Automotive Particulate Matter and Gaseous Emission Factors from On-Road Measurement in Las Vegas, NV

Claudio Mazzoleni, Hampden D. Kuhns, Hans Moosmüller, Robert E. Keislar, Peter W. Barber, Djordje Nicolic, Norman F. Robinson, and John G. Watson
(Desert Research Institute, Reno, NV)

NARSTO Emission Inventory Workshop
October 14-17, 2003, Austin, Texas

Acknowledgments

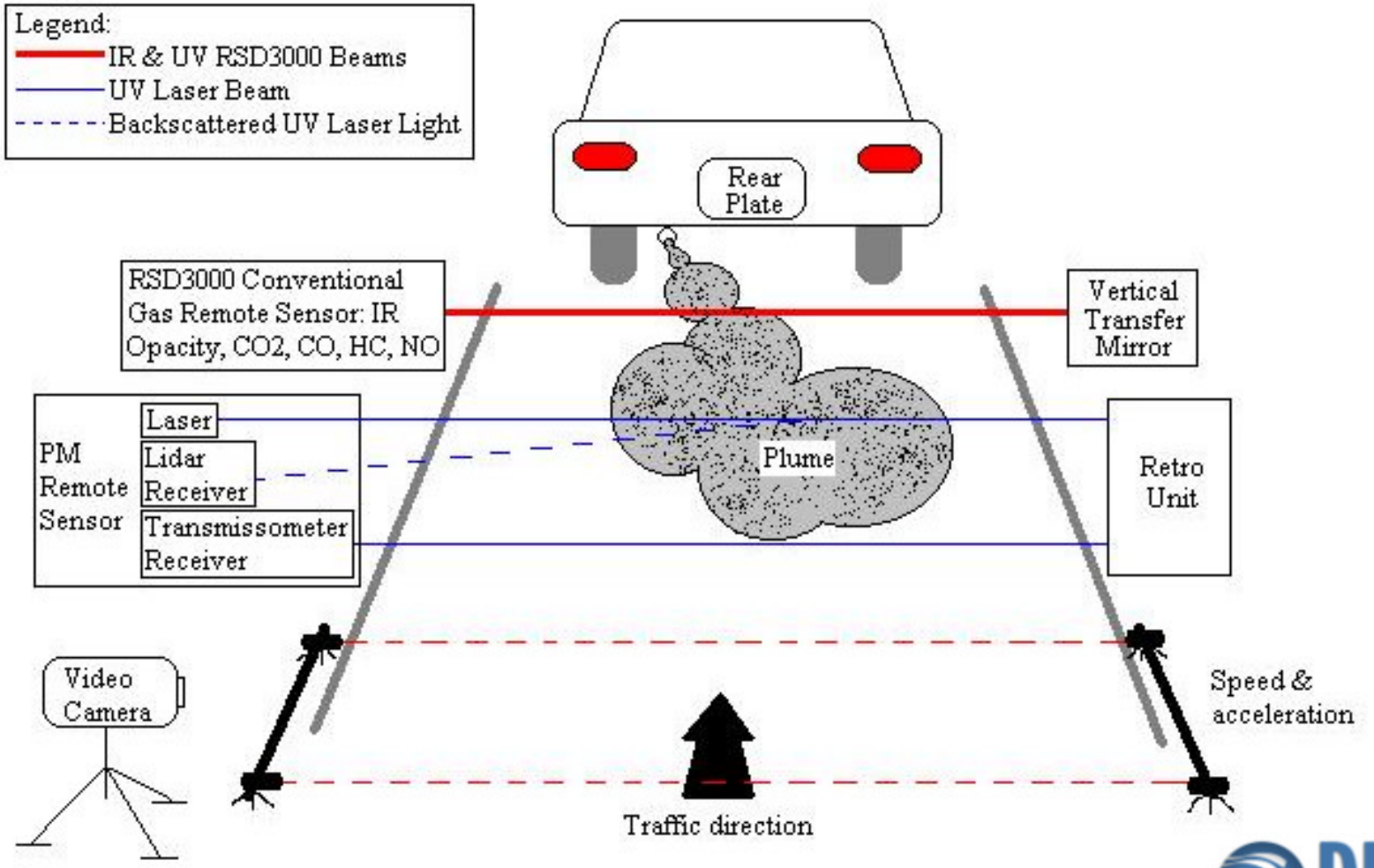
- **Coauthors.**
- **Dan Wermers, Rick Purcell, Larry Sheetz, DRI Facilities.**
- **Vicken Etyemezian, and Ali Yimer.**
- **Federal Transit Administration (Contract 26-70030), Clark County, NV (Contract C1062-99-item 26), DoD SERDP (Contract CP-1336), Coordinating Research Council (Contract E56-1), Desert Research Institute.**

Outline

- Vehicle Emission Remote Sensing Systems:
  -Commercial gaseous remote sensor
  -Newly developed PM remote sensor
- Las Vegas, NV experiment
- Results
- Conclusions

Desert Research Institute

Principles of Remote Sensing Systems



See poster by Hans Moosmüller et al.

