

## APPENDIX A

# On-Road Testing of Prototype Plume Following Instrumentation

Prepared by Sierra Research  
12/2009

This Section describes testing in December 2009 of a prototype of the vehicle-mounted plume following instrumentation. The target vehicle, shown in Figure A-1, was a cosmetically well-preserved 1975 Suzuki GT750, 2-stroke motorcycle with 28,244 miles. The vehicle owner, George van Klan (GvK), took the vehicle out of storage and started it up on 12/23/09, the day before our test, and said that it had visible smoke. He reported that it had not been started for more than one year, and had only a small amount of year-old gasoline. As observed by Sierra the next day, it did have visible smoke when started up with the old fuel and also, after topping off with fresh fuel, \* during startup and during almost all accelerations that were observed in the following hour from the plume following vehicle.

The on-road testing was performed with GvK driving the Suzuki, and Josh Willter and Frank Di Genova following in Sierra's Chevrolet Caprice prototype plume following vehicle. The drive was video-taped and with in-cabin audio recorded by Pulse pen. Driving was performed over a period of about one hour on the outskirts of the City of Napa, California, commencing about 12:00 noon on 12/24/2009.

A series of charts at the end of this section documents the CO<sub>2</sub> and PM<sub>2.5</sub> concentrations recorded for the drive, along with chase car speed (from GPS) and the position of a target switch, showing (small uptik in the "target" trace) when the "observer" believed that the chase car was "seeing" the target's plume. Also included at the end of the section is a copy of the observer's contemporaneously collected notes about the drive.

