

The Weekend Ozone Effect – The Weekly Ambient Emissions Control Experiment

Douglas R. Lawson
National Renewable Energy Laboratory
doug_lawson@nrel.gov

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- California Air Resources Board
- Caltrans
- Desert Research Institute
- Envair
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- South Coast Air Quality Management District
- Wiltech

The Problem

Ambient ozone levels are as high or higher on weekends than on weekdays in many urban U.S. locations, despite much lower emissions of the ozone precursors (hydrocarbons, carbon monoxide, and nitrogen oxides)

Why?

Ambient Observations

- Of 78 southern California monitoring sites in five air basins, 28 had statistically significant **higher** Sunday O₃ levels, while 49 of the remaining 50 sites showed **no significant WD/WE differences**.
- Average Sunday NO_x and VOC concentrations at all monitoring sites were 25-41% and 16-30% **lower** than on weekdays, respectively.

Policy Question

- These large WE emission reductions allow decision-makers to ask “What if” questions regarding how emission reductions influence ambient ozone concentrations.

Policy Questions

- Which is the most effective and least costly means of reducing ambient ozone in urban locations – NO_x controls, VOC controls, or both?
- When highest average ozone levels fall on weekends, how do you design an effective strategy to reduce ambient ozone levels?

OVERVIEW

- Study Design
- Hypotheses tested in study
- Study Activities
- Conclusions

Overall Study Approach/Design

- Meet with government/industry groups throughout study period to share information (<http://www.arb.ca.gov/aqd/weekendeffect/weekendeffect.htm>)
- Retrospective Analysis of Ambient Data
- Formulation of Study Hypotheses
- Emission Inventory Development
- Field Study
- Data Analysis
- Air Quality Simulation Modeling
- Publish Results in Peer-Reviewed Literature

Peer-Reviewed Publications

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Selected Papers on Weekday and Weekend Ozone Differences in Southern California

772 **Weekday/Weekend Ozone Differences: What Can We Learn from Them?**
 J.P. Miller and D.P. Kahlman, San Bernardino Air Quality Research Center, and C.T. Webb, Central Motor Club

780 **Day-of-Week Behavior of Stagnation Events in Three U.S. Cities**
 R.A. Piel and C. Seigneur, Atmospheric and Environmental Research, Inc., and R. White, Washington University

802 **Evolution of the Magnitude and Spatial Extent of the Weekend Ozone Effect in California's South Coast Air Basin, 1981-2000**
 C.M. Taylor, W.W. Steiner, D.E. Cayan, and R.E. Orville, Desert Research Institute, and D.R. Lawson, National Renewable Energy Laboratory

816 **Differences between Weekday and Weekend Air Pollutant Levels in Southern California**
 D.L. Weiland and L.J. Seaman, *ibid.*

828 **Weekday versus Weekend Activity Patterns for Ozone Precursor Emissions in California's South Coast Air Basin**
 L.F. Collins, D.L. Cox, T.M. Cook, H.H. Hsieh, P.T. Roberts, and P.A. Spier, Science Technology, Inc., and D.R. Cooper, National Renewable Energy Laboratory

844 **Diurnal and Weekday Variations in the Source Contributions of Ozone Precursors in California's South Coast Air Basin**
 F.W. Poth, D.E. Cayan, D. Collins, J.C. Seaman, L.L. Jones, W.G. Jaffe, and R.E. Orville, Desert Research Institute, and D.R. Lawson, National Renewable Energy Laboratory

856 **Modeling Weekday/Weekend Ozone Differences in the Los Angeles Basin for 1987**
 S. Gherini and J.P. Seaman, Atmospheric Research, Inc., and A.M. Dunker, Science Technology, Inc., and D.R. Cooper, National Renewable Energy Laboratory

876 **Day-of-Week Patterns of Particulate Matter and Its Chemical Components at Selected Sites in California**
 W. Menden, B. Tan, S.C. Owen, and C. Ussell, California Air Resources Board

878 **Day-of-Week Patterns in Toxic Air Contaminants in Southern California**
 W. Menden, California Air Resources Board

897 **Selective Leaching of Soluble Metals from Waste Printed Circuit Boards**
 C.C. Chaudhry, D. Gao, R. Ghosh, and S. Ghosh, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia

905 **Technological Evolution for the Hazard Assessment of Tire Crumb for Use in Public Playgrounds**
 D.A. Bivins, DuPont Performance Polymers, K.L. Miller, Atlanta Office of Superfund and Research and T.L. Gault, University of Idaho

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What's Behind the "Weekend Ozone Effect" in Southern California?