Desert Research Institute

Advantages and Limitations of Remote Sensing

Advantages:

- **Large amount of vehicles measured (good fleet representation).**
- **Excellent vehicle selectivity. Each vehicle identified by rear plate. Fuel type, vehicle weight category, model year, origination are known.**
- **Low cost per vehicle, non invasive.**

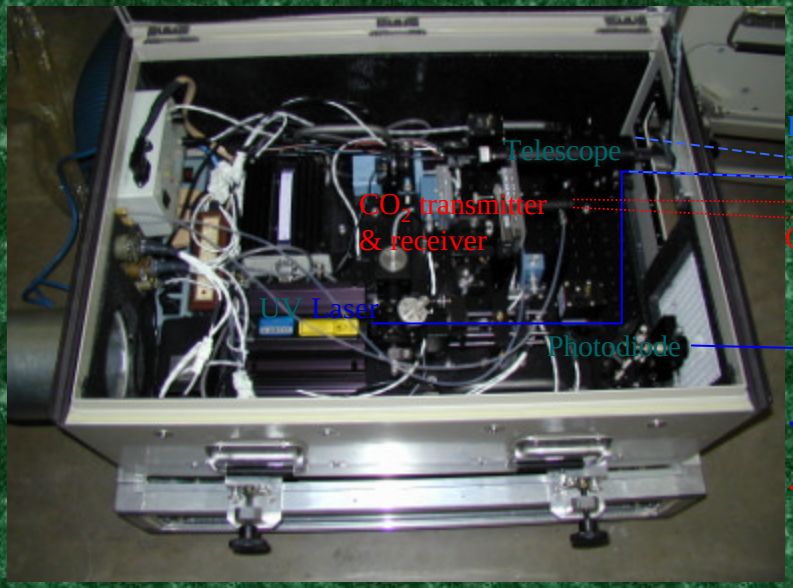
Limitations:

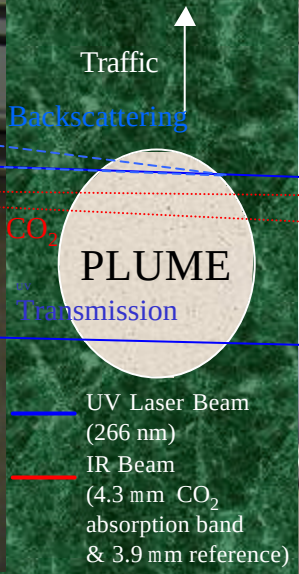
- **Instantaneous emission (0.5 sec.).**
- **Limited operating conditions.**
- **Limited measurements techniques.**

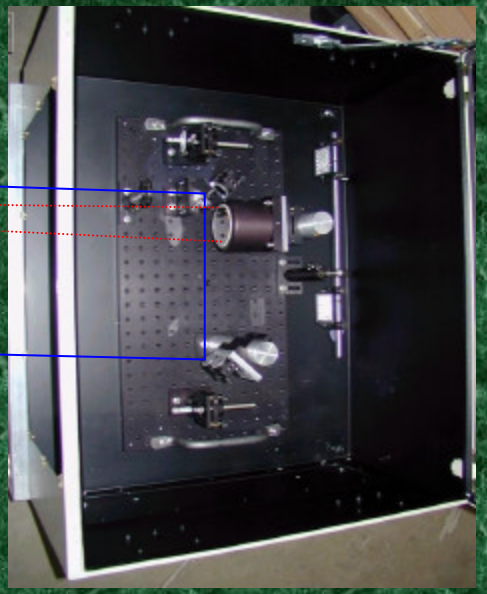
DRI
Desert Research Institute

PM & Gaseous Remote Sensing System

Desert Research Institute







Fuel Based Emission Factors Calculation

- Pollutant column density: ρ_{c_P}
- Emission factor [$grams_P/kg_{fuel}$]:

$$EF_P = CMF_{fuel} \frac{\frac{r_{c\_P}}{r_{c\_CO2}}}{CMF_{CO2} + \left(CMF_{CO} \frac{r_{c\_CO}}{r_{c\_CO2}} + CMF_{HC} \frac{r_{c\_HC}}{r_{c\_CO2}} \right)}$$

