dew point range	-110°C to +30°C
Sensitivity (1 Hz)	0.05 ppmv (SNR=1)
Frequency	25 Hz
Accuracy	2-10%
Precision	≤ 1%
Size	36 x 25 x 19 cm
Power	15 W
Weight	6 kg
Operation	automated

HIPPO was first campaign where VCSEL exposed to the elements…a learning curve.

Experimental



Summary: VCSEL data in HIPPO

- Calibrations conducted under a wide variety of conditions:
  - a) temperatures (186-303 K)
  - b) pressures (100-1020 hPa)
  - c) mixing ratios (0.3-30,000 ppmv)
  - d) low laser light intensities on detector (i.e. degraded optics)

  -over 40 sets of experiments from 2009-2011, usually ~ 20 points/exp.

- Used a combination of flowing, static experiments and intercompared with a variety of methods (sampling, setup critical in data interpretation)

- VCSEL QC/QA'd data (H1-H5) has been submitted to the FTP archive

- Don't anticipate changes in values, though we may add additional data in places where it is currently removed with additional flag for accuracy

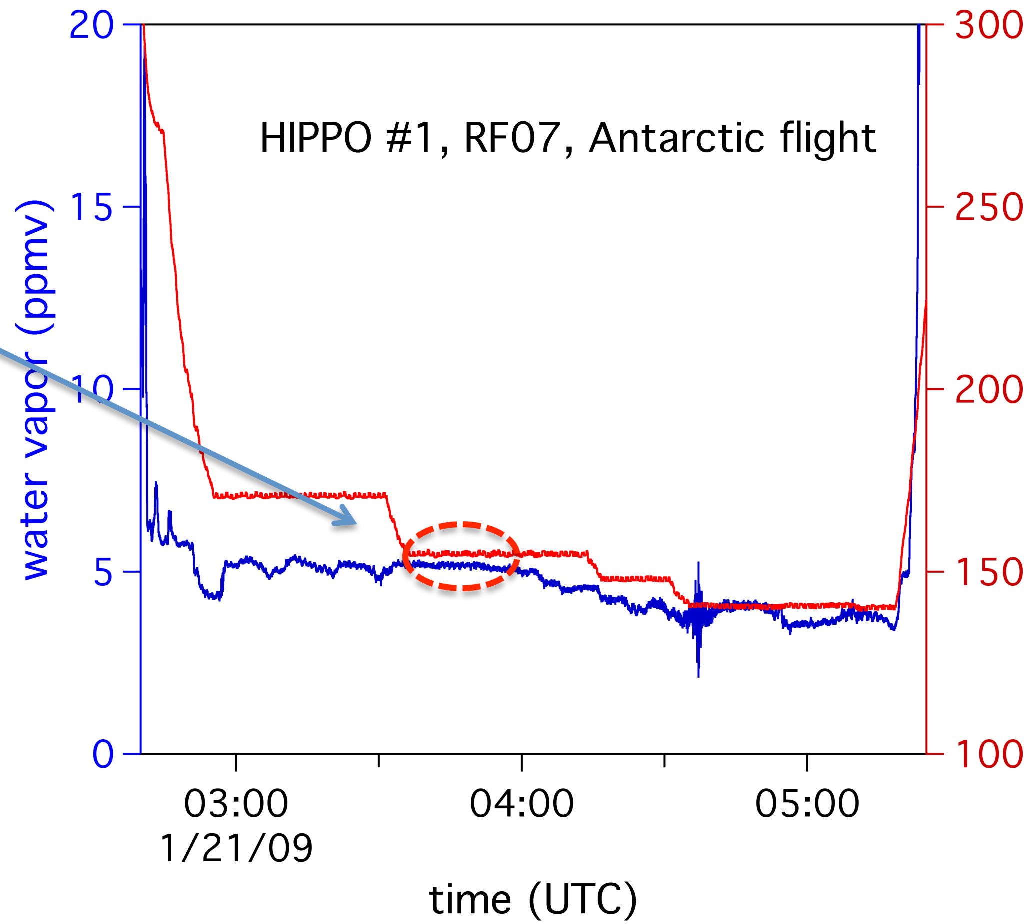
HIPPO 1

- 95% data coverage, RF01-RF07

- precision at 5.2 ppmv:
  ≤0.8% at 1 Hz (1σ)
  (10 min. segment)
  (some of this is real atmospheric variability)

- unknown material coated mirrors after landing in CHC
  (instrument not covered on tarmac)

- no data thereafter



- data quality very good for flights when data available

HIPPO 2

• nylon cover protected instrument while on tarmac

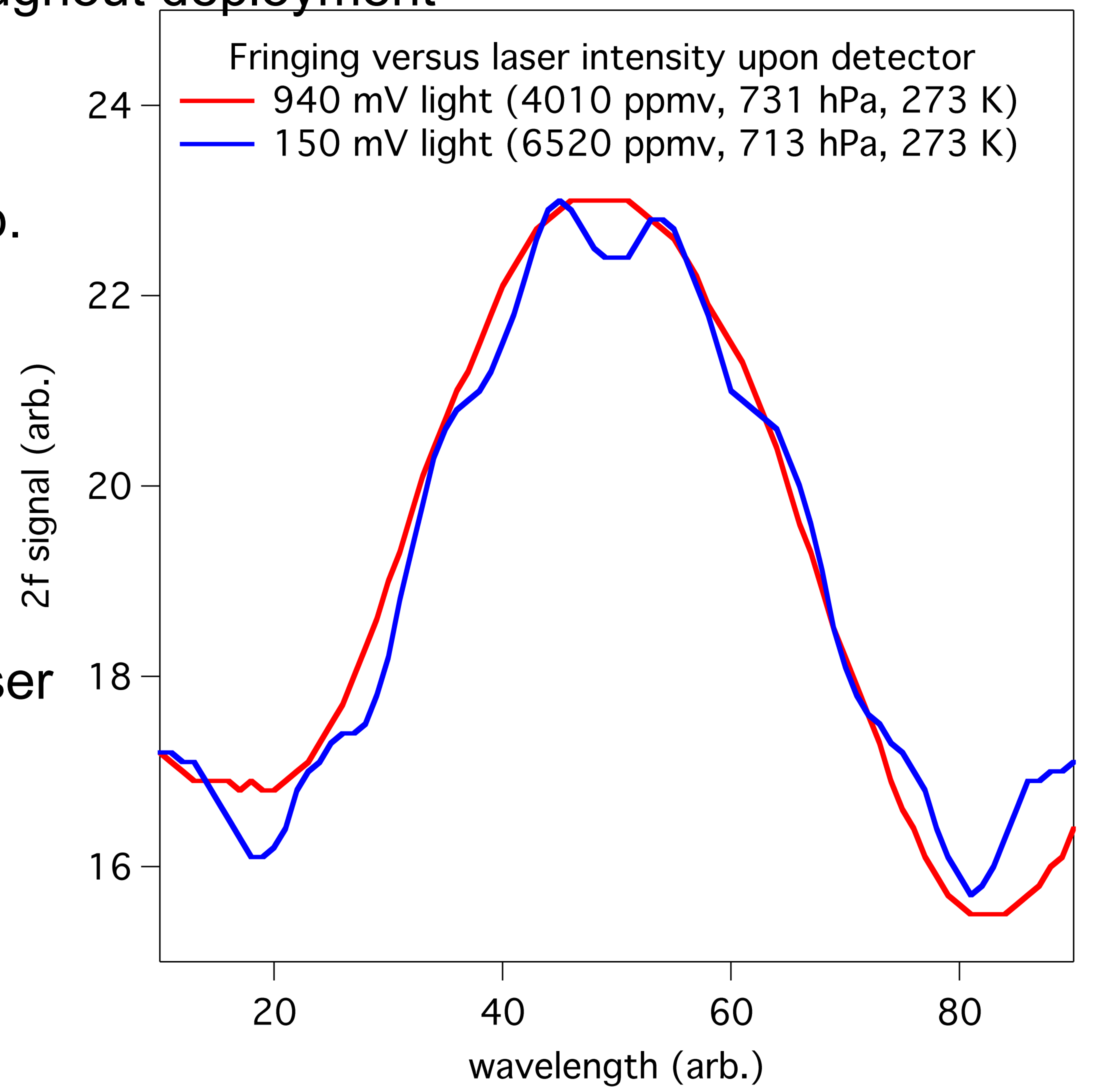
• gradual decrease of signal throughout deployment

• data coverage 70% overall
(missing data mainly in lower trop.
and RF08, Honiara to Midway)