Hypotheses Addressed by Study

Hypotheses	Importance for Ozone Production	Confidence Level
1. NOx emissions reduction		
2. NOx emissions timing (NOx “boost”)		
3. Pollutant carryover near the ground		
4. Pollutant carryover from aloft		
5. Increased weekend VOC emissions		
6. Increased photolysis due to decreased PM		

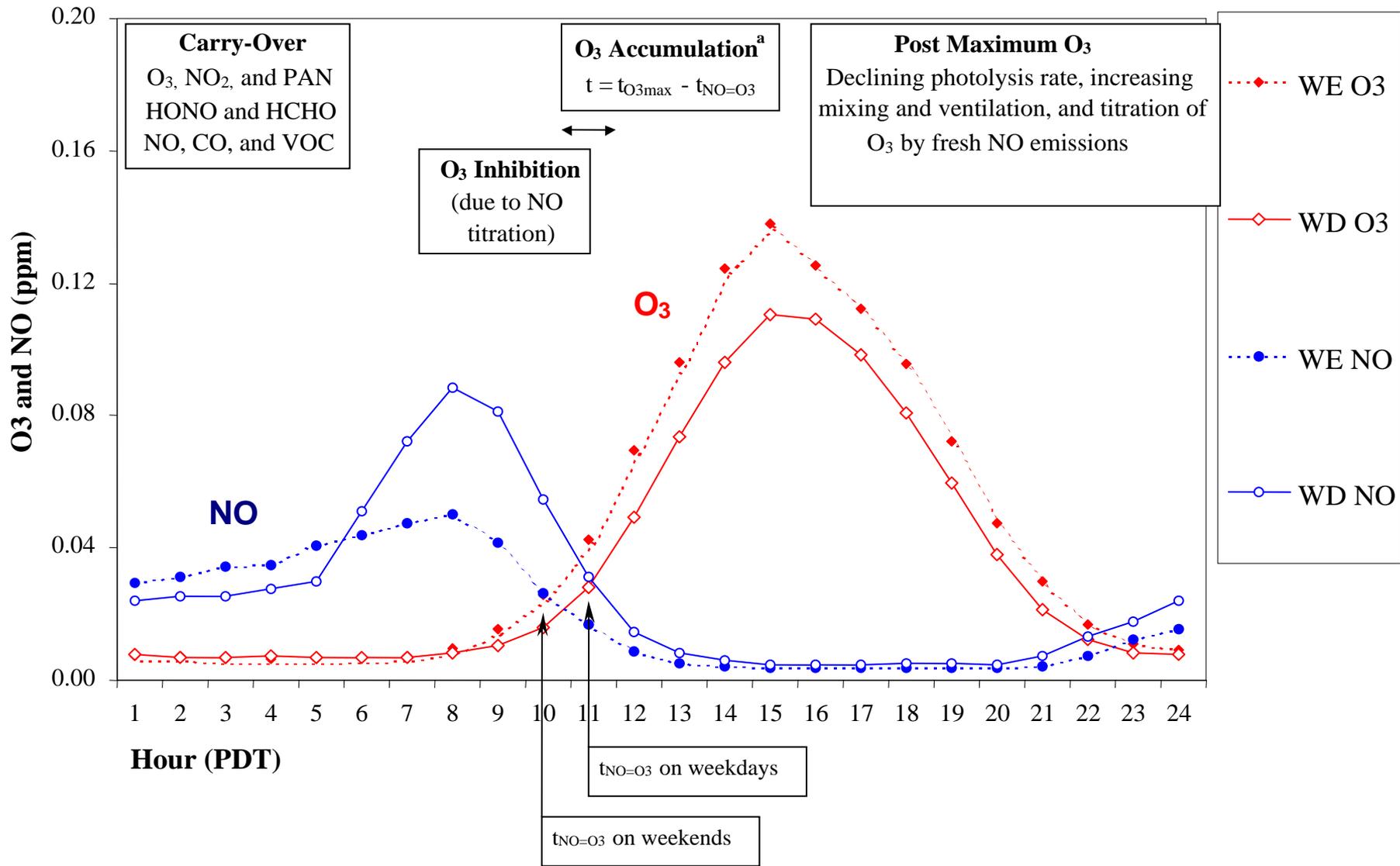
SUMMARY:

Weekday/Weekend Emission Inventory Differences

- Truck and bus freeway activity decreased by up to 80% on weekends
- 12-18% reduction in VOC emissions on Saturday and Sunday relative to weekdays
- 35-41% reduction in NO_x emissions on Saturday and Sunday relative to weekdays
- 30% increase in VOC/NO_x ratio on weekends relative to weekdays