Following is a summary narrative of the drive.

---

\* The Suzuki was factory-equipped with a separate lubricating oil tank that and system that metered lube oil into the fuel at a rate, according to GvK, of about 2%.

**Figure A-1**  
**Target Smoking Vehicle: Model Year 1975 Suzuki GT750 2-Stroke Motorcycle**



## Summary of Results from Plume Following of a Smoky Motorcycle

The engine start and initial driving started out extremely “dirty” with spikes and clouds of blue smoke at several early accelerations that produced visible blue smoke plumes having PM<sub>2.5</sub> concentrations in excess of 1000 ug/m<sup>3</sup> (based on DataRAM measurements).

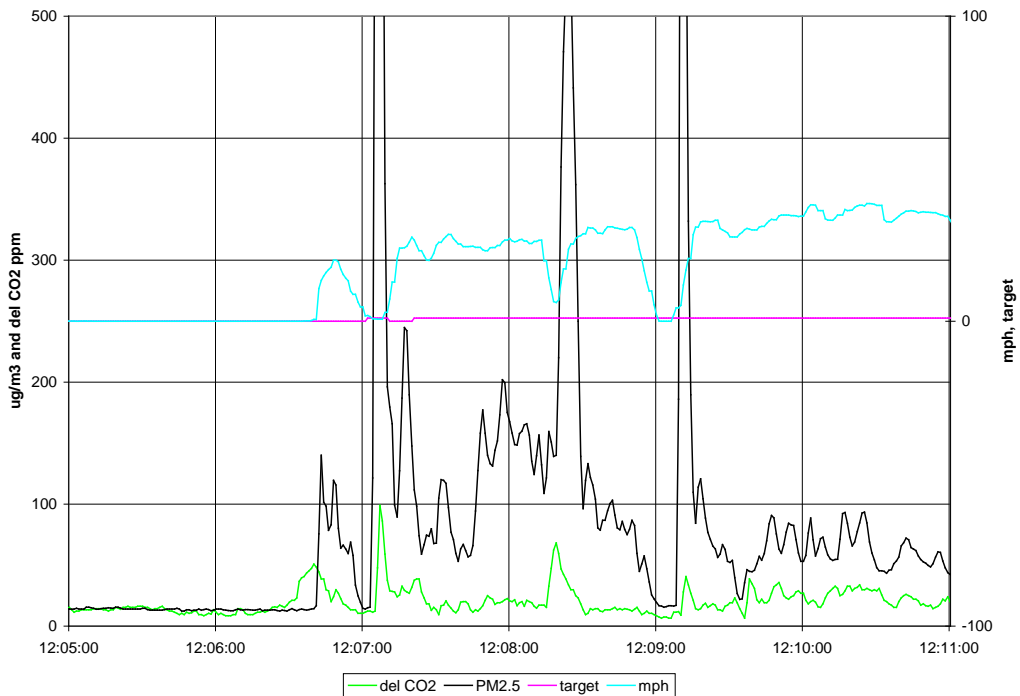
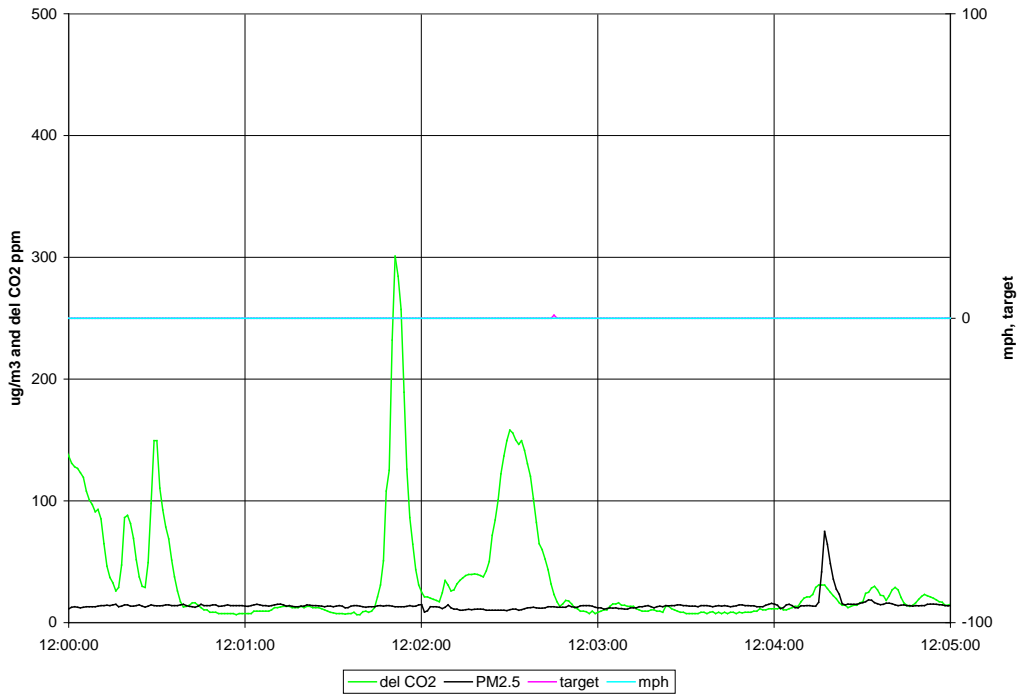
However, the Suzuki cleaned up dramatically over the course of driving and most of the steady-state driving had no visible emissions. Accordingly, GvK was asked to drive “a little more aggressively” in the second half of the driving, which resulted in having some “dirtier” spikes, and it was dirty on the mostly steady speed freeway trip back to its Napa home. During that freeway drive, the Suzuki still exhibited wisps of visible smoke, each of which we could easily discern in the PM measurements. In fact, it was the dirtiest freeway drive we have seen so far, generally ranging from about 20-100 ug/m<sup>3</sup> with a background on the order of 10-15 ug/m<sup>3</sup>) and, except for the accelerations, appeared generally dirtier than the steady cruising on country roads at lower speed.