Where CMF = carbon mass fraction

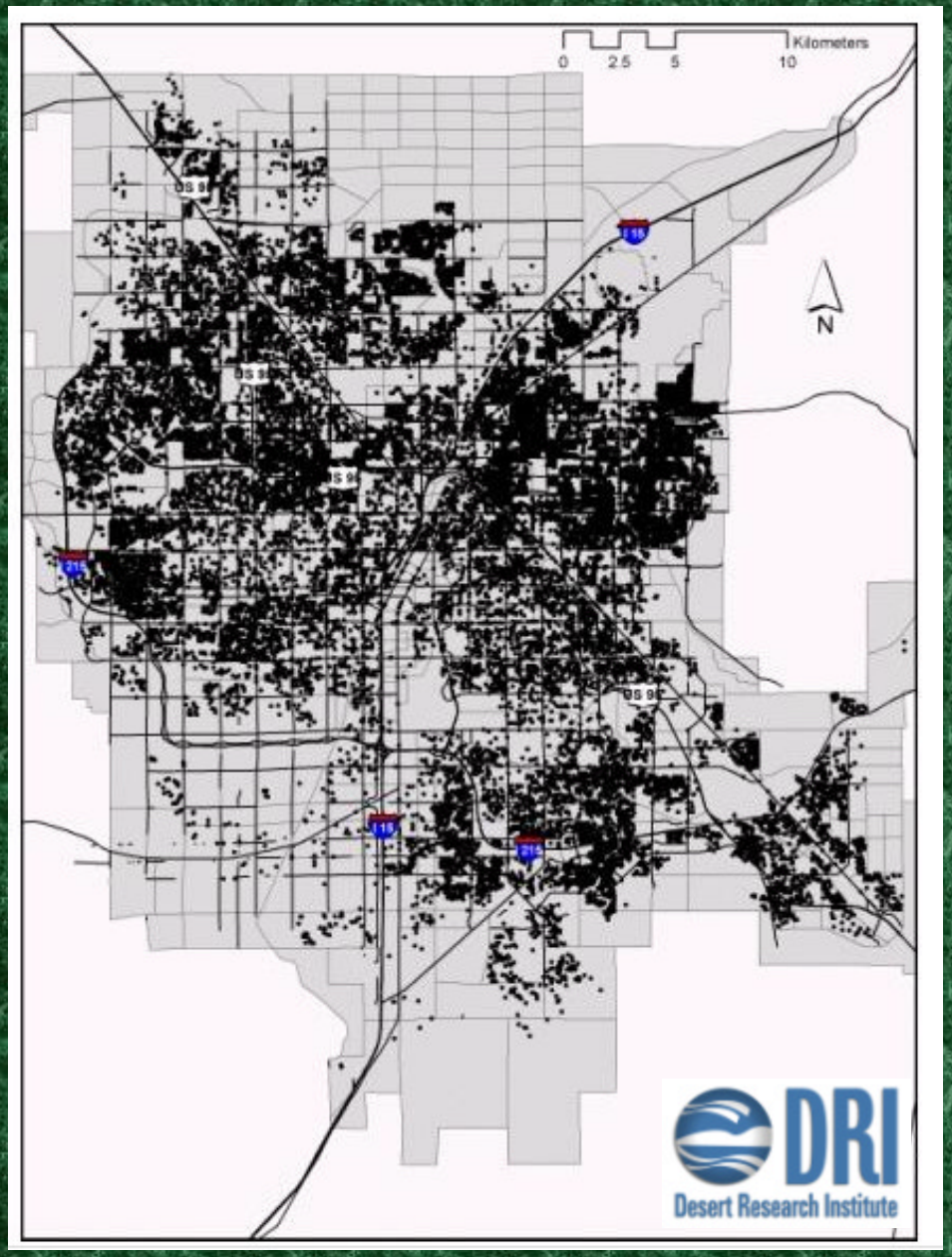
Desert Research Institute

Current PM Remote Sensor Limitations:

- Data acquisition system too slow to fully take advantage of the signal available.
- No overlap between CO_2 and PM beams.
- Absence of built-in CO, HC and NO remote sensors.

Las Vegas Experiment

Black dots: location of registered ownership for remotely sensed light duty gasoline vehicles in Clark County (2000-2002).