Data Analyses

Azusa, Summer 1995



Mean Wednesday
 ± 1 sigma

Mean Sunday
 ± 1 sigma

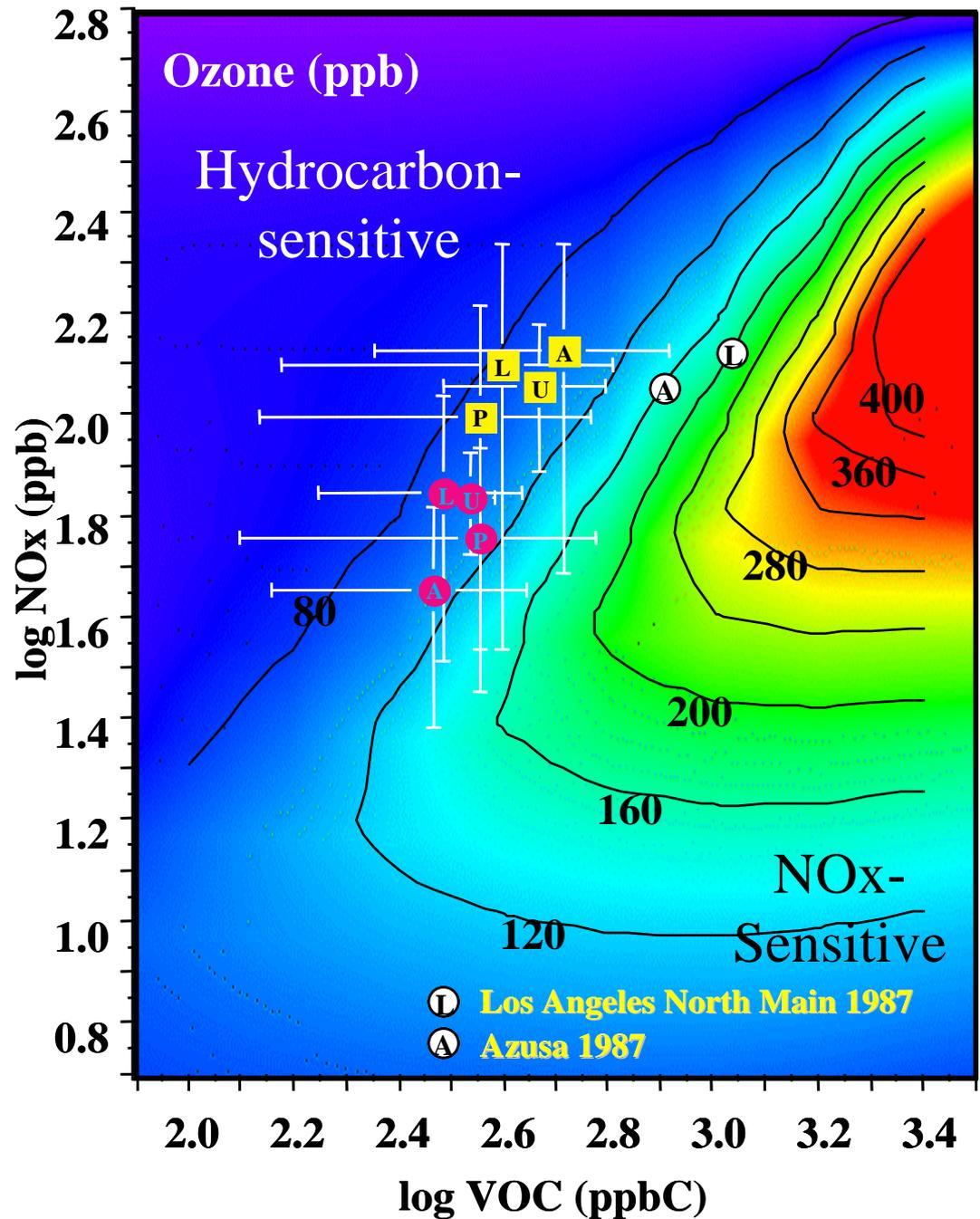
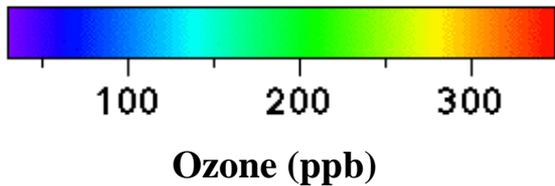
Monitoring Stations