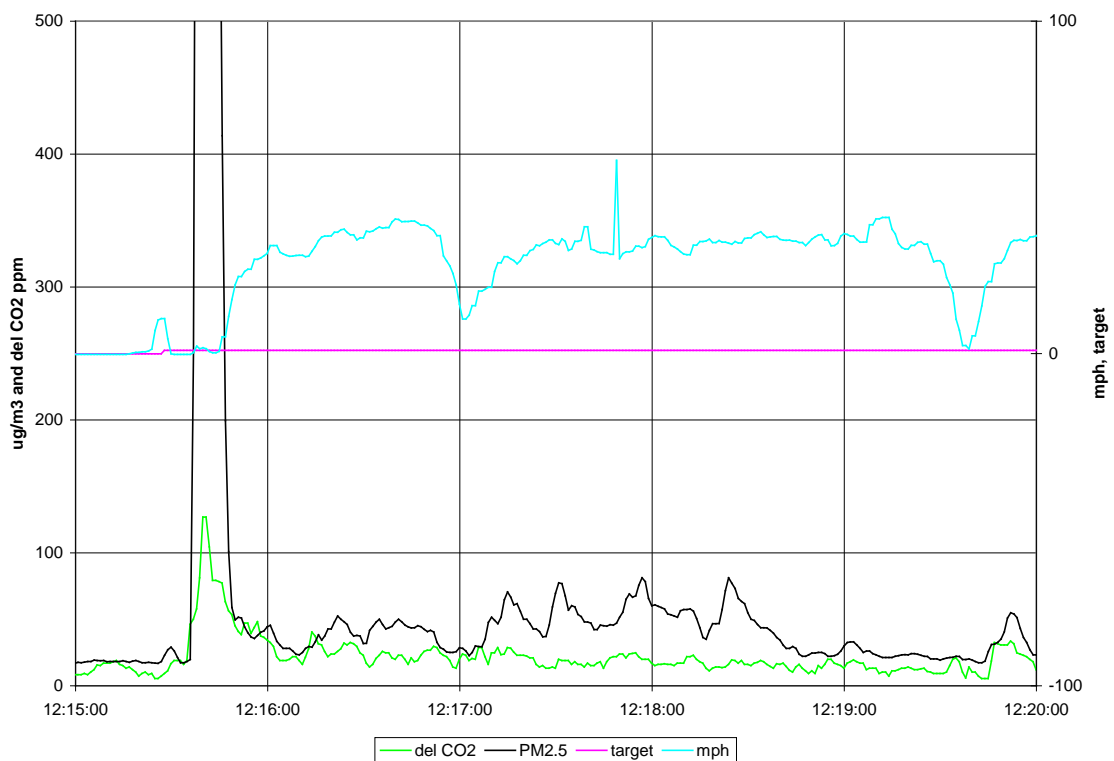
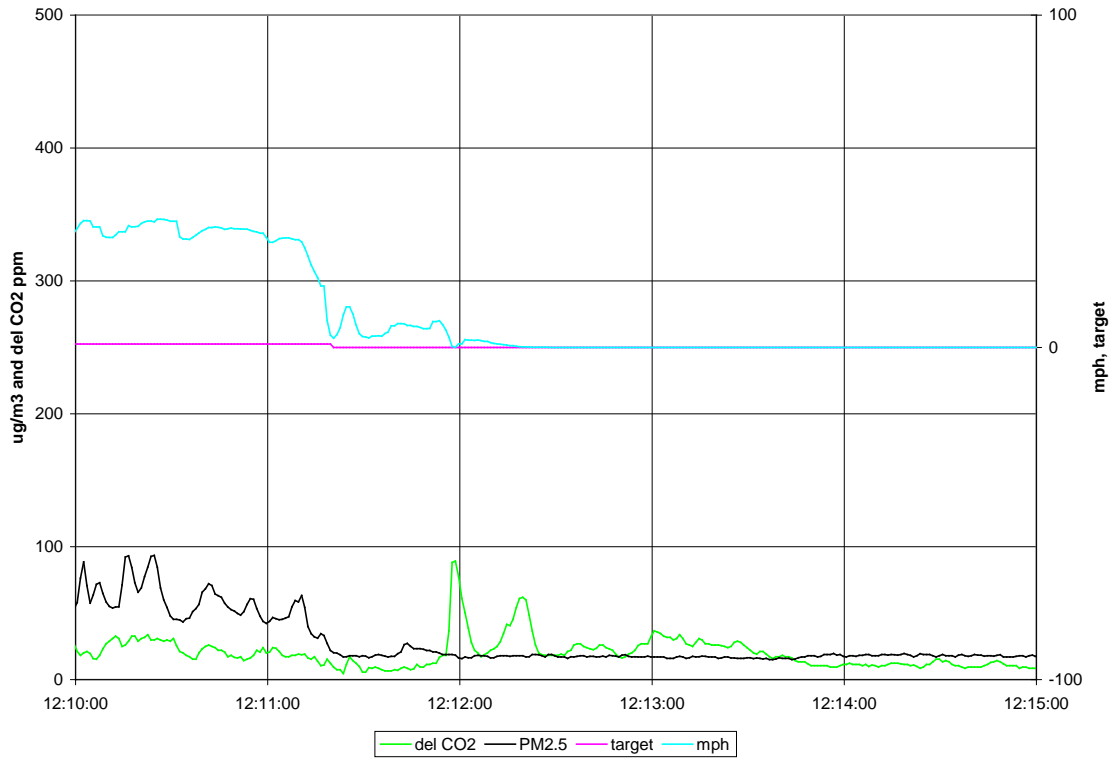
During the drive, there were just a few times when the observer could see a CO<sub>2</sub> spike and small PM<sub>2.5</sub> spike from the bike together and there was no visible plume (at one point, the observer commented for the cockpit audio record, on the lack of visible plume). In general, however, the video did not show the visible plumes very well, even though the plumes at close range were unsightly and smelly. Most of the time, in fact, the motorcycle had no visible emissions, even though it had startup spikes and even warmed-up high power spikes that pegged the measurement at 1000 ug/m<sup>3</sup>. Furthermore, it should not be a surprise, but is still worth noting, that the DataRAM, a light scattering photometer, did a good job at measuring visible emissions (based on an crude comparison of when emissions were visible to the eye and when higher concentrations were observed in real time on the DataRAM).