• interior optics cleaned and/or
replaced in CHC

• noisier data (and drift) at low laser
light intensities due to etalons

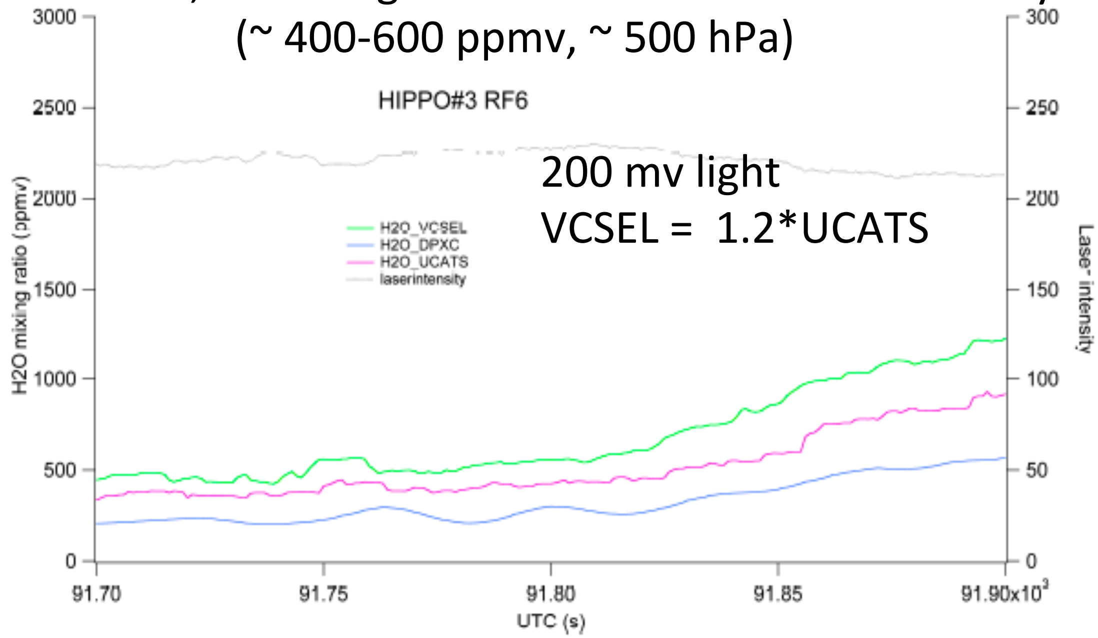
• created linelocking problems,
esp. switching lines

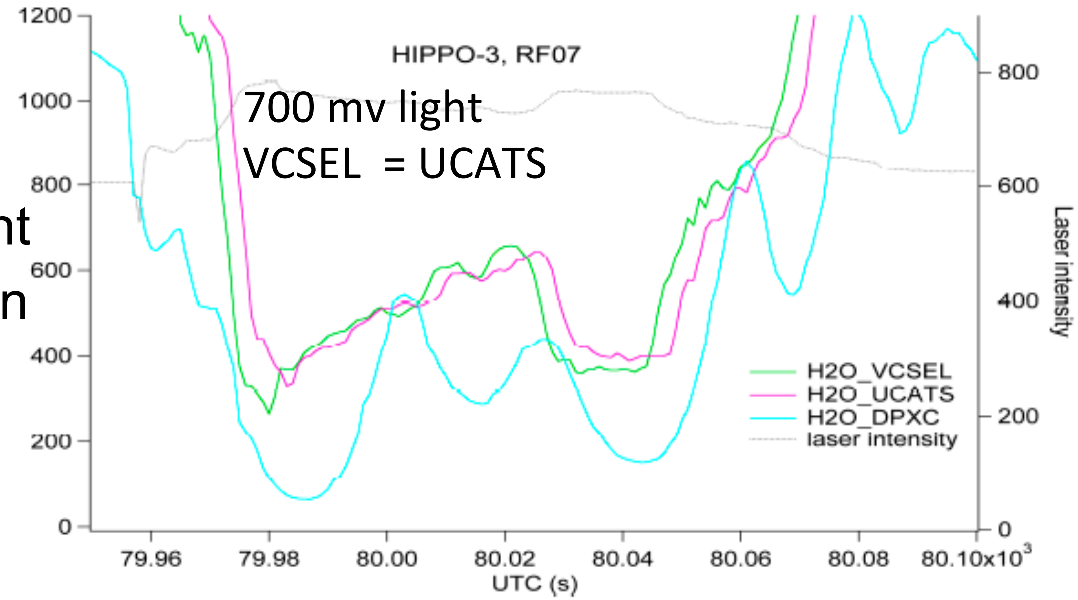


HIPPO 3

- aluminum, sealed cover used (better, though condensation remained a problem)
- cleaned interior optics at CHC, return to ANC
- data coverage ~ 70% (missing mainly lower trop.)
- post-mission laboratory studies with constant H_2O, varying light for all three modes of operation

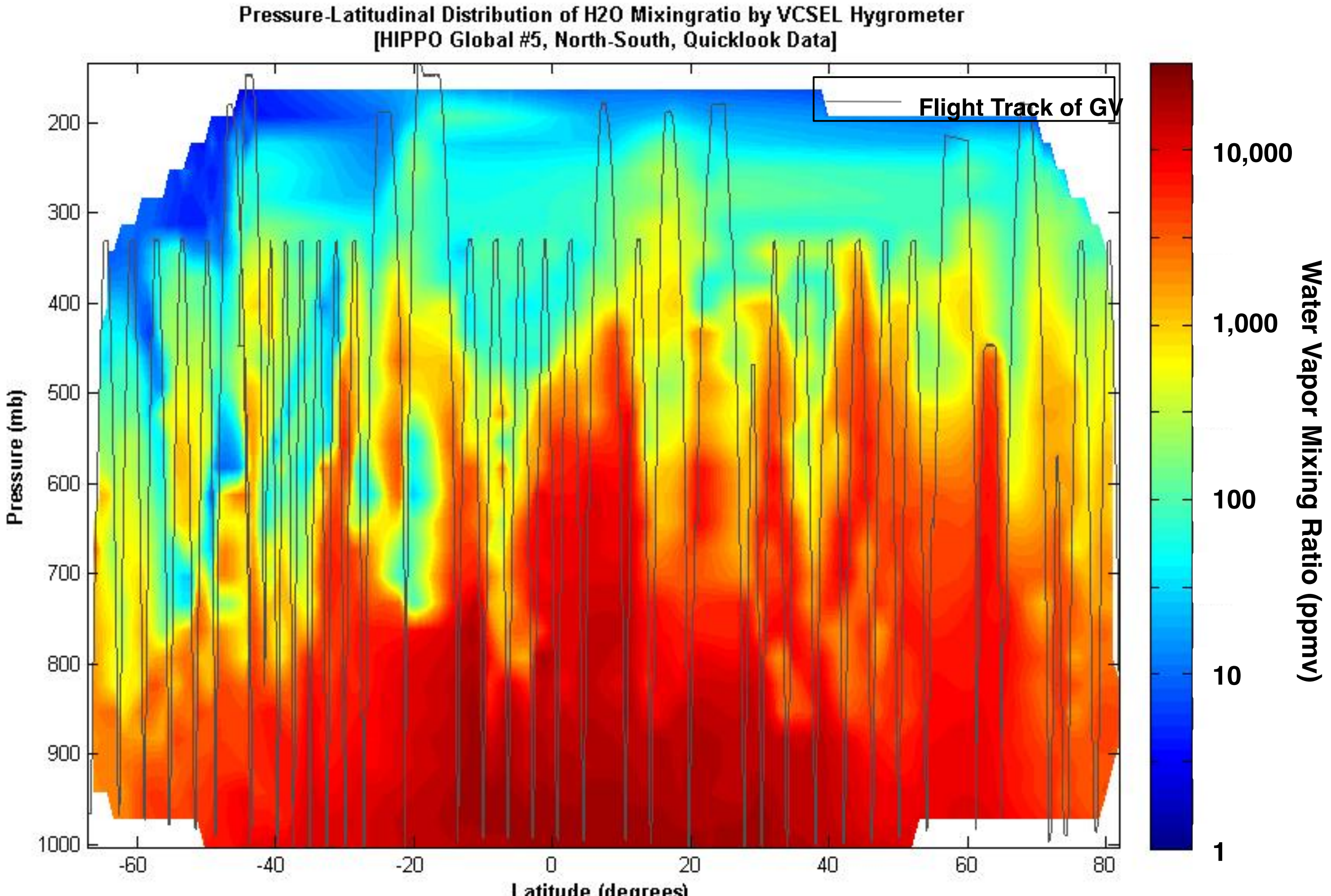
VCSEL, UCATS agreement vs. VCSEL laser intensity:
(~ 400-600 ppmv, ~ 500 hPa)