A – Azusa

L – Los Angeles, N. Main

P – Pico Rivera

U – Upland



STUDY CONCLUSIONS

RESULTS OF HYPOTHESIS TESTING BY STUDY INVESTIGATORS

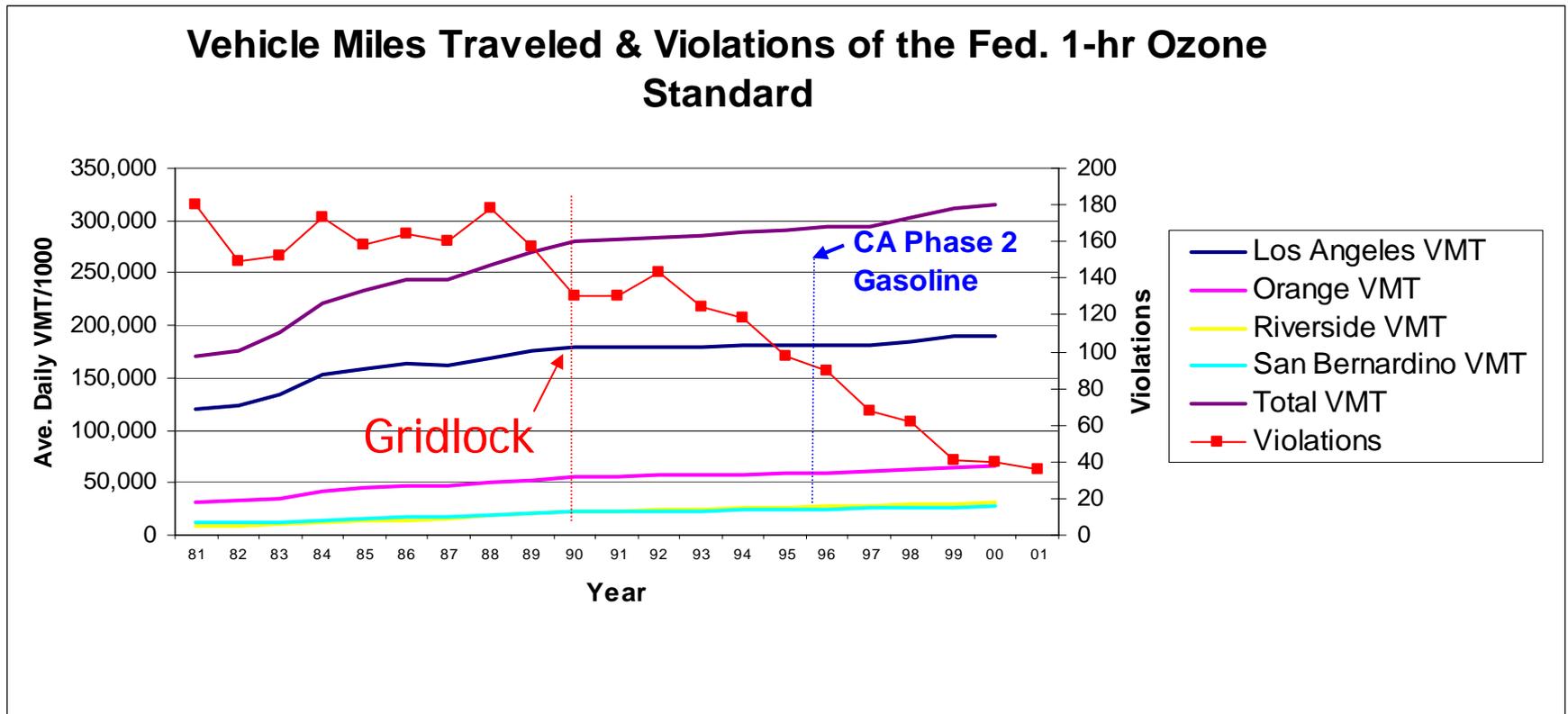
Hypotheses/Supported by Study	Importance for Ozone Formation	Confidence Level
1. NOx emissions reduction – YES	Significant	High
2. NOx timing (NOx “boost”) – NO	Insignificant	High
3. Pollutant carryover near the ground – YES	Small	High
4. Pollutant carryover from aloft – NO	Insignificant	Medium
5. Increased weekend VOC emissions – NO	Small to Insignificant	Medium
6. Increased photolysis due to decreased PM – NO	Small to Insignificant	Medium

Supported by Study Results = **Yes**

Not Supported by Study Results = **No**

OZONE TRENDS IN THE SOUTH COAST AIR BASIN

“Forecasting is difficult, especially when it involves the future.” – Casey Stengel