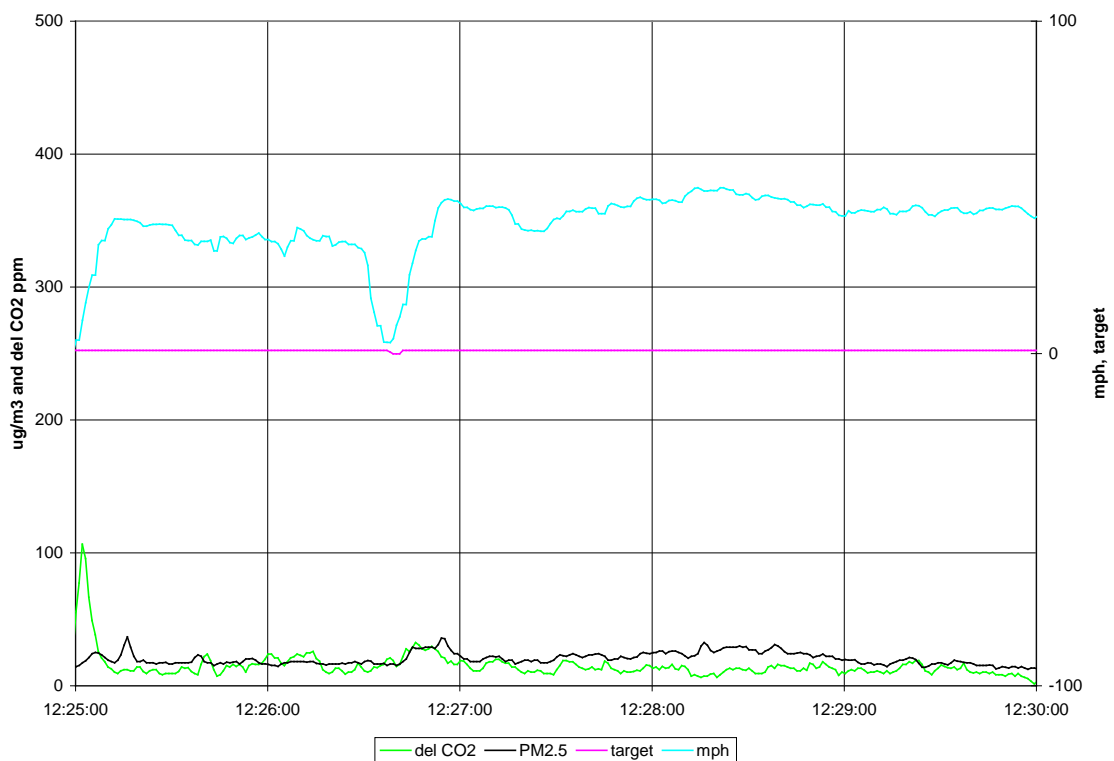
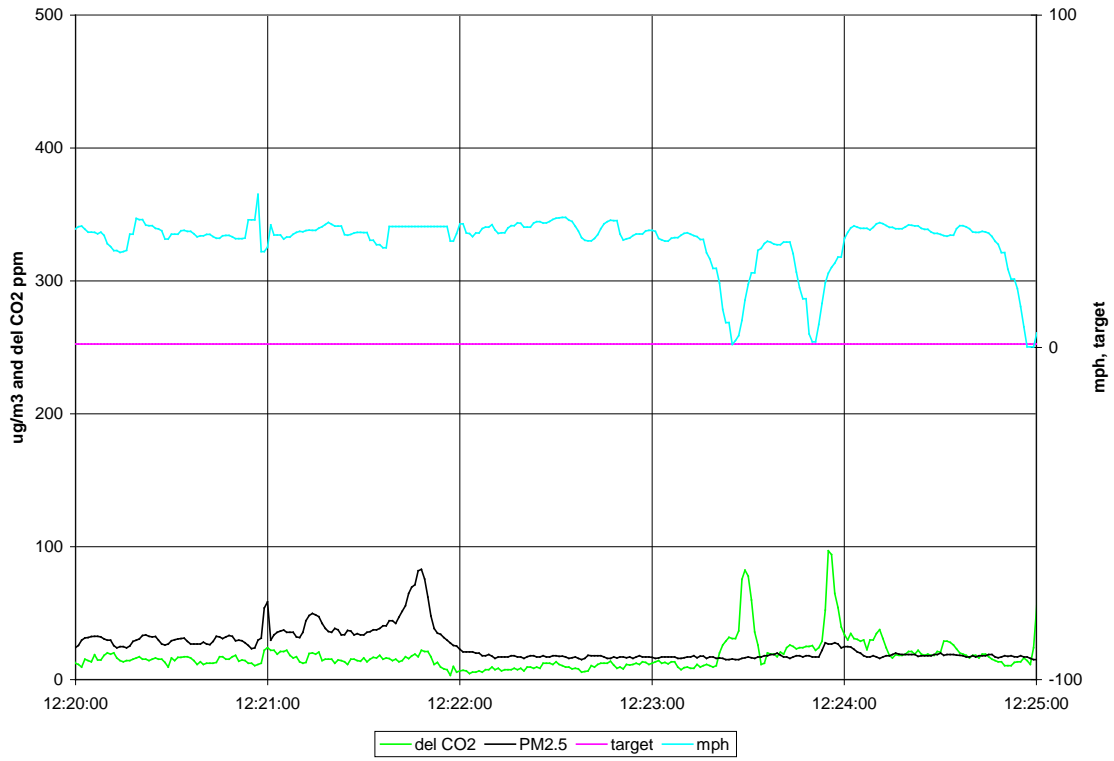
During the drive, many of the PM increases due to the motorcycle were difficult or impossible to discern from background “on the fly.” PM<sub>2.5</sub> background for this drive varied from about 8.5-15 ug/m<sup>3</sup>. In earlier Sacramento drives, on-road background PM<sub>2.5</sub> concentrations varied from about 15 up to nearly 50 ug/m<sup>3</sup>. Also, there were a number of instances where we observed distinctive CO<sub>2</sub> plumes with no change in PM. And sometimes a PM spike either preceded or followed the associated CO<sub>2</sub> spike by a few seconds.