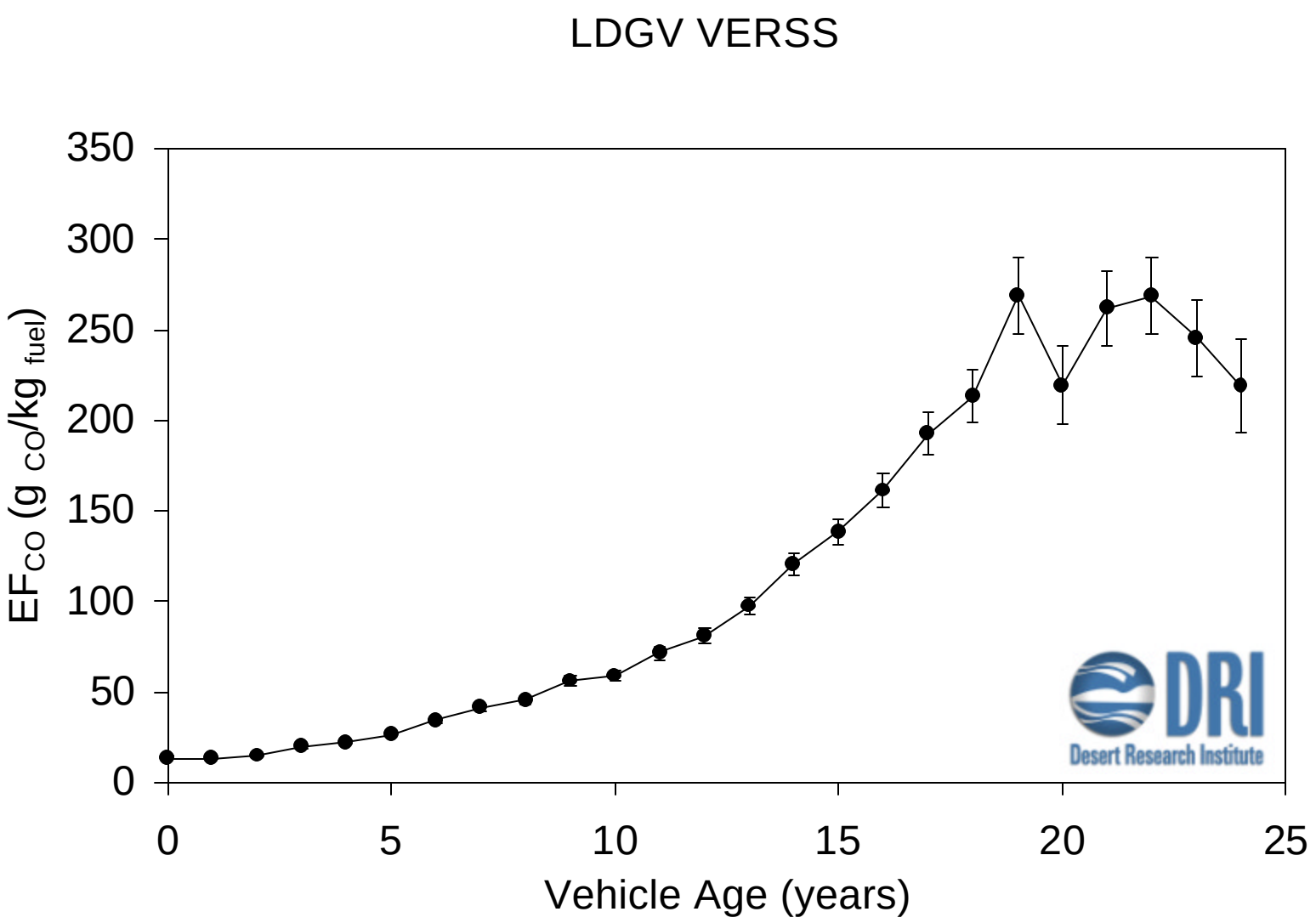
Number of Measured Vehicles in Las Vegas, NV

	Number of Matched License Plates With Valid CO_2	**CO**	**HC**	**NO**	**PM**
2000	22152	22130	21831	21155	Not measured
2001	10188	10030	9914	9660	6047
2002	9561	9409	9249	8716	8768
Detection limits in $g_{Pollutant}/Kg_{Fuel}$		5	1	1	0.3