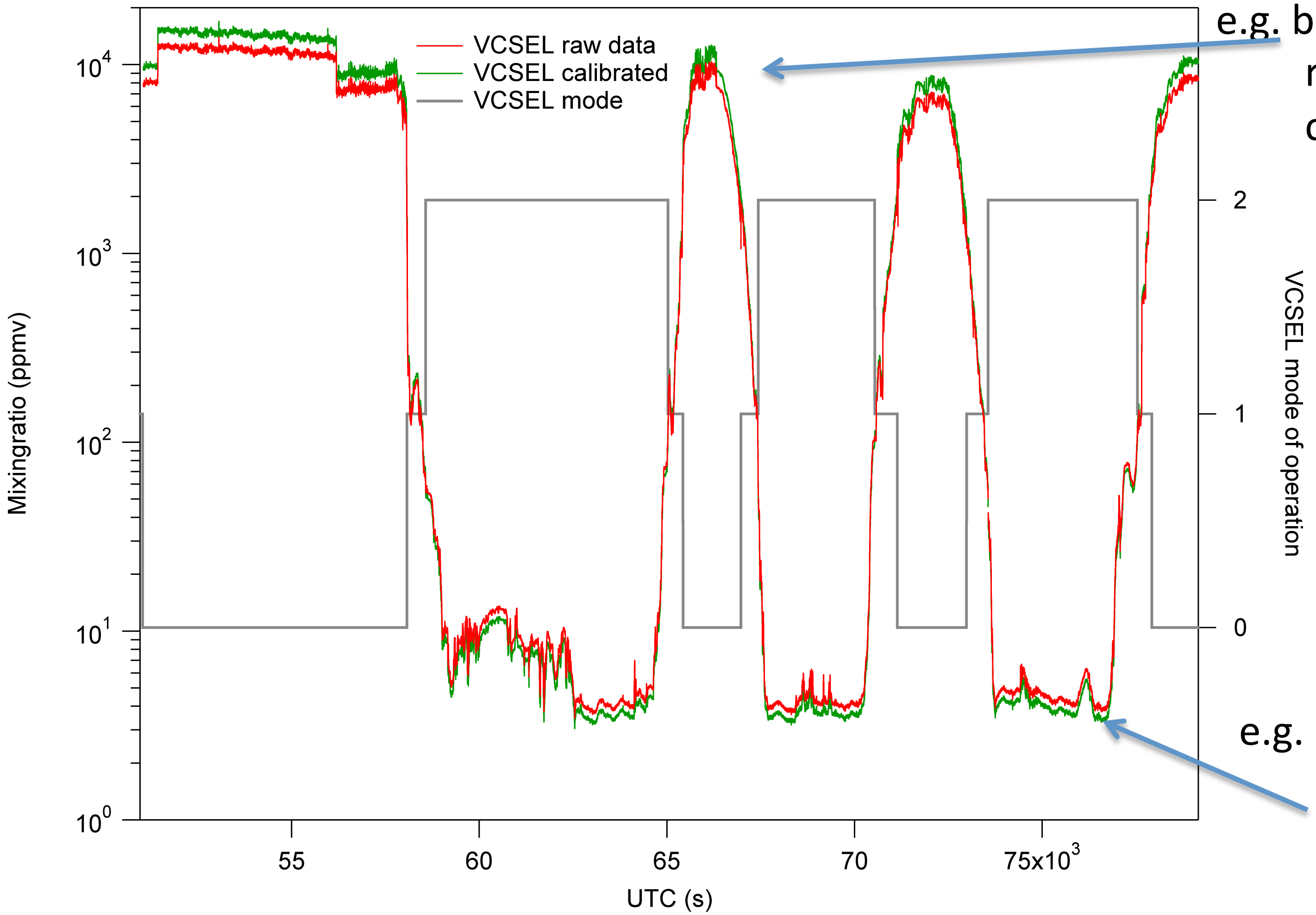


HIPPO 4/5

- harder, dielectric coating mirrors (higher reflectivity, more durable)
- new fiber collimator and feedthrough (more robust)
- dessicant placed inside cover (prevented condensation)
- only mirror cleaning a few times (no interior optics)
- data coverage >99% in both campaigns



Comparison of raw data to final data



e.g. boundary layer:
raw: 7500 ppmv
calibrated: 9010 ppmv

e.g. lower stratosphere:
raw data: 4.3 ppmv
calibrated 3.8 ppmv

lower troposphere data increased by ~ 20%
upper troposphere data decreased by ~ 10-15%
exact values dependent upon actual temp., pressure

Timing / Synchronization

VCSEL data acquisition triggered by pulse-per-second signal from GPS

- absorption feature scanned at 1500 Hz
- internal clock integrates 60 scans into $\Delta t=0.04$ s measurements (25 Hz)

hh:mm:ss timestamped by G-V data acquisition immediately after GPS signal

x.00 data in archive is averaged $-x.50 \leq t < +x.50$

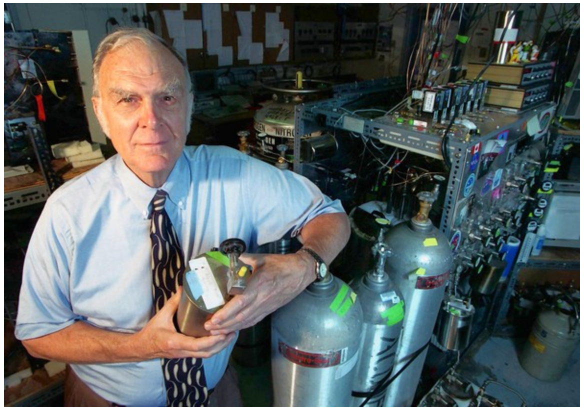
(i.e. 1 s average centered on x.00)

Other issues:

Any data when switching absorption lines (1853.03, 1853.37 nm) or mode (direct, 2f) were automatically removed ± 3 s in archived data

HIPPO VCSEL summary

- All H1-H5 data where laser light > 300 mV have been submitted to the QCQA ftp archive (late Feb.); data between 300-500 mV have been corrected
- Low laser light intensity data, often noisier and less accurate due larger uncertainties in correction factors, will be added with uncertainty flag
- Sensor improvements after H3 were critical for VCSEL success in H4, H5
- When sufficient light on the detector, VCSEL accuracy 6% ± 0.3 ppmv (usually UT/LS of H1-H3; all of H4, H5)
- Intercomparisons with final UCATS data to be conducted (H2O_X ?)



…in memory of a giant in our field,
F. Sherwood Rowland

VET TES EN NOV TAM TVM

MIRTHE
PRINCETON UMBC TEXAS A&M JOHNS HOPKINS CCNY RICE

Light attenuation experiments: lower trop. data (6ºC dp, 850 hPa)