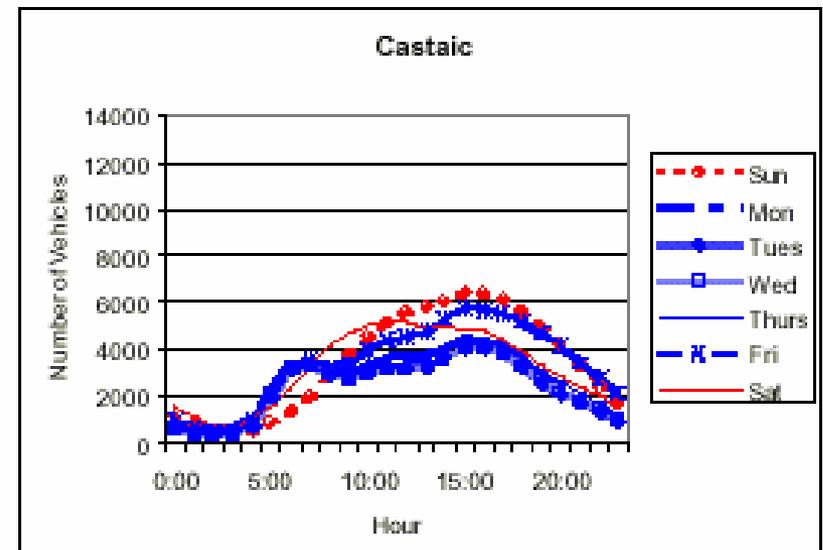
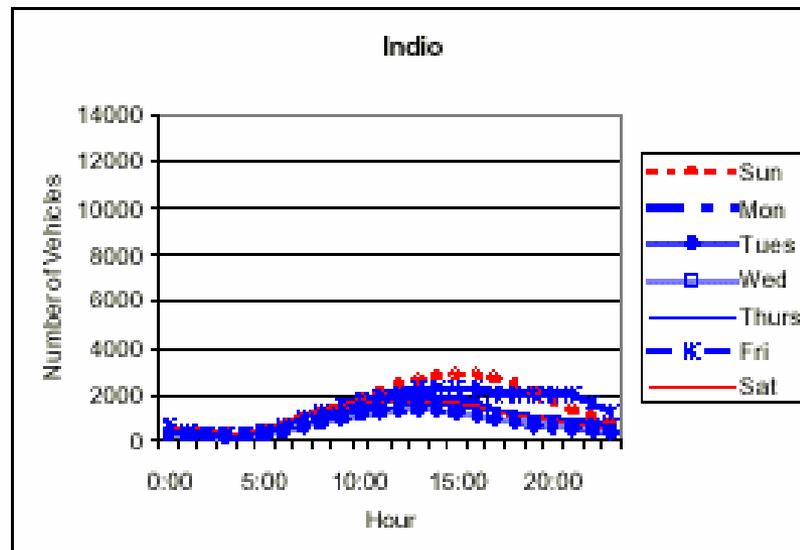
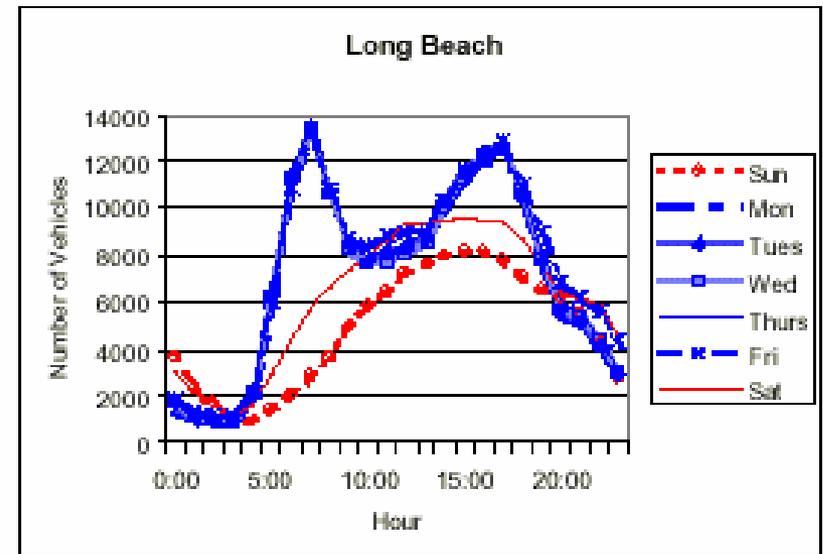
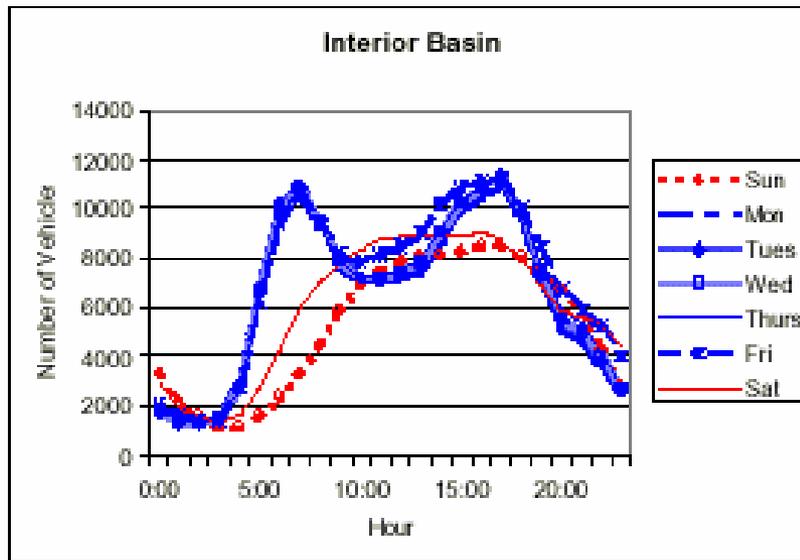
Observations

- Atmospheric scientists/policy makers can seldom conduct controlled experiments of the kind that are needed to address policy-relevant issues.
- Emission changes that occur every Saturday and Sunday, relative to weekdays, allow us to ask how those changes influence ambient pollutant concentrations.
- This study's data are of such high quality that we are able to observe and quantify differences in emissions and ambient levels of ozone and its precursors, even between Saturdays and Sundays, relative to weekdays.