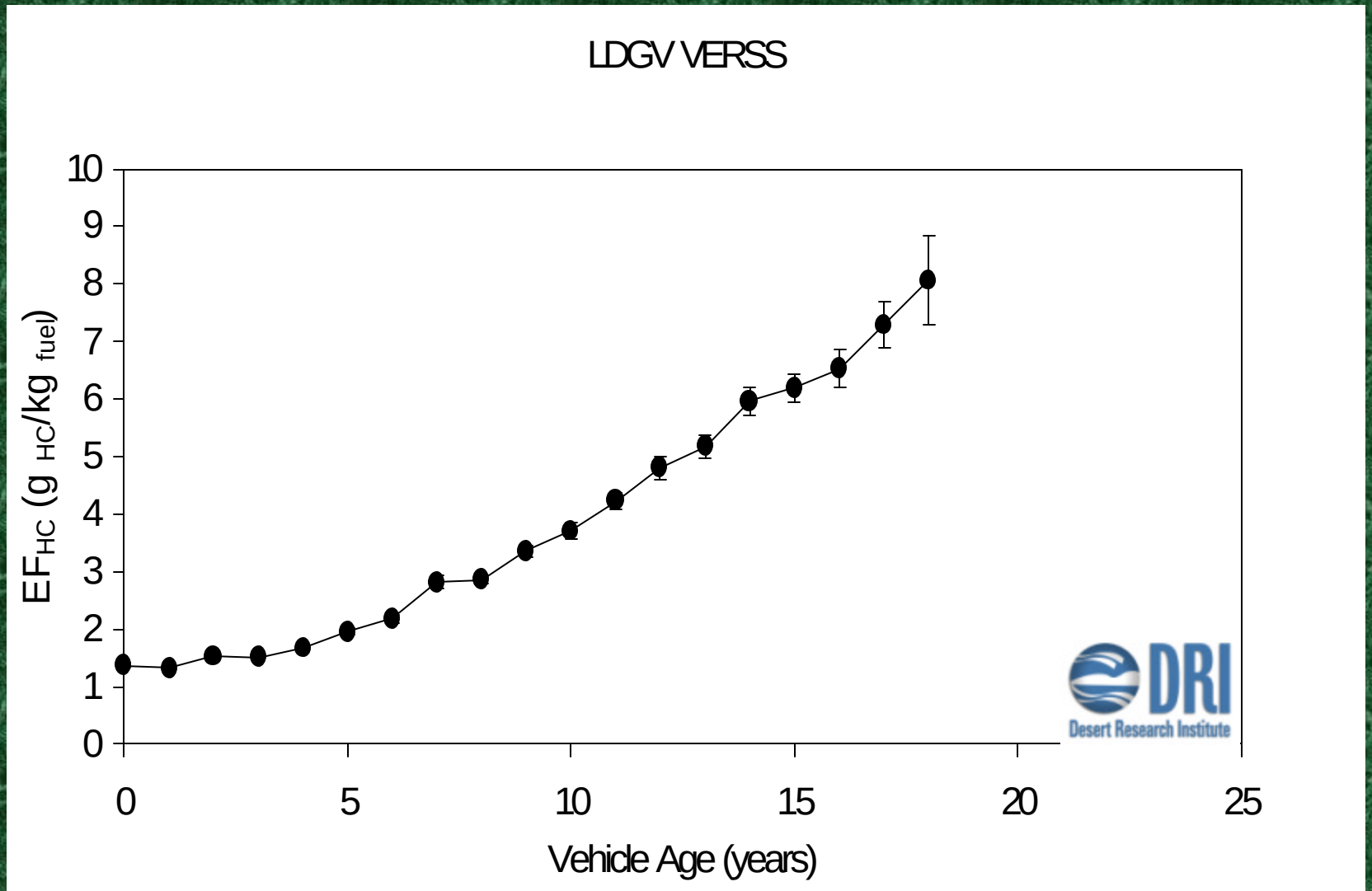
Fleet Average Emissions

Vehicle Type	CO (g_{CO}/Kg_{Fuel})	HC (g_{HC}/Kg_{Fuel})	NO (g_{NO}/Kg_{Fuel})	PM (g_{PM}/Kg_{Fuel})
LDGV	49	2.8	8.8	0.06
LDDV	19	2.3	15.2	1.6
HDGV	56	2.6	10.3	0.05
HDDV	10	1.6	19.9	1.5

