

Breathe London Mobile Monitoring: Instrument Uncertainty Documentation

Section 1 (NO₂, NO, and CO₂)

19 Oct 2020

Table 1: Instrument Uncertainty Summary Table¹

Bold statistic for each row represents the dominant uncertainty for that species

Instrument	Species	MDL	Accuracy ³	Precision	Reference Gas Concentration Uncertainty
AERODYNE RESEARCH, Inc. CAPS	NO ₂	0.54 ppb	± greater of 0.36 ppb or 2.63%	± greater of 0.18 ppb or 0.36%	±5%
ecotech Serinus 40	NO	3.7 ppb	± greater of 7.7 ppb or 7.1%	± greater of 1.2 ppb or 1.9%	±5%
LI-COR LI-7200RS	CO ₂	NR ²	± greater of 4.3 ppm or 0.61%	± greater of 0.11 ppm or 0.04%	±2%

¹The uncertainties are summarized for each species by reporting the statistic from the vehicle with the greater uncertainty (of the two vehicles) under each metric (MDL, accuracy, etc.).

²CO₂ MDL not reported due to high atmospheric background concentrations

³Accuracy presented here is worst-case, as it includes any directional instrument bias and is defined as symmetric. See below for methods, and see Bias section for individual instrument biases.

Table 2: Manufacturer Instrument Specifications

Instrument	Species	Manufacturer Specs
AERODYNE RESEARCH, Inc. CAPS	NO ₂	Limit of Detection (3s, 10s): <0.1 ppb Sensitivity (S/N = 3): <1 pppb (1 s)
ecotech Serinus 40	NO	Zero Drift (7 days): < 1.0 ppb Span Drift (7 days): < 1.0% of reading Lower Detectable Limit: 0.4 ppb Precision: Greater of 0.4 ppb or 0.5% of reading Linearity: ±1% of full scale
LI-COR LI-7200RS	CO ₂	Zero Drift: ±0.1 ppm typical; ±0.3 ppm maximum Gain Drift: ±0.02% typical; ±0.1% maximum Accuracy: ±1% RMS Noise: 0.08 ppm @ 5 Hz

Method Detection Limit (MDL)

The MDL is calculated using 1 hz zero time series data. Sources of zero timeseries data include weekly (~5 minute) zero checks performed at NPL, longer (~1 hour) zero checks performed at NPL, and instrument-initiated zero checks (for NO₂ only). We calculate the +3σ MDL for each distinct zero period and define the instrument MDL as the median MDL across all valid zero periods.

vehicle	species	unit	total n (s)	n distinct periods	mdl
27522	CO2	ppm	6940	7	0.092
27533	CO2	ppm	3494	8	0.3313
27522	NO	ppm	7226	6	0.0019
27533	NO	ppm	6810	6	0.0037
27522	NO2	ppb	378555	17463	0.5447
27533	NO2	ppb	362950	11120	0.371

Bias

Instrument bias is calculated from the span and zero timeseries data, where observed is the measured 1 Hz value and target is the reference concentration (or 0 for zero data):

$$bias = median (observed - target)$$

$$bias\ percent = 100 * median ((observed - target) / target)$$

Sources of timeseries data are 5-minute weekly span and zero checks performed at NPL. Bias is expressed both in terms of absolute concentration (zero and span data) and percentage (span data). The bias is first calculated for each distinct span or zero period, and the final result is the median from all valid periods.