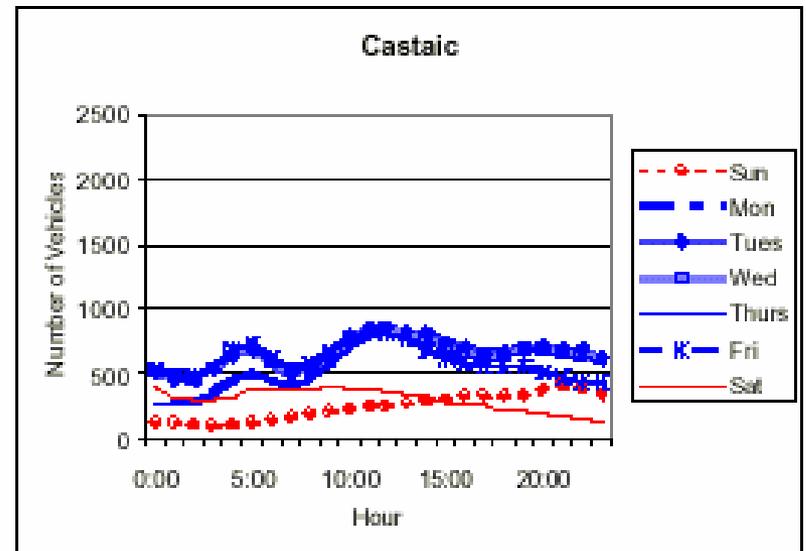
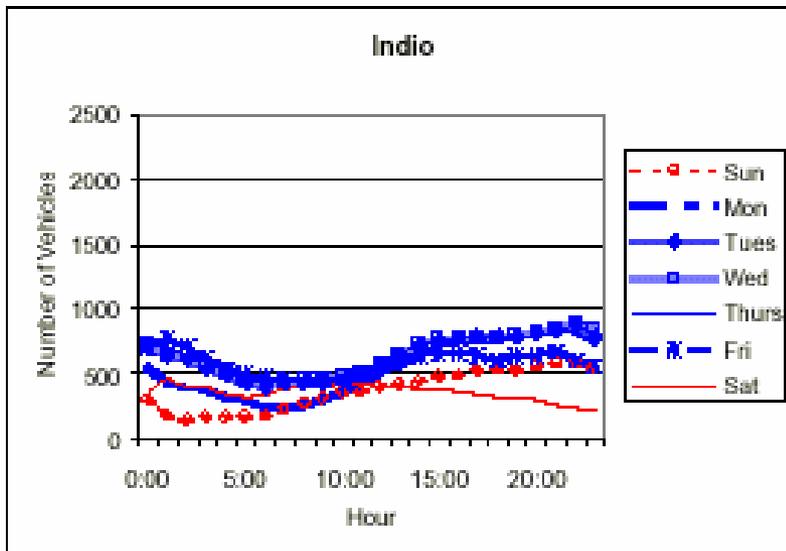
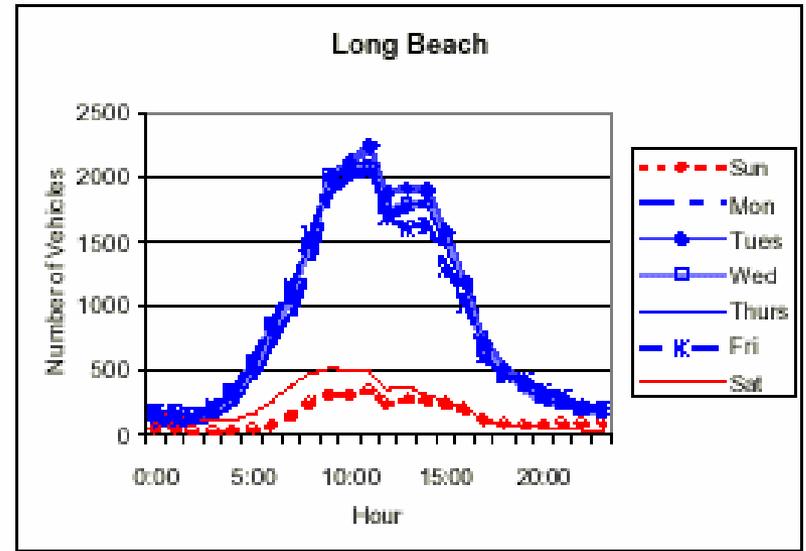
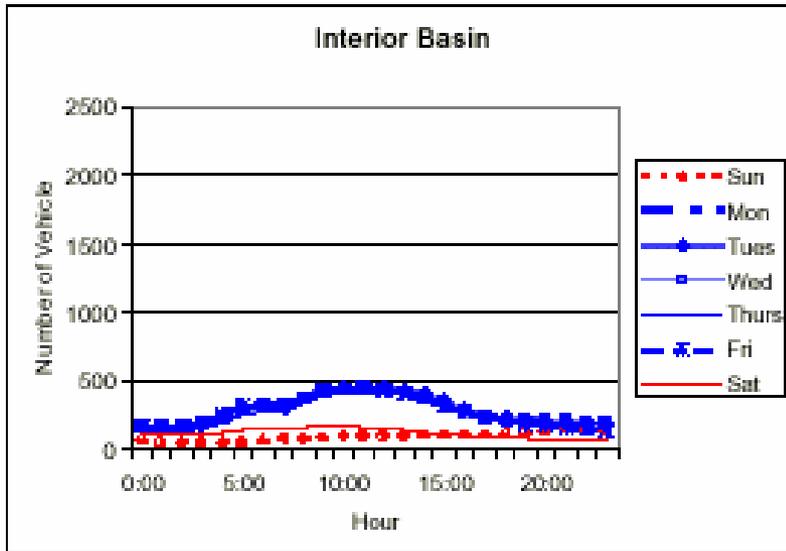
Conclusions

- NO_x reductions in Southern California (and other urban U.S. locations) increase ambient ozone levels.
- Ozone reductions in the SoCAB since 1987 are mostly due to VOC, and not NO_x, emission reductions.
- At current VOC levels, total NO_x emission reductions as large as 80-90% will be needed before the NO_x disbenefit can be overcome.
- Emission projections for 2010 suggest that ambient weekday ozone levels in the SoCAB may be as high as today's weekend ozone levels.
- If effective VOC controls can be put in place (repairing/eliminating high VOC-emitting vehicles), the amount of ozone in source regions would be reduced and the issue of ozone downwind of the source areas might be moot if the national ambient standards for ozone are met downwind.