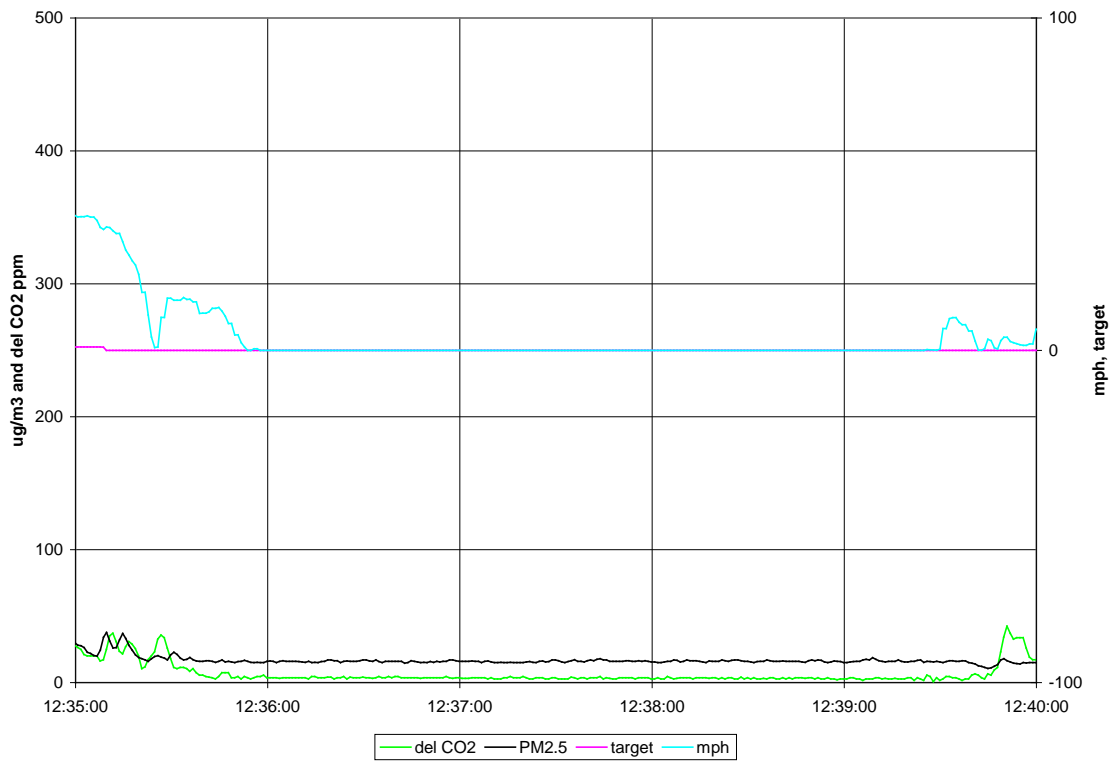
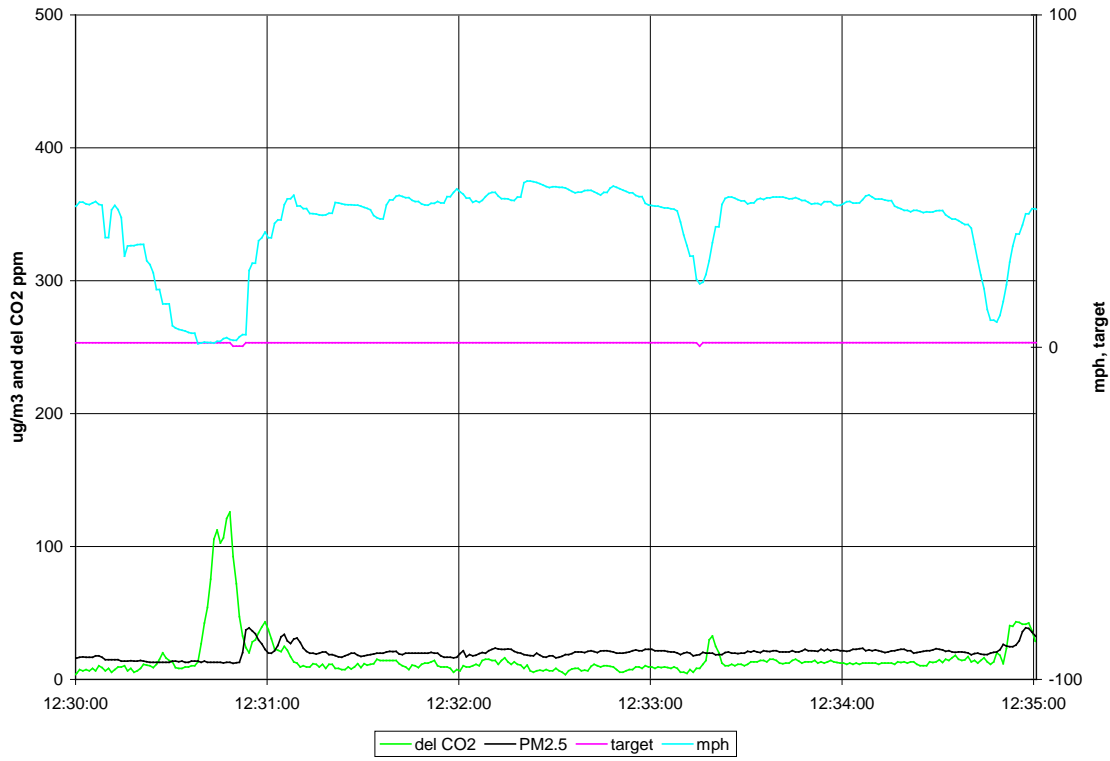
Finally, although it’s time consuming to review, we note that the video was extremely helpful in reviewing data from this and other drives.