vehicle	species	unit	reference concentration	total n (s)	n distinct periods	bias	bias percent
27522	CO2	ppm	0	6940	7	-4.2919	
27522	CO2	ppm	1000 or 1006 ± 20	1311	9	-2.493	-0.25%
27533	CO2	ppm	0	3494	8	-2.535	
27533	CO2	ppm	1000 or 1006 ± 20	618	4	5.11	0.51%
27522	NO	ppm	.48 ± .024	2075	7	0.0203	4.23%
27522	NO	ppm	0	7226	6	-0.003	
27533	NO	ppm	.48 ± .024	1265	6	-0.0143	-2.98%
27533	NO	ppm	0	6810	6	-0.0026	
27522	NO2	ppb	0	378555	17463	-0.021	
27522	NO2	ppb	504 ± 25	1373	9	8.6195	1.71%
27533	NO2	ppb	0	362950	11120	-0.008	
27533	NO2	ppb	504 ± 25	1840	10	9.0173	1.79%

Note: the inconsistency between bias results during span and zero calibrations (e.g. NO2 -.021 zero bias vs. +8.62 span bias for vehicle 22) is likely a result of uncertainty in the span calibration process related to challenges in maintaining a constant reference concentration, and not a sign of non-linearity in the instrument itself.

Accuracy

Instrument accuracy is calculated from the span and zero timeseries data. Instrument accuracy is calculated as the 95th percentile of the absolute difference or percent difference of all 1hz measurements from the target span or zero value:

$$accuracy = \pm P95 (abs(observed - target))$$

$$accuracy\ percent = \pm 100 * P95 (abs(observed - target) / target)$$

Accuracy is expressed both in terms of absolute concentration (zero and span data) and percentage (span data). The accuracy is first calculated for each distinct span or zero period, and the final result is the median from all valid periods.

vehicle	species	unit	reference concentration	total n (s)	n distinct periods	accuracy	accuracy percent
27522	CO2	ppm	0	6940	7	4.3354	
27522	CO2	ppm	1000 or 1006 ± 20*	1311	9	4.27	0.42%
27533	CO2	ppm	0	3494	8	3.3535	
27533	CO2	ppm	1000 or 1006 ± 20*	618	4	6.1325	0.61%
27522	NO	ppm	.48 ± .024	2075	7	0.034	7.08%
27522	NO	ppm	0	7226	6	0.0039	
27533	NO	ppm	.48 ± .024	1265	6	0.027	5.63%
27533	NO	ppm	0	6810	6	0.0077	
27522	NO2	ppb	0	378555	17463	0.3632	
27522	NO2	ppb	504 ± 25	1373	9	10.1034	2.00%
27533	NO2	ppb	0	362950	11120	0.2555	
27533	NO2	ppb	504 ± 25	1840	10	13.2358	2.63%

*the CO₂ cylinder was changed in February 2019

Precision

Instrument precision is defined as the 1σ noise from the 1hz span or zero timeseries. Sources of zero timeseries data include weekly (~5 minute) zero checks performed at NPL, longer (~1 hour) zero checks performed at NPL, and instrument-initiated zero checks (for NO₂ only). Sources of span timeseries data are weekly (~5 minute) span checks performed at NPL. Precision is expressed both in terms of absolute concentration (zero and span data) and percentage (span data). The precision is first calculated for each distinct span or zero period, and the final result is the median from all valid periods.

vehicle	species	unit	reference concentration	total n (s)	n distinct periods	1σ	1σ percent
27522	CO2	ppm	0	6940	7	0.0307	
27522	CO2	ppm	1000 or 1006 ± 20	1311	9	0.1997	0.02%
27533	CO2	ppm	0	3494	8	0.1104	
27533	CO2	ppm	1000 or 1006 ± 20	618	4	0.3802	0.04%
27522	NO	ppm	.48 ± .024	2075	7	0.0075	1.55%
27522	NO	ppm	0	7226	6	6.00E-04	
27533	NO	ppm	.48 ± .024	1265	6	0.0089	1.85%
27533	NO	ppm	0	6810	6	0.0012	
27522	NO2	ppb	0	378555	17463	0.1816	
27522	NO2	ppb	504 ± 25	1373	9	1.2935	0.26%
27533	NO2	ppb	0	362950	11120	0.1237	
27533	NO2	ppb	504 ± 25	1840	10	1.818	0.36%