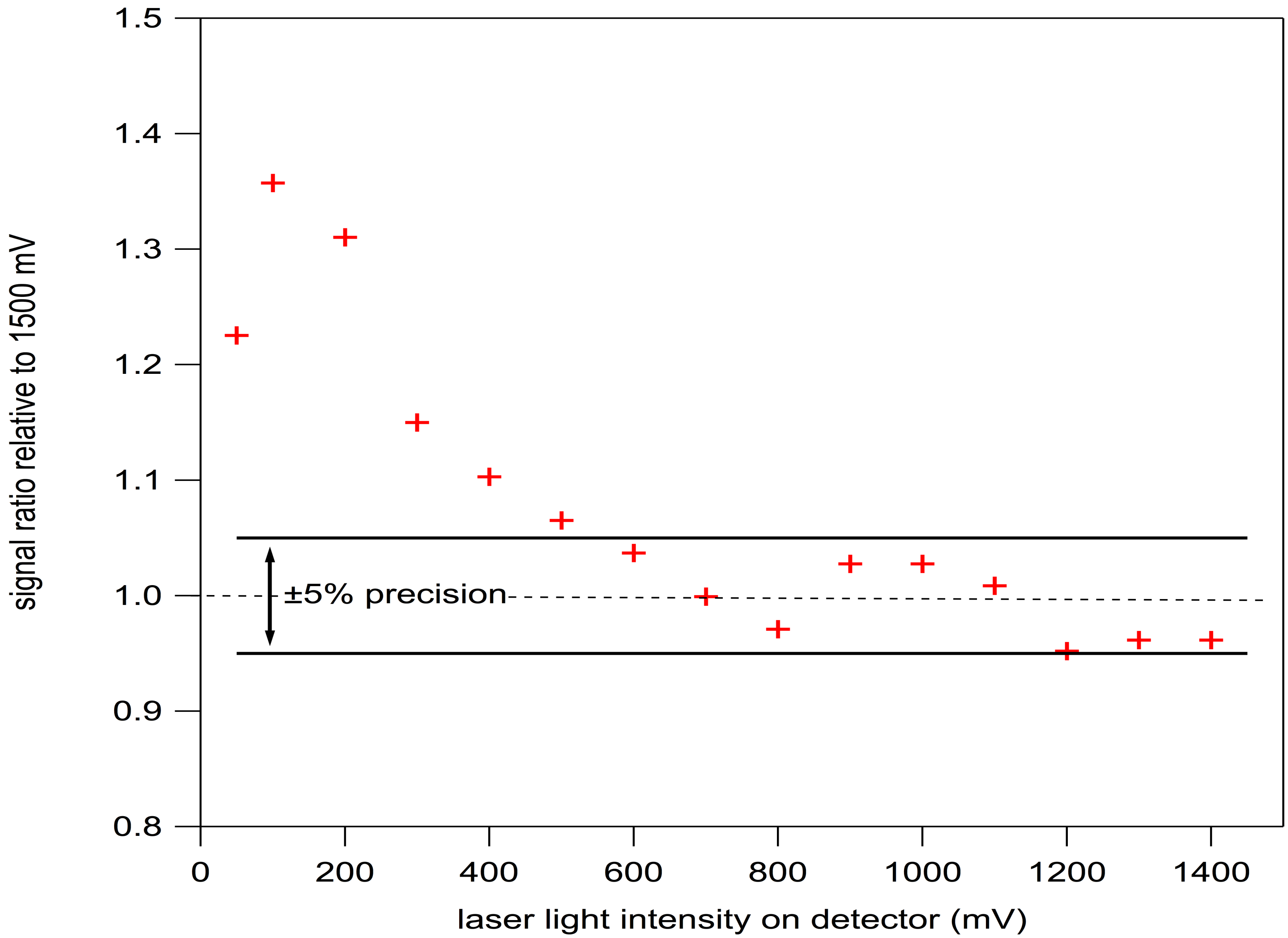
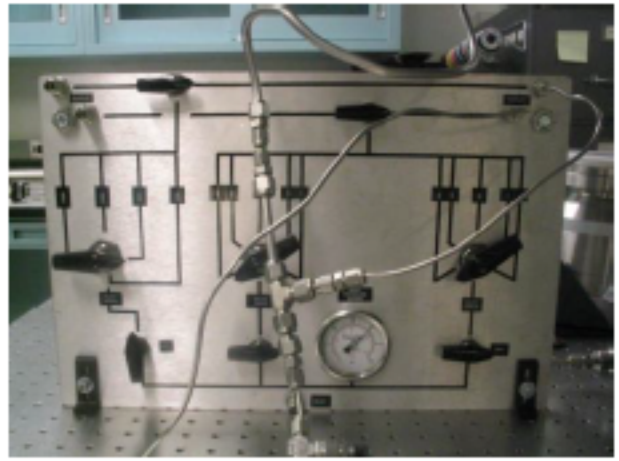
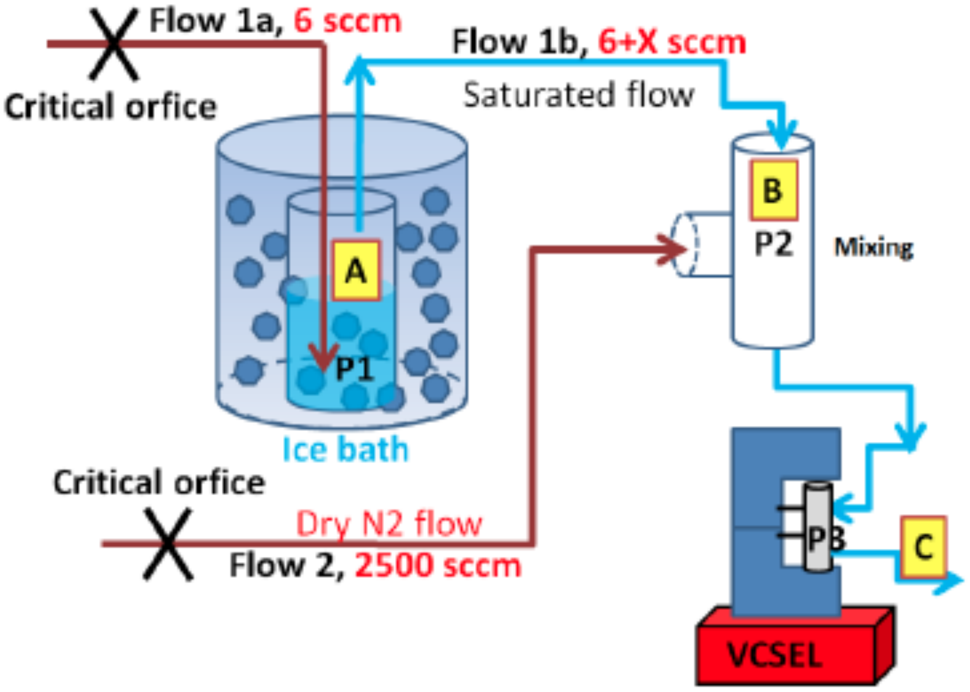


Figure 3. Relative difference for the weak absorption concentration when artificially decreasing the laser light intensity at the detector by a variable fiber attenuator. The introduction of the attenuator itself created a 5% amplitude etalon in the otherwise constant signal.

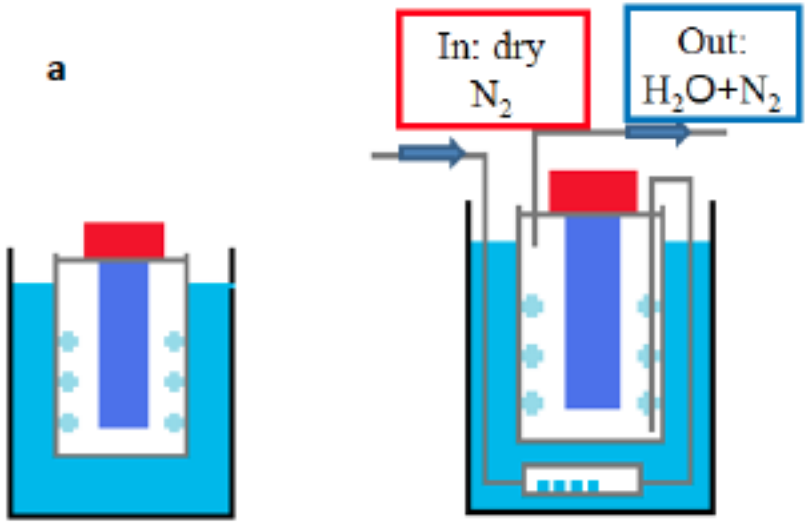
calibration systems



Scheme diagram of critical orfice system



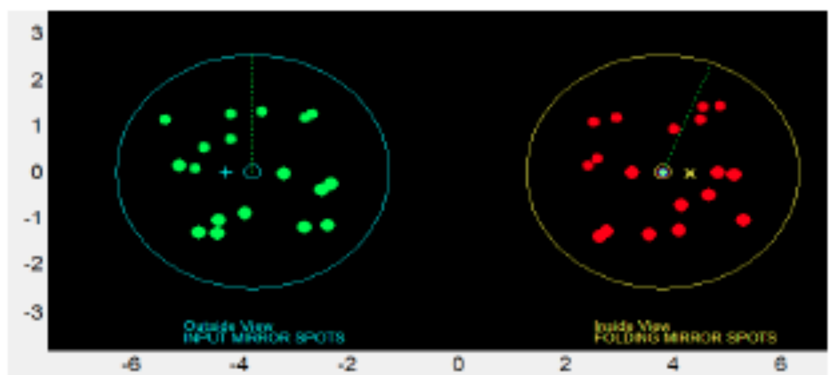
Flowing and static frost point measurements



UHV fiberized low temp., press. system

a

b

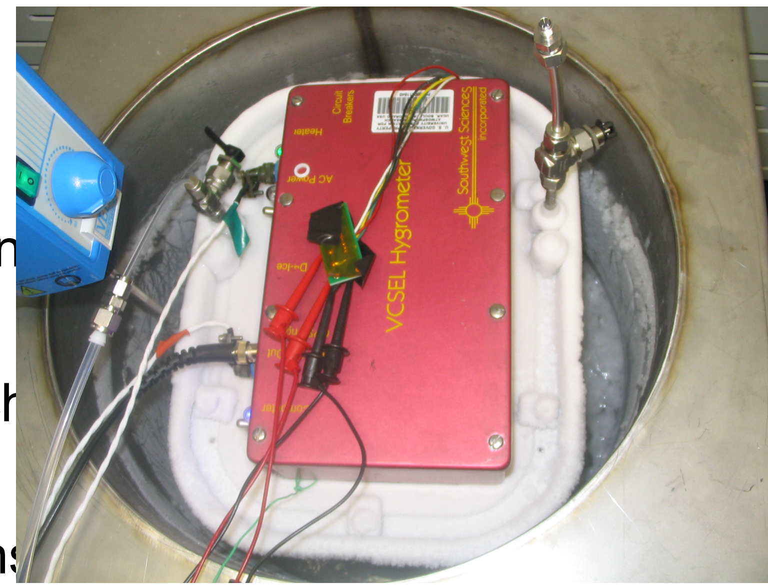


Avoids leaks in o-rings at very cold temperatures (<-60 C); mocked optical setup consistent with aircraft instrument