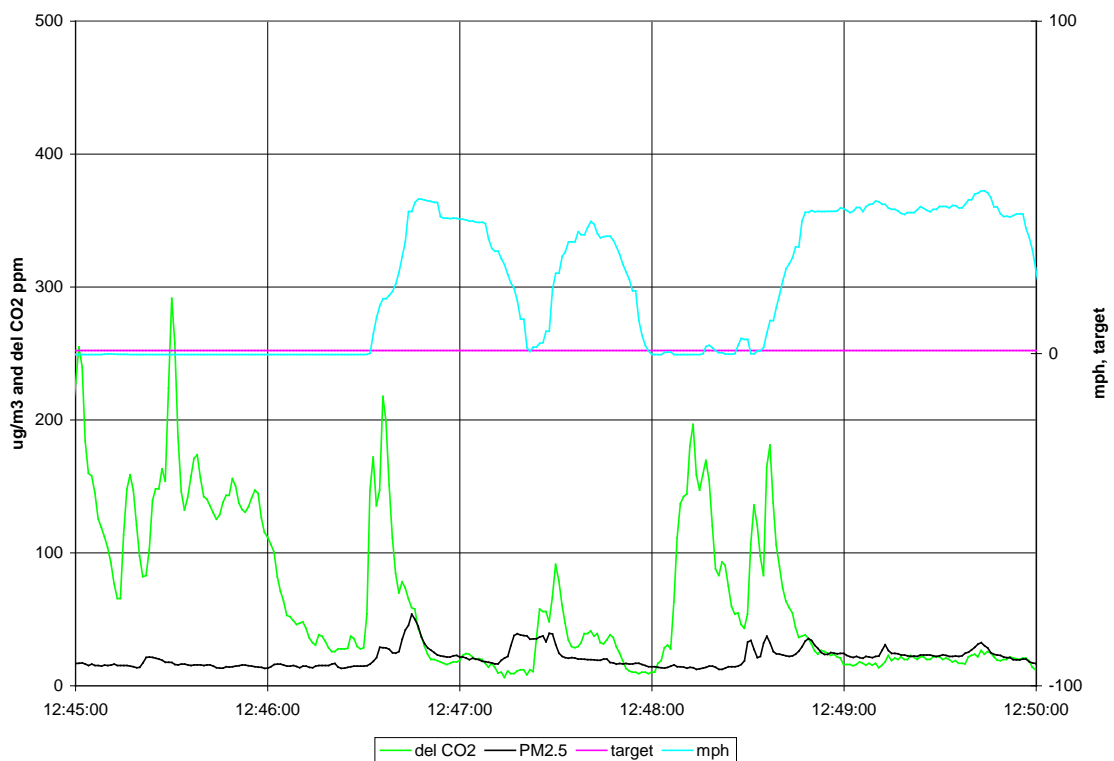
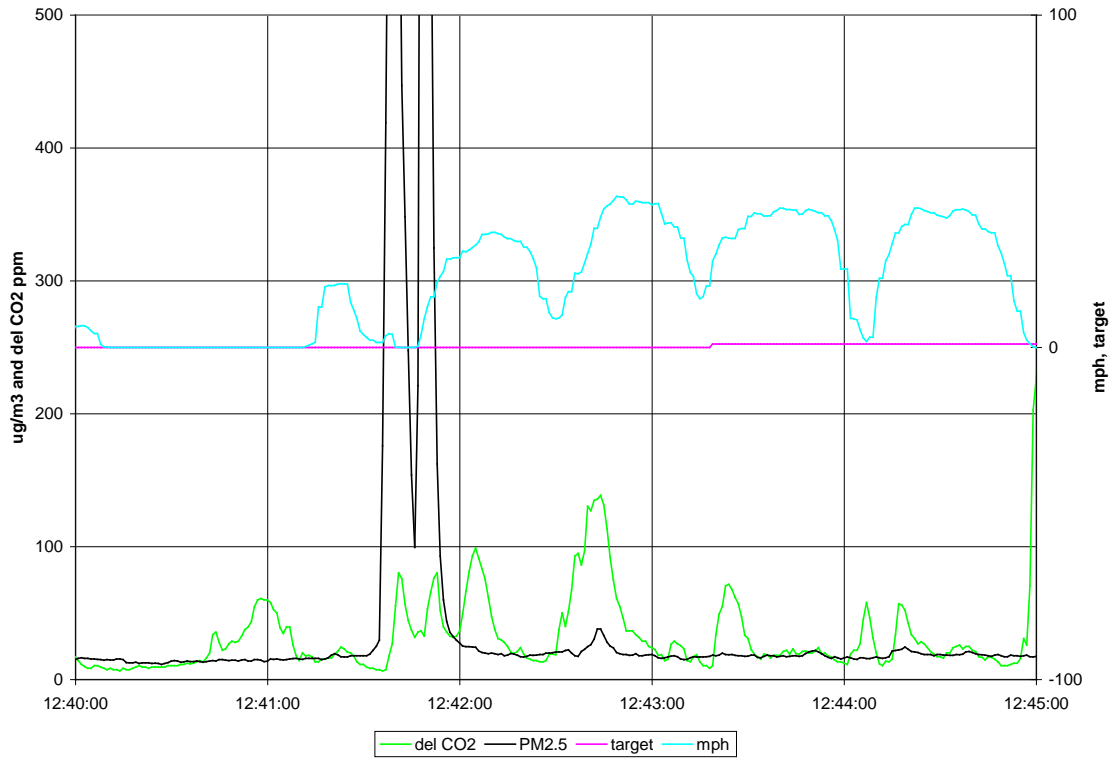
Charts showing CO<sub>2</sub> concentration (amount above background), PM<sub>2.5</sub> concentration, chase car vehicle speed, and target switch (indicating when in the plume):