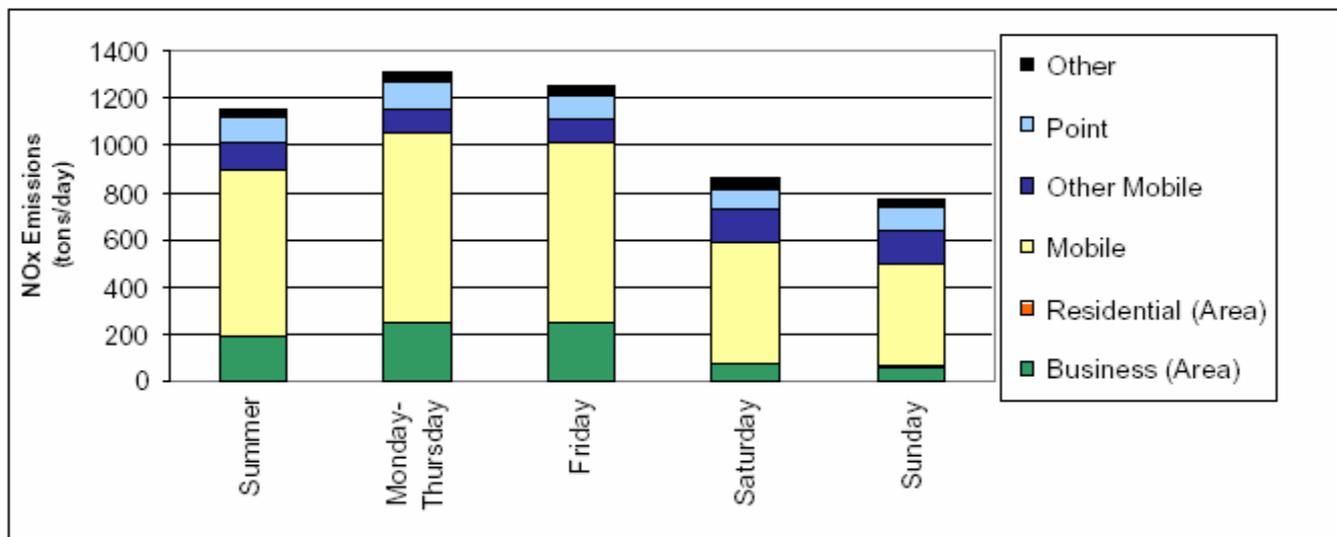
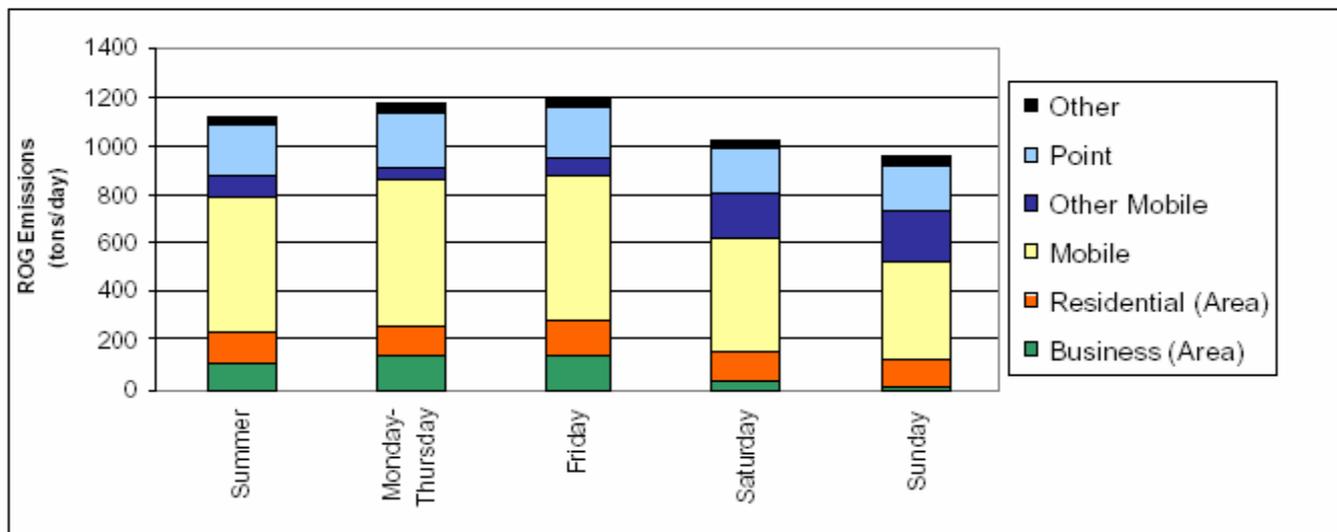
Average LD Volumes at Freeway WIM Sites



Average HD Volumes at Freeway WIM Sites



Estimated Day-of-Week Emission Inventory After Applying Emission Activity Scaling Factors



Ambient Measurements – Field Study

- Field study conducted Saturday, September 30 through Sunday, October 8, 2000
- Unique because this was an emissions-based study
- Ambient measurements made at routine AQMD and other fixed monitoring sites
- Mobile measurements made by sampling van at a variety of source locations and on various freeway loops

Sampling Locations During Field Study, September 30-October 8, 2000



Weekday/Weekend O₃ Study – Gasoline Source Profile Testing – 0647 hrs on Oct. 2, 2000