Calibrations: flowing and static

Flowing: critical orifice system (1-2500 sccm) (saturated or unsaturated)

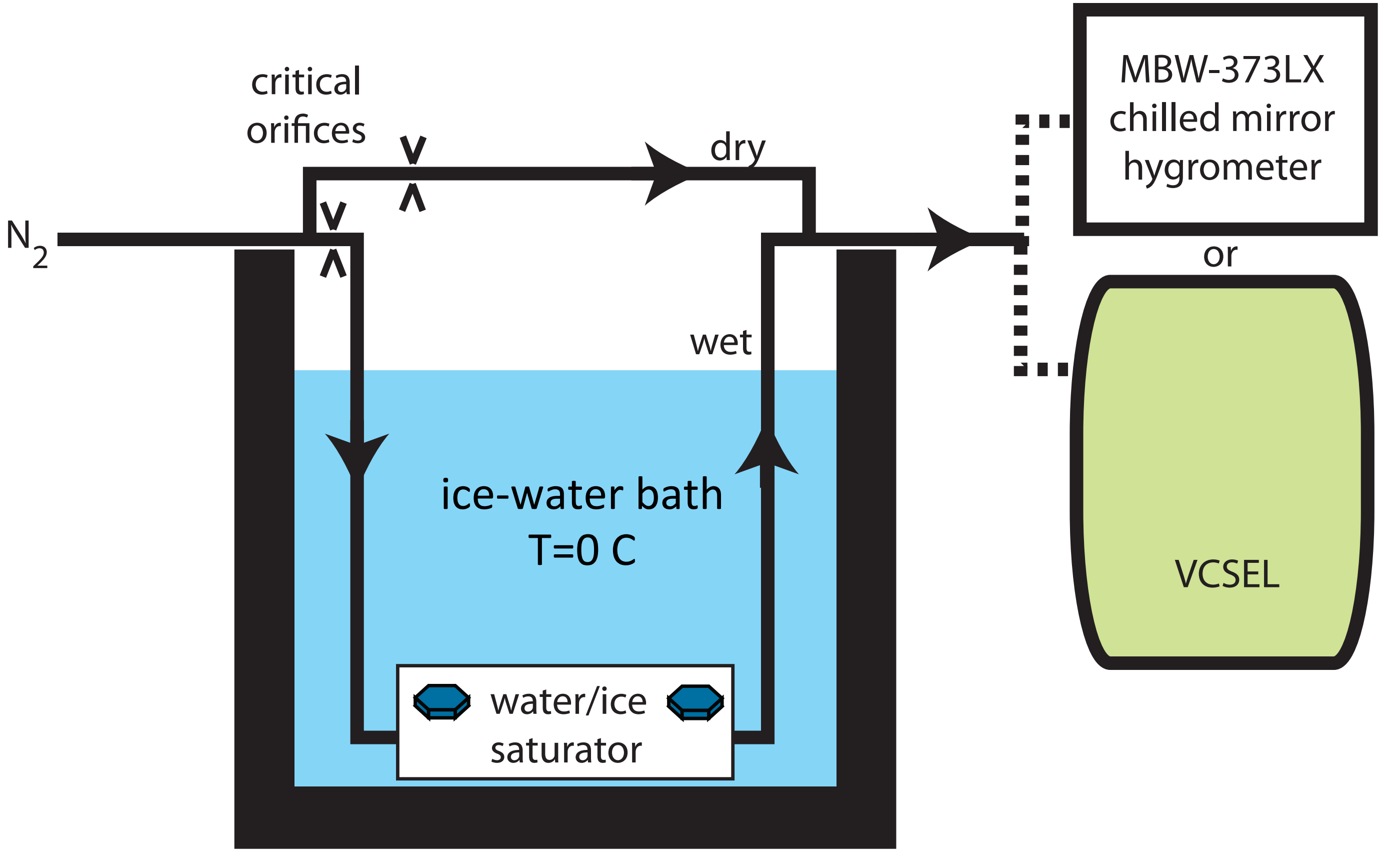
- flows extremely stable and reproducible (±2% over 2.5 years)
- avoids drifts in flow controllers, warm up times, PID controls
- flow only dependent upstream (not downstream) pressure
- use ice-water baths for saturator for reproducibility



Static:

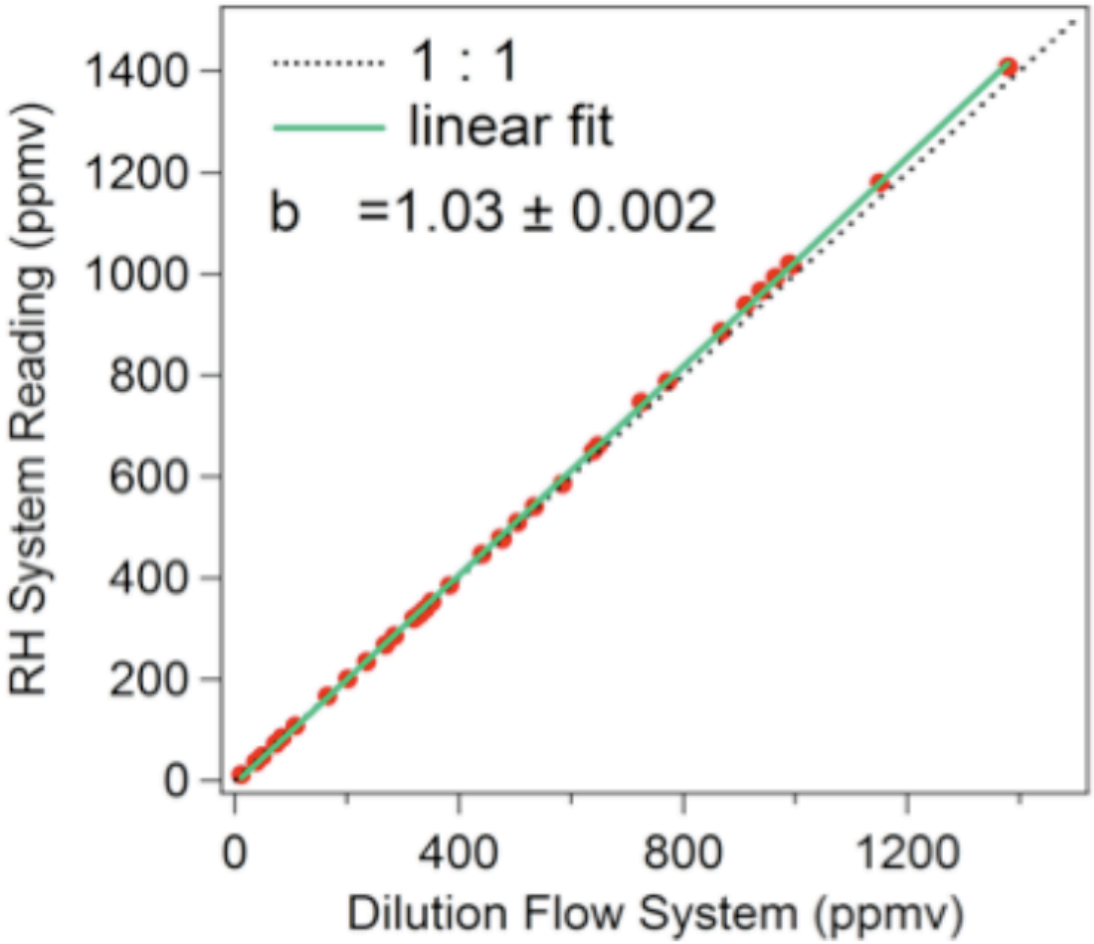
1. isolate VCSEL inside sealed housin
2. add 10-100 mL liquid water
3. immerse VCSEL/housing and reach
   steady-state temperature
4. Use liq. N_2/organic solid-liquid baths
   or regulated temperature bath (±0.02 K stability at -80°C)
5. Clausius-Clapeyron eqn. (Murphy and Koop, 2005) to determine
   ice vapor pressure

Calibrations: 1) standard dilution of flows (1013 hPa, 298 K)