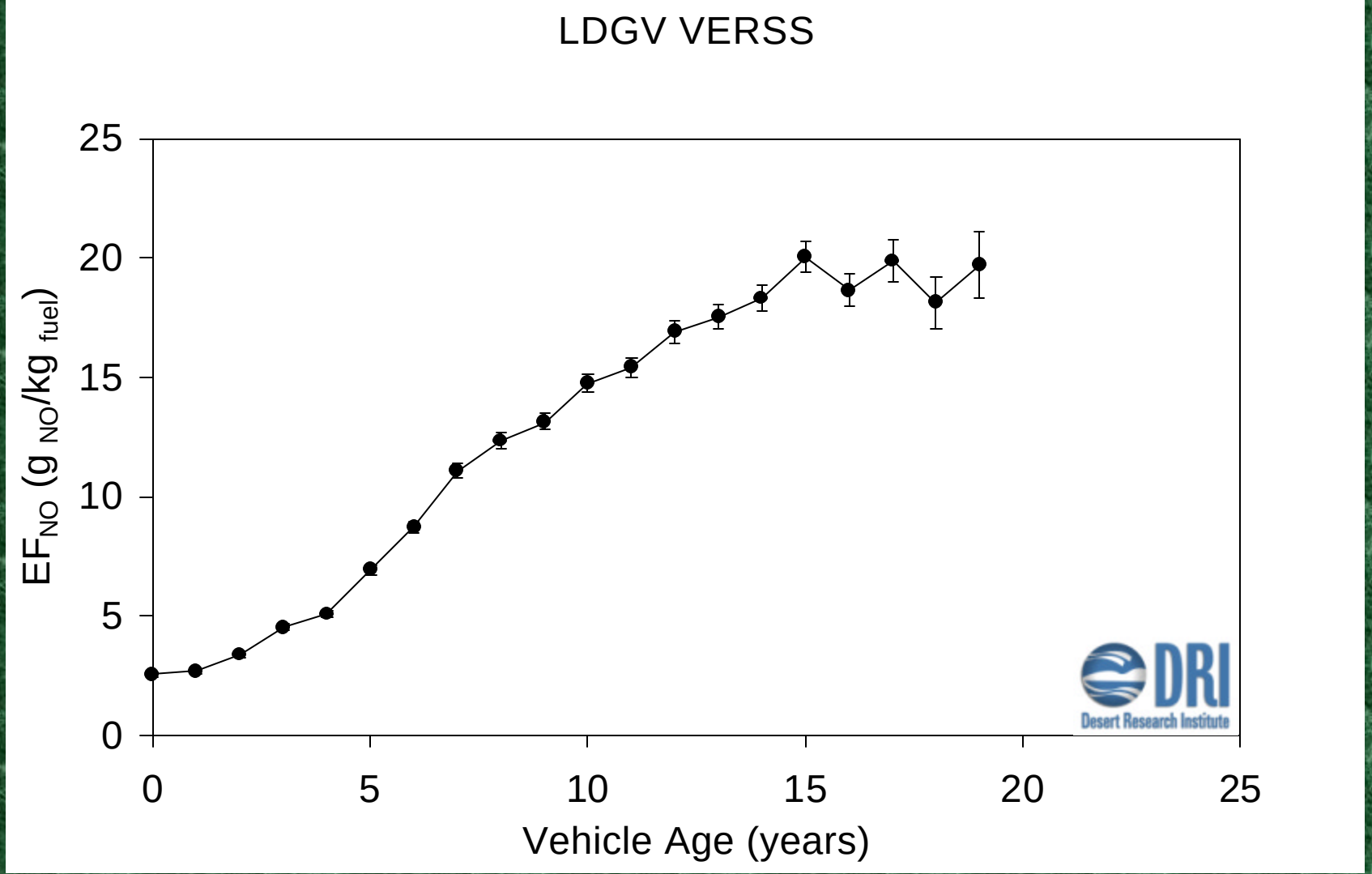
CO Emission with Age



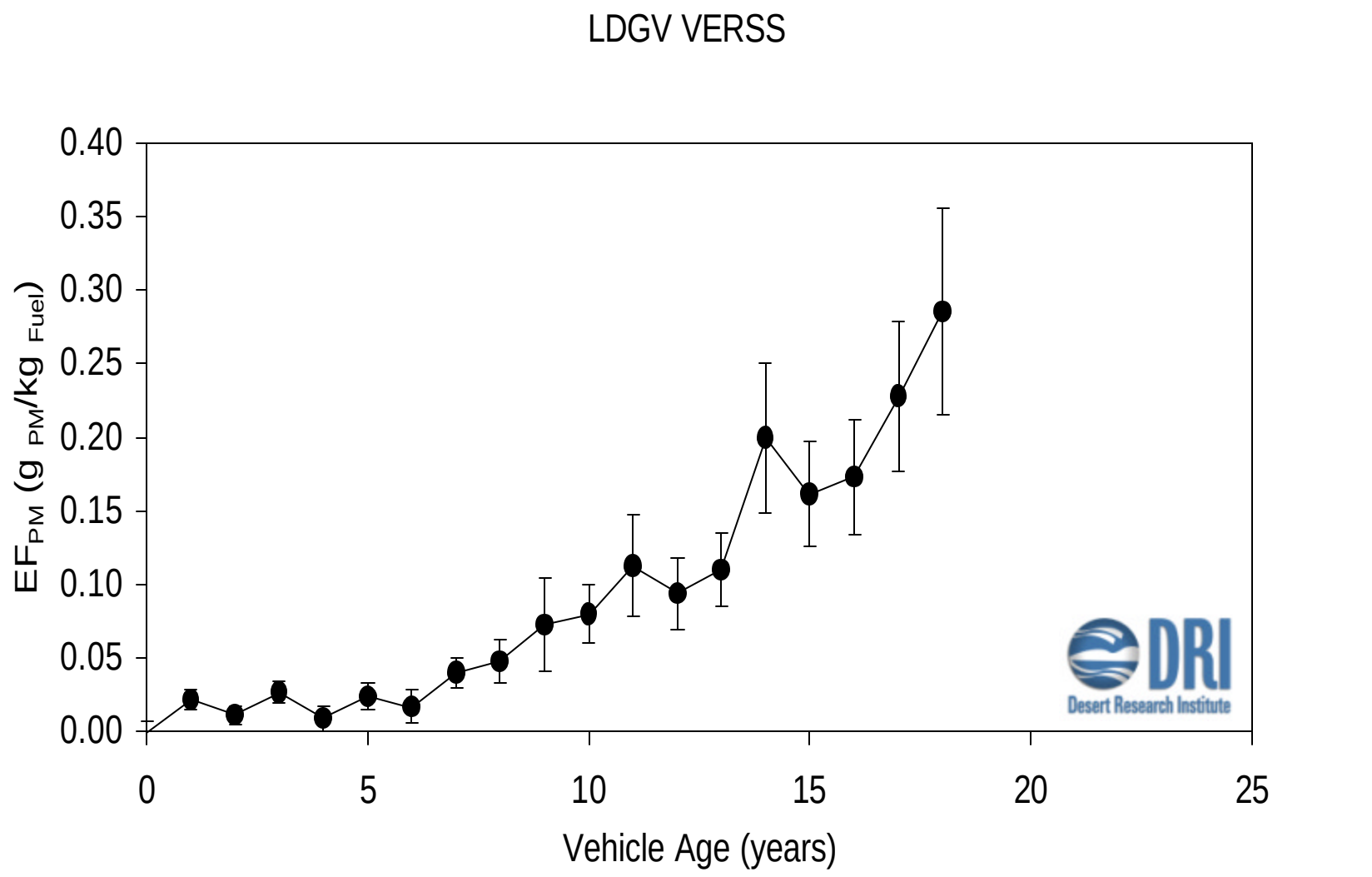
HC Emission with Age



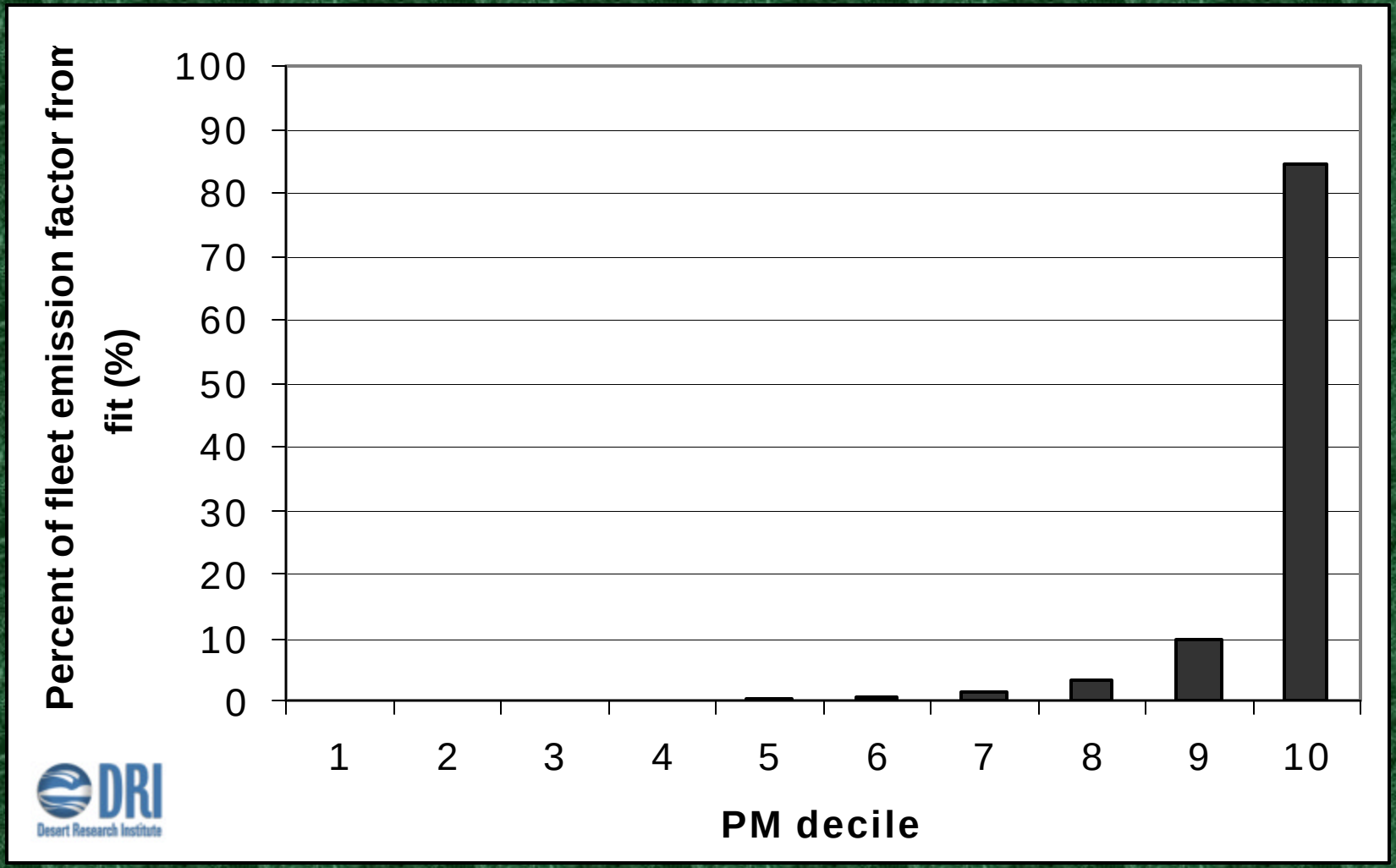
NO Emission with Age



PM Emission with Age



Deciles Plot of Fitted Fleet Emission Distribution



DRI
Desert Research Institute

Distributions Summary

Measure type	Distributions: Noise Emission	Contribution to fleet emission factor by highest 10% of emitters From fit
UV Backscattering PM	DE W	> 82 %
UV Transmission PM	DE W	> 85 %
CO	DE G	75 %
HC	DE W	49 %
NO	DE G	47 %

Overlap Between Different Pollutants

	Number Of Vehicles	Fraction Of Measured Fleet
Total number of vehicles	15237	
No high emitters in any category	11024	**72.35%**
High emitters in one category		**Total: 18.20 %**
CO	618	4.06%
HC	365	2.40%
NO	899	5.90%
PM	891	5.85%
High emitters in two categories		**Total: 6.83 %**
CO & HC	474	3.11%
CO & NO	53	0.35%
CO & PM	67	0.44%
HC & NO	210	1.38%
HC & PM	84	0.55%
NO & PM	151	0.99%
High emitters in three categories		**Total: 2.36 %**
CO & HC & NO	70	0.46%
CO & HC & PM	190	1.25%
CO & NO & PM	10	0.07%
HC & NO & PM	89	0.58%
Highest emitters in all four categories	42	**0.28 %**