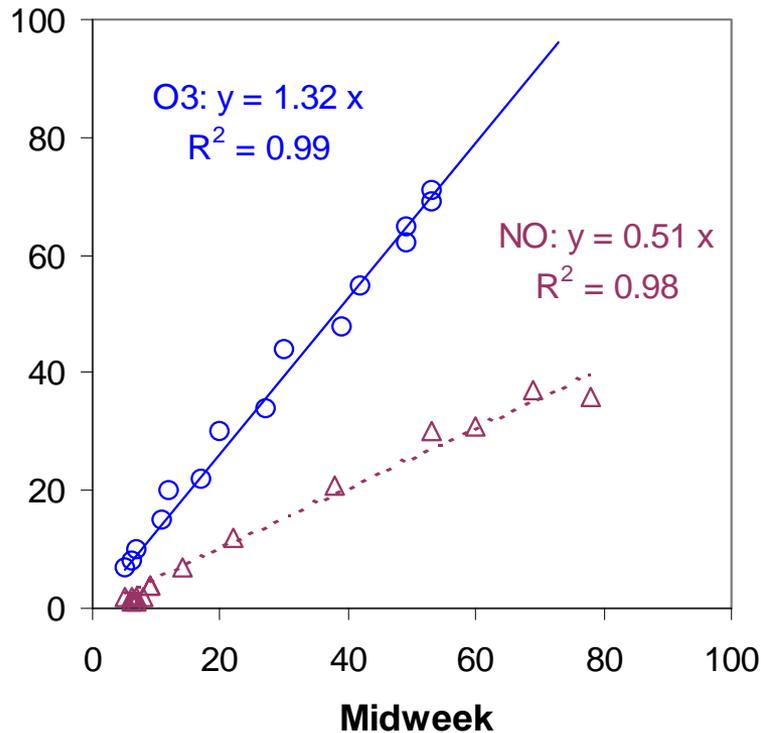


Weekday/Weekend O₃ Study – Diesel Source Profile Testing – 0222 hrs on Oct. 3, 2000

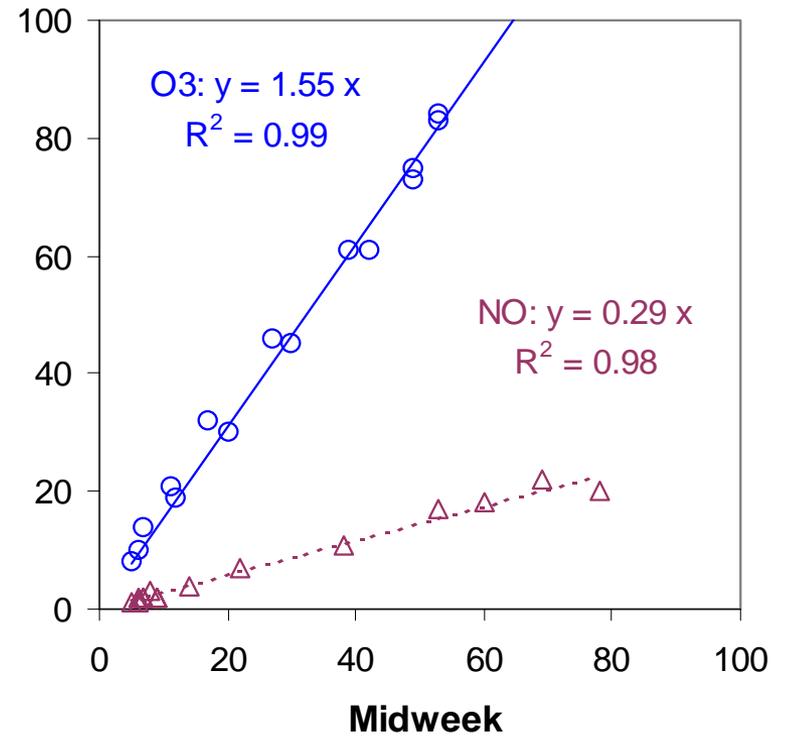


Correlations of Saturday and Sunday Versus Midweek* Hourly Daytime (0600 to 2000, PDT) O₃ and NO at Azusa, 1999-2000

Saturday



Sunday



* Tuesday to Thursday

Weekday Correlations of Hourly O₃ and NO

Location	Daylight (0600-2000)			
	Ozone		Nitric Oxide	
	Slope	R ²	Slope	R ²
<u>Friday/Midweek</u> ¹				
Los Angeles N. Main	0.98	1.00	0.89	0.99
Pico Rivera	0.96	1.00	0.86	0.98
Azusa	0.98	0.99	0.94	0.96
Upland	1.02	1.00	1.03	0.99
<u>Saturday/Midweek</u>				
Los Angeles N. Main	1.29	0.98	0.61	0.99
Pico Rivera	1.27	1.00	0.69	0.99
Azusa	1.31	0.99	0.51	0.98
Upland	1.26	0.99	0.62	0.99
<u>Sunday/Midweek</u>				
Los Angeles N. Main	1.49	0.96	0.43	0.97
Pico Rivera	1.50	0.98	0.39	0.99
Azusa	1.55	0.99	0.29	0.98
Upland	1.44	0.97	0.29	0.91
<u>Means</u>				
Friday/Midweek	0.99	1.00	0.93	0.98
Saturday/Midweek	1.28	0.99	0.61	0.99
Sunday/Midweek	1.50	0.98	0.35	0.96

¹ mean of Tuesday, Wednesday, and Thursday values