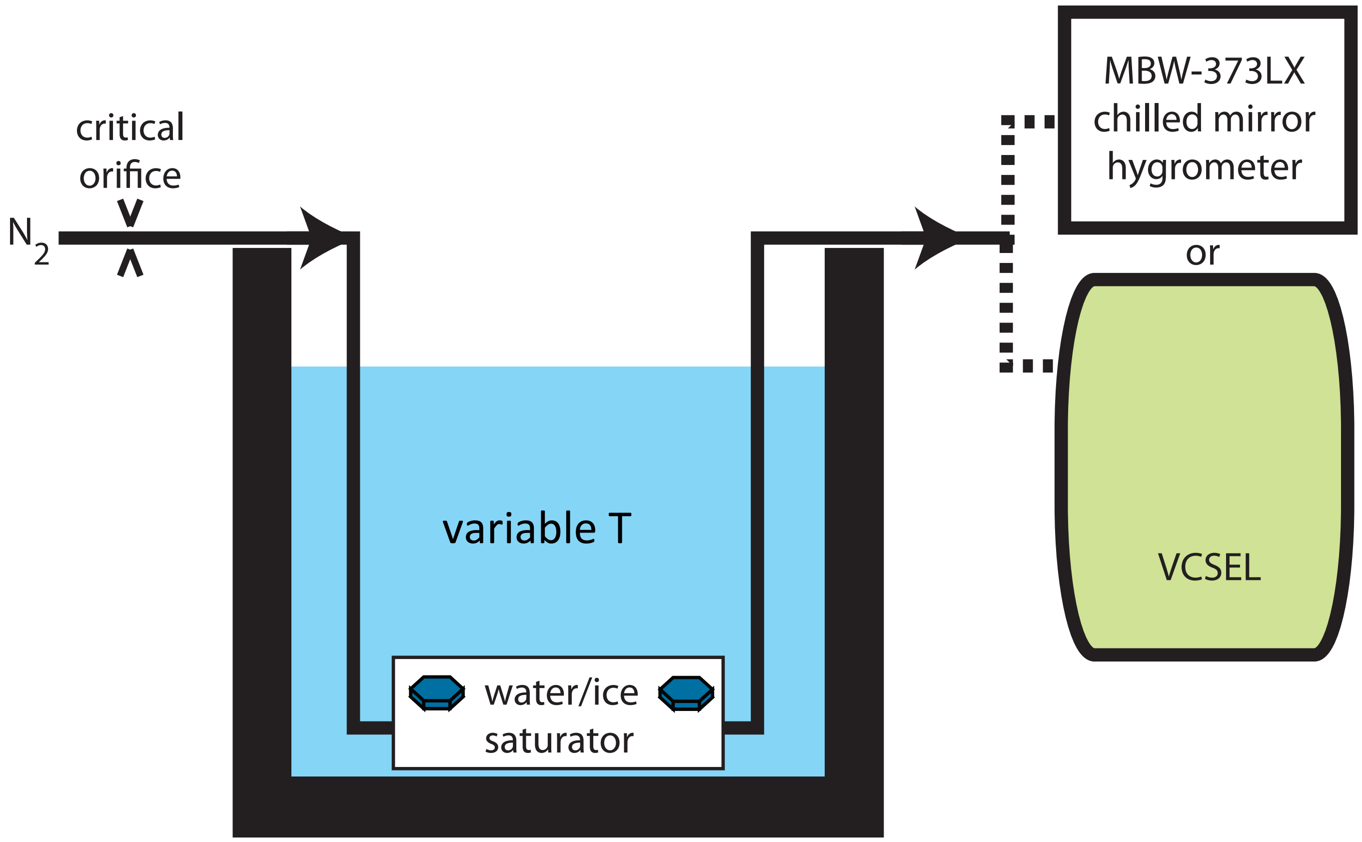
caveat: unknown H_2O in "dry" nitrogen (typically 1-5 ppmv)

Calibrations: 2) flowing, sub-saturated conditions at RT



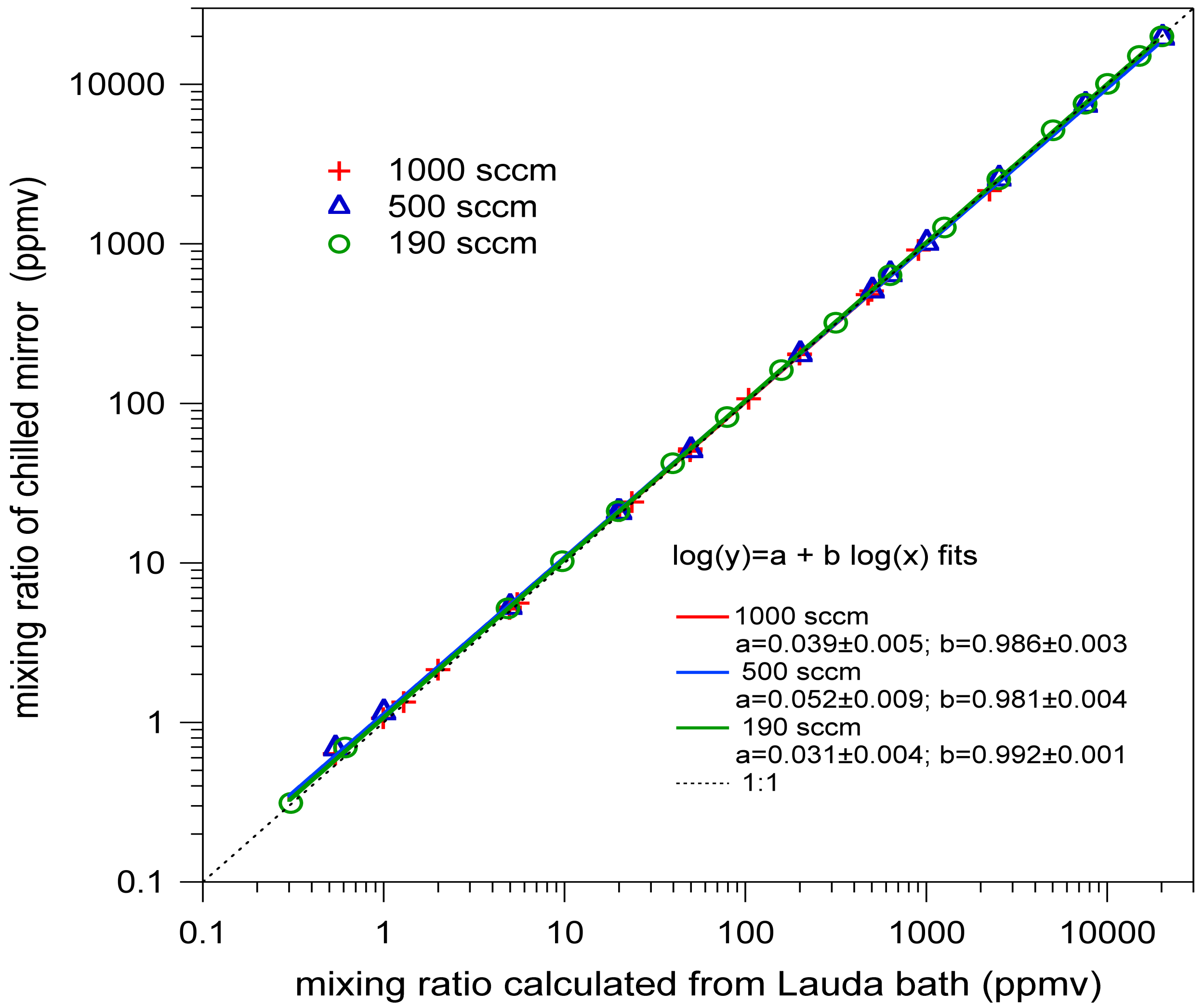
excellent agreement with chilled mirror system

Calibrations: 2) flowing, saturated conditions at RT



saturate "dry" nitrogen in 1 L volume, 200-1000 sccm flows (bath -85 to +20°C)
amount of water determined by Clausius-Clapeyron Eqn. (bath temp.)