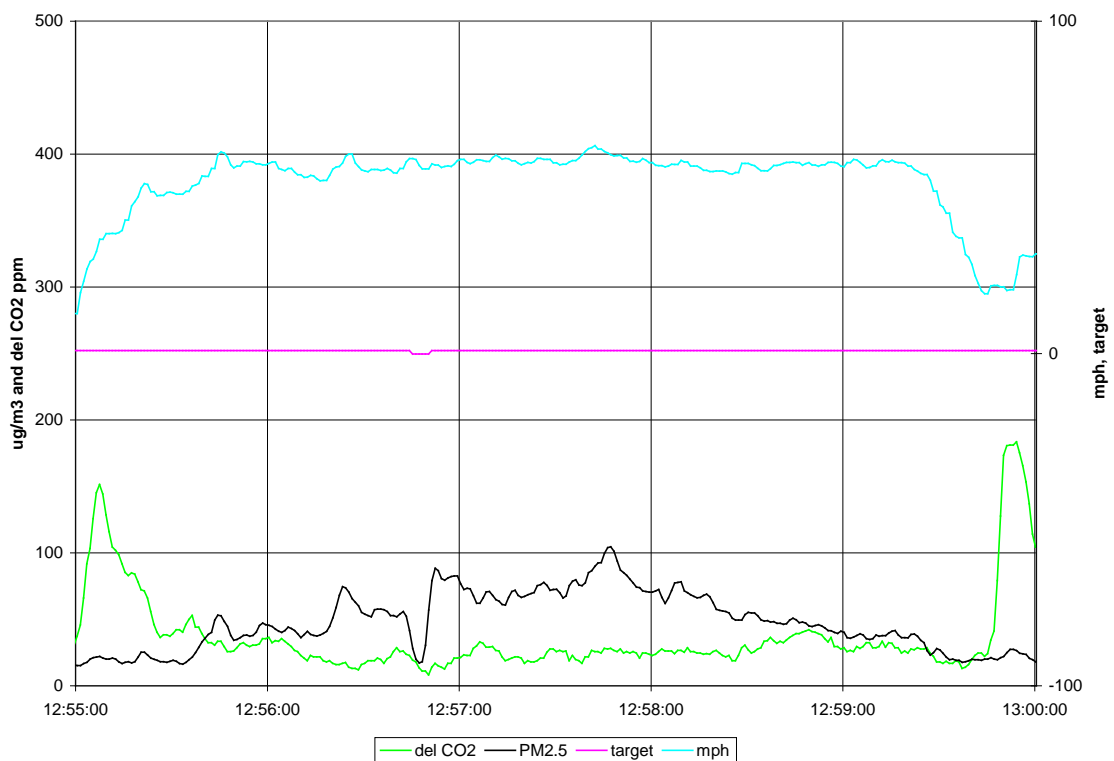
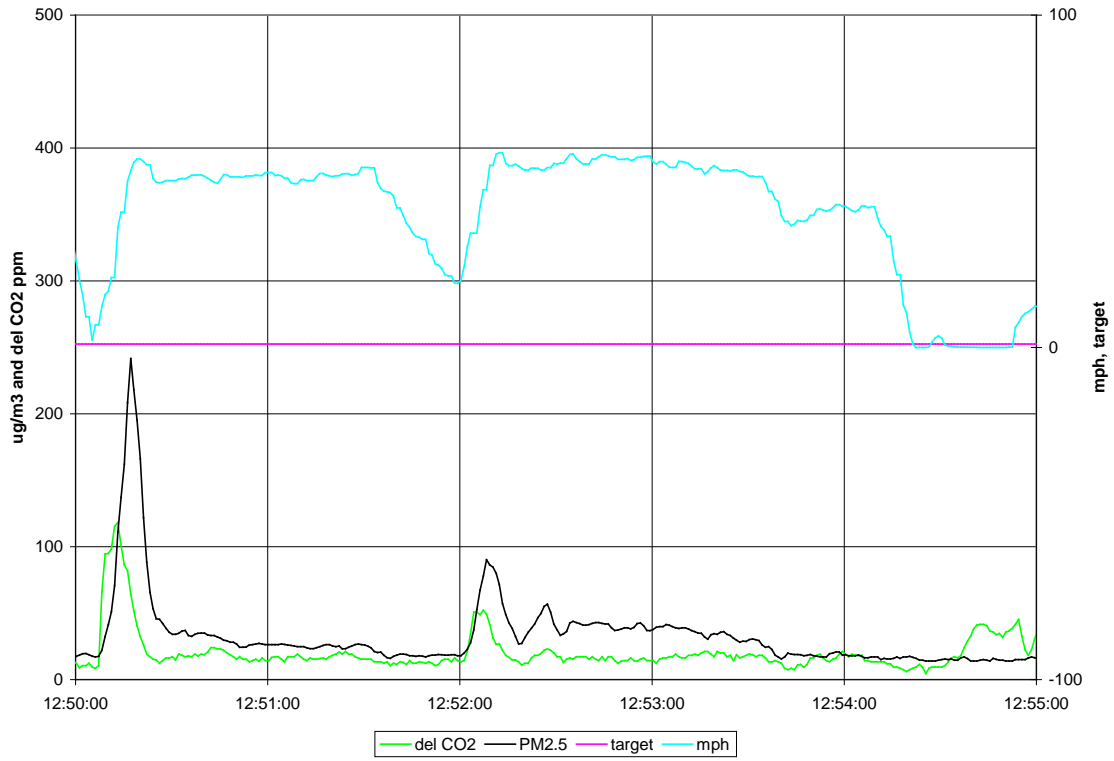