DRI
Desert Research Institute

Future Improvements

- Increase signal to noise ratio
  - Higher acquisition rate
  - Larger collection system
  - Increased detector sensitivity
  - Increased laser power
- Built-in gaseous detection and improved collinearity
- On-road comparison with other measurement techniques

DRI
Desert Research Institute

Conclusions

- PM remote sensor was used to determine on-road fleet average PM emissions.
- PM emissions increase with vehicle age.
- PM emission distribution is highly skewed with more than 80% of the total PM fleet emission factor due to only 10% of highest emitters.
- Low overlap was found between highest emitters groups for different pollutants.
- Current PM LIDAR system has limited sensitivity for individual low emitters, but can detect individual gross PM polluters.
- Software and hardware redesign is in progress and will greatly increase the signal to noise ratio.

References

- Barber, P. W.; Moosmüller, H.; Keislar, R. E.; Kuhns, H. D.; Mazzoleni, C.; Watson, J. G.; **On-Road Measurement of Automotive Particle Emissions by Ultraviolet Lidar and Transmissometer: Theory**, *Applied Optics*, submitted for publication.
- Moosmüller, H.; Mazzoleni, C.; Keislar, R. E.; Barber, P. W.; Kuhns, H. D.; Watson, J. G.; **On-Road Measurement of Automotive Particle Emissions by Ultraviolet Lidar and Transmissometer: Instrument**, *Environ. Sci. Technol.*, accepted for publication.
- Kuhns, H. D.; Mazzoleni, C.; Moosmüller, H.; Nikolic, D.; Barber, P. W.; Keislar, R. E.; Li, Z.; Etyemezian, V.; Watson, J. G.; **Remote sensing of PM, NO, CO, and HC emission factors for on-road gasoline and diesel engine vehicles in Las Vegas, NV**, *Science of the Total Environment*, accepted for publication.
- Mazzoleni C., Kuhns H. D., Moosmüller H., Keislar R. E., Barber P. W., Robinson N. F., Nikolic D., and Watson J. G.; **On-Road Vehicle Particulate Matter and Gaseous Emission Distributions in Las Vegas, NV and Comparison with other Areas**, *J. Air and Waste Manag. Assoc.*, submitted for publication.
- Mazzoleni C., Moosmüller H., Nussbaum N., Kuhns H. D., Keislar R. E., Barber P. W., Hilto S., and Watson J. G.; **Effectiveness of Inspection and Maintenance Programs for Estimating Real World Emission**. *J. Air and Waste Manag. Assoc.*, submitted for publication.