Calibrations: 1) flowing, saturated conditions at RT

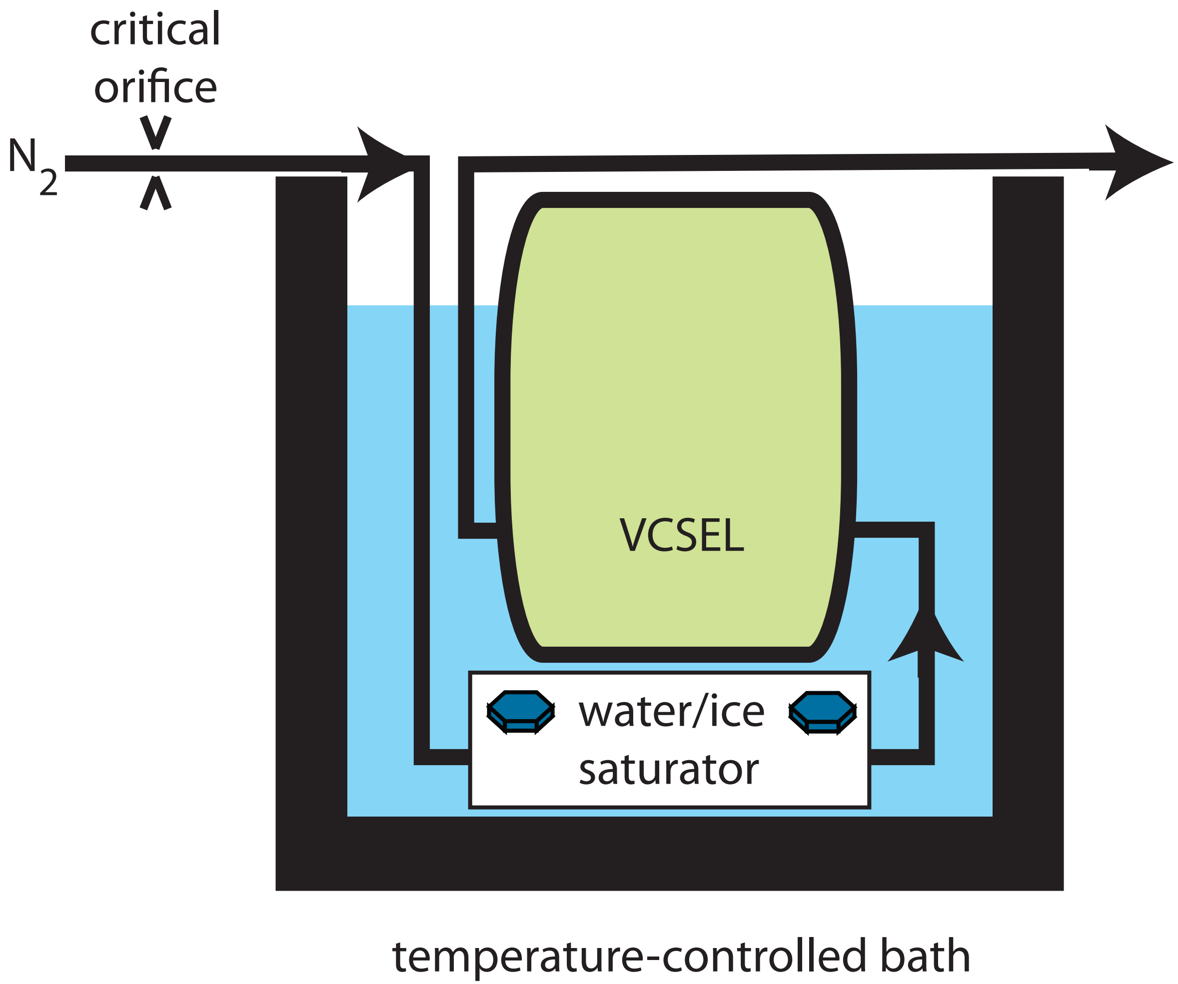


two independent methods of saturation agree extremely well to 0.3 ppmv

➔ bath, chilled mirror temperatures well-calibrated

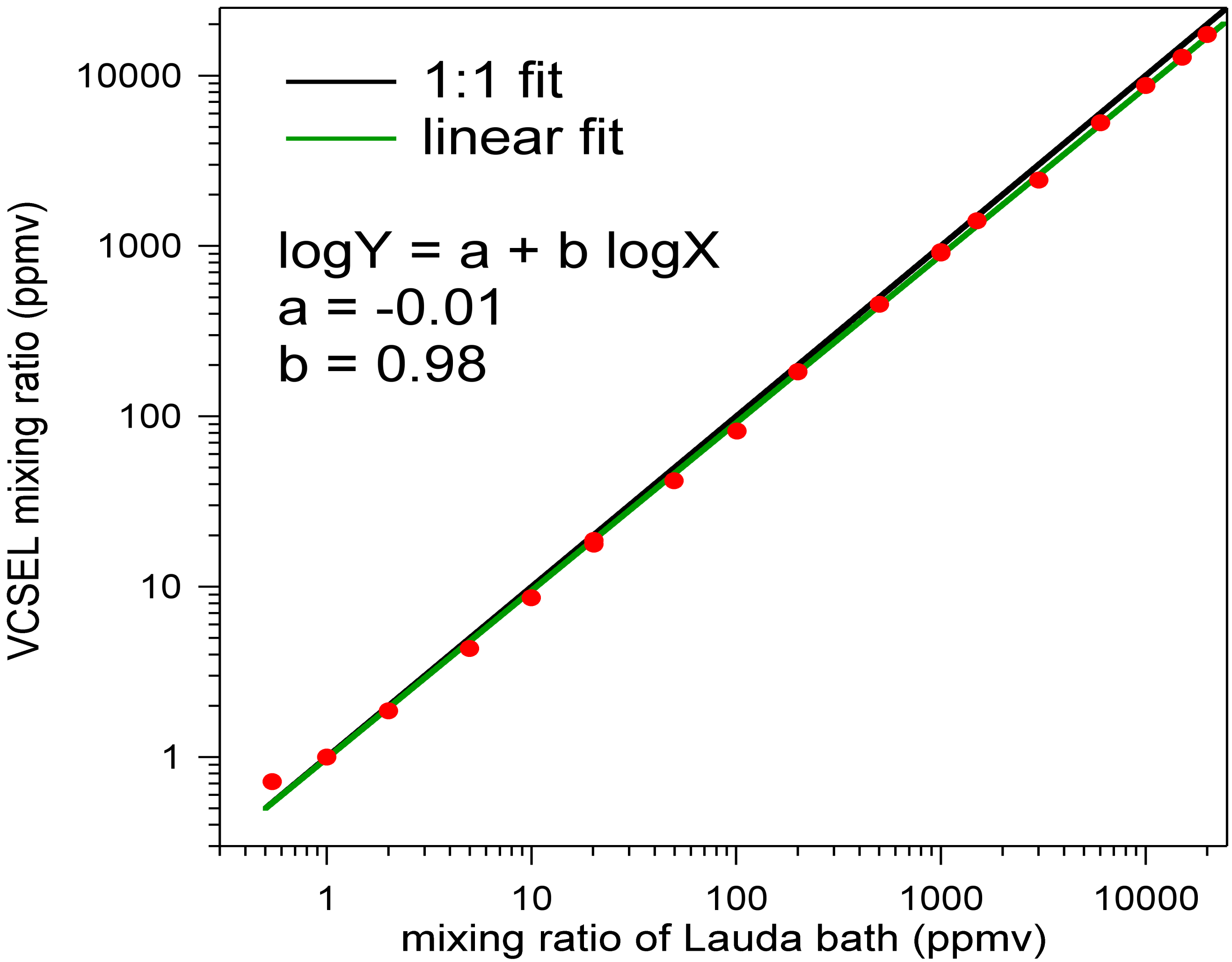
no dependence upon flow rates 190-1000 sccm ➔ fully saturated flows

Calibrations: 3) flowing, saturated near bath temp.



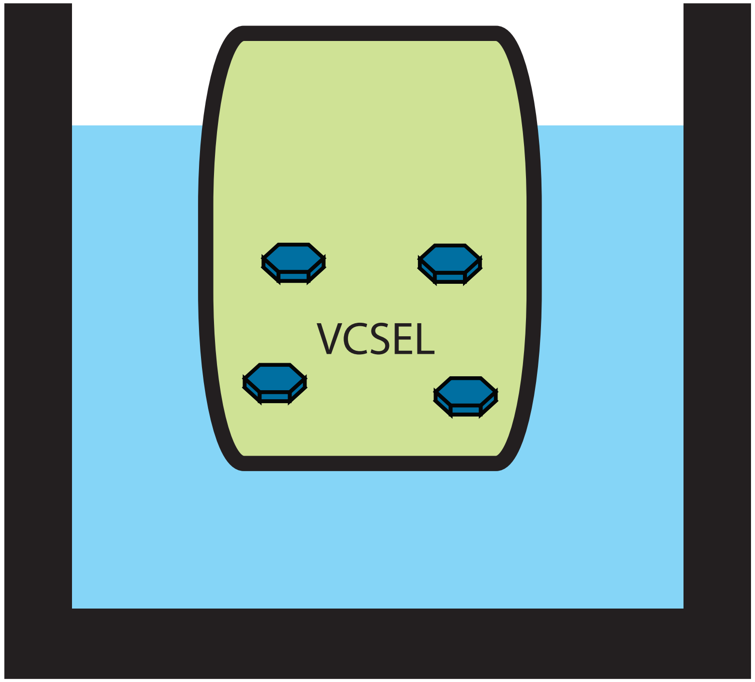
simultaneous concentration, pressure, and temperature conditions

Calibrations: 3) flowing, saturated near bath temp.