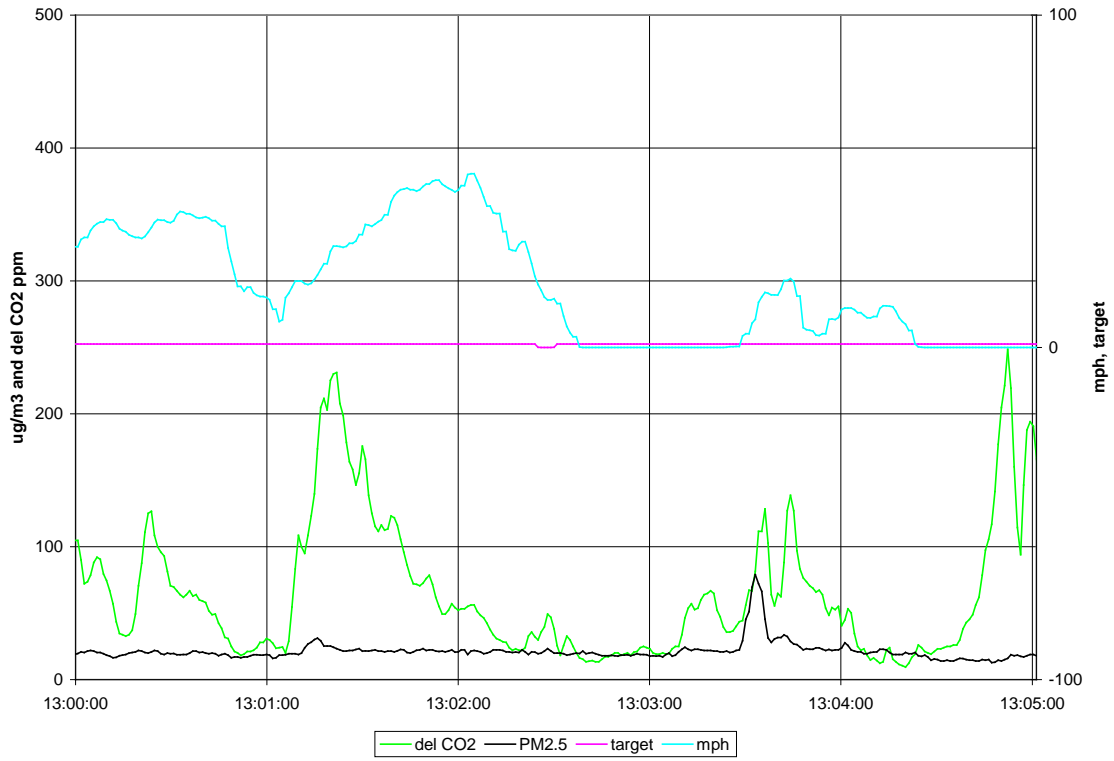












Observer's Notes During the Suzuki Two-Stroke Motorcycle Plume Following

~3900 left 27

124109 0134 start in NADA

~12101 mark M160 gas PC  
O2 test switch OK

Suzuki; GT 750

sec 1912

5 EL 2000

2021 140MS 400ppm

left 502g

1,00069 1min  
10 41671hr

900MS

2144 35mph 30' 80MS 420ppm

2207 off target, he gets gas

2297 at gas station ~17MS 410ppm  
2367 18 396

2459 launch 24 408

2545 country rd

2630 22 400 37mph 25'

2820 38 404 38 mph 50'

2880 looks like background 38 mph 40'  
17, 397

2940 Launch

2960 Launch  
slight PM + CO<sub>2</sub>

3022

3130 Launch onto Dry Creek

3181 42 mph 50' 24, 400

3227 53 mph 50'

3383 Turnaround (saw own CO<sub>2</sub> plume) +  
his was smoky too (just after ours)

3485 50' 49 mph 19, 395

3528 target get ahead, then resumed 50'

3590 19, 398

3638 plums from other vehs

3682 at home base

bike is 34 yrs old 28,244 miles

4010 resume driving - going  
4046 - I saw 1500 ug

(4124 noticed I forgot target switch)

4140 60 ft 42 mph

4177 Launch

4244 waiting for DSL train (wine train)

~ 5' from ahead, killing

4318 Launch

4330 accel - light pectrs

4366 lamb

4436 lamb, 2 humps; maybe not allow target

4527 " WOT <sup>75%</sup> 150' visible, smell  
~200mg peak

4640 " WOT <sup>75%</sup> 150' visible, smell  
~90mg peak

470 150' 40 405

and o

4827 29 south ramp

4908 60mph 75'  
passed with train  
smelling more now

4968 70-80mg + seeing  
west of smoke

accel it

5053 60mph 75' 45 427

5205 left accel

5343 saw lamb, but busy with stream

5390 end of chase

PAID George van Klam \$150 for 1/2 hrs  
12/24/09  
bulk 12/24/09