simultaneous concentration, pressure, and temperature conditions

Calibrations: 4) organic, liq. N_2 bath

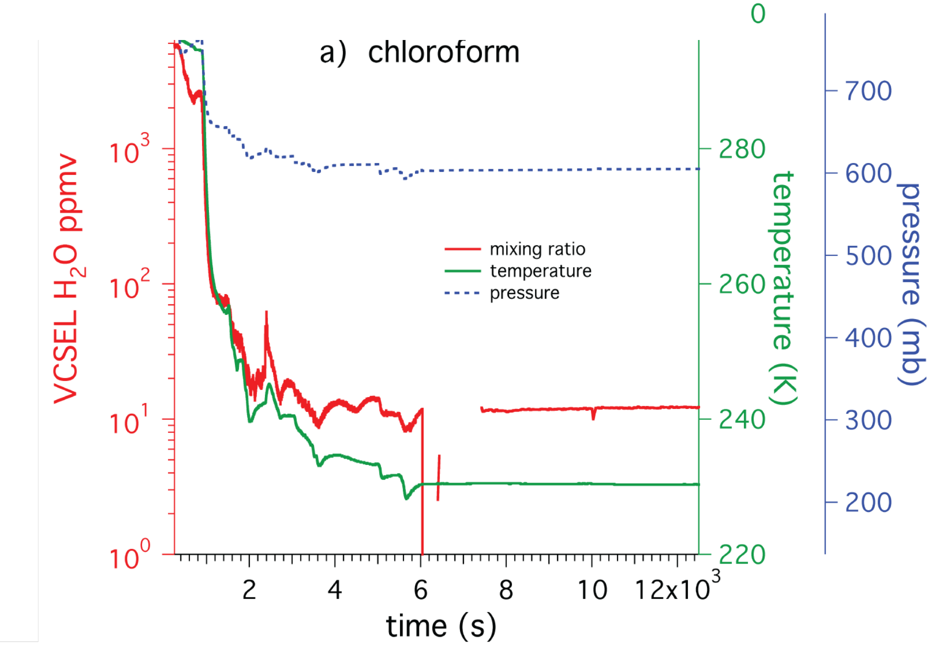


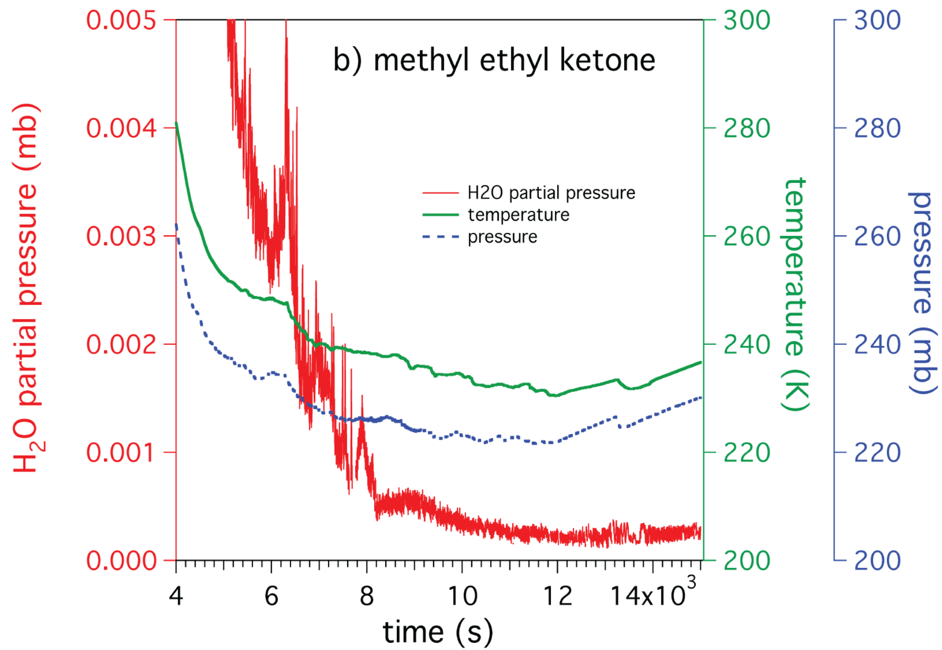
temperature-controlled bath

<u>organic (melt. temp.)</u>

chloroform (-63.41°C)
2-butanone (-86.64°C)
acetone (-94.7°C)

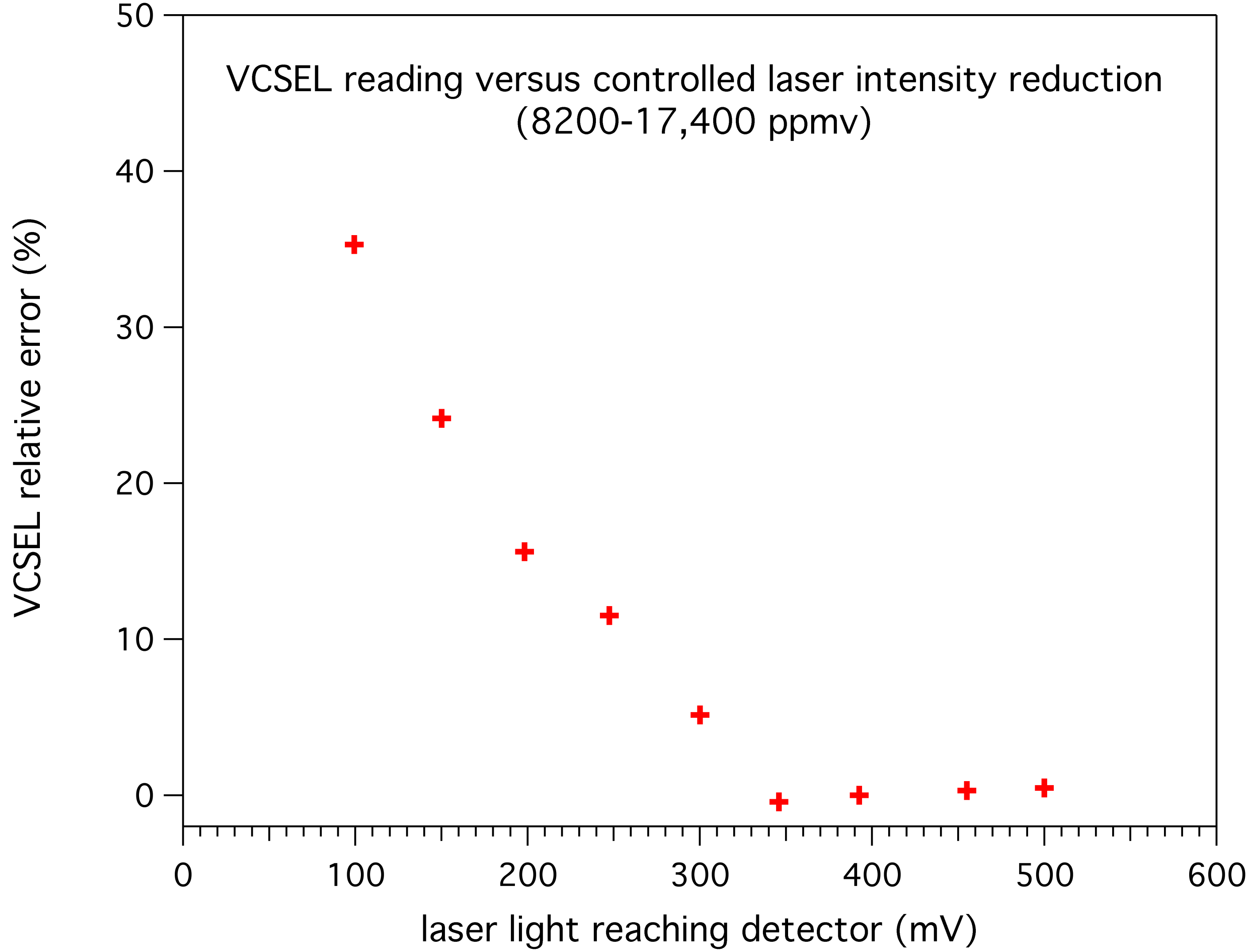
Calibrations: 4) organic, liq. N_2 slush bath





organic (melt. temp.)	nominal	VCSEL (ppmv)
chloroform (-63.41°C):	11.23	11.7 ± 0.2
2-butanone (-86.64°C):	0.77	1.07 ± 0.21
acetone (-94.7°C):	0.18	0.50 ± 0.30

Experimental results at low light intensity



VCSEL shows a high bias below 350 mV; more studies needed

Changes for HIPPO 4/5

To help avoid low laser intensities on detector:

- harder dielectric coatings with Ni-mirrors (tested late in PREDICT)
- higher reflectivity of 1854 nm light than old mirrors
- replace fiber optic feedthrough with new one

...but ultimately the problem lies with interior, recessed surfaces on detector side (i.e. one can clean the mirrors endlessly with little improvement)

Priorities now until mid-April:

1. Replace broken cartridge heater in mirror (broke in PREDICT)
2. Replace fiber optic feedthrough
3. Sensitivity experiments to very low laser light intensities
4. Calibrations at simultaneous temps., pressures, and mole fractions of UT/LS

Submit HIPPO-2/HIPPO-3 data by end of April.