Use of California Remote Sensing Pilot Project data for on-road fleet and emissions characterization, and evaluation of the Enhanced Smog Check program

Final Report to California Bureau of Automotive Repair
and Air Resources Board

by
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Executive Summary

This report demonstrates how a large number of remote sensing records can be used to characterize the on-road fleet by vehicle characteristics and driving behavior, and to estimate emission reductions from the Smog Check program. Of the over 2 million raw remote sensing measurements provided, 580,000 valid measurements under moderate vehicle load were matched with California vehicle registration information, and used in this analysis. The majority of the useable measurements came from light- and medium-duty vehicles registered in the South Coast air basin, although substantial numbers of vehicles were also measured in the Sacramento and San Diego air basins. Smaller numbers of vehicles were measured in the San Francisco, San Joaquin, and San Luis Obispo air basins.

Average on-road HC and CO emissions by model year are higher for South Coast vehicles than vehicles operating in Sacramento and San Diego; however, San Diego vehicles have higher NOx emissions than South Coast vehicles. The conditions under which the vehicles were operating at the time of measurement (based on calculated vehicle specific power, or VSP) were similar for four of the five air basins; however, vehicles in the San Diego air basin had substantially higher VSP. Adjusting the emissions of the South Coast vehicles to the VSP distribution of the San Diego vehicles has little effect on their HC and CO emissions, but results in a significant increase in NOx emissions for virtually all model years, making the NOx emissions of the South Coast vehicles comparable to those of the San Diego vehicles. Vehicles measured in two basins that have similar overall VSP distributions can have VSP distributions within speed groups that are substantially different. It may be desirable to adjust emission rates to a common distribution of VSP and speed when comparing average emissions across geographical areas; however, there were not enough remote sensing measurements in this study to test what effect such an adjustment would have on average emissions by model year.

A slightly smaller percentage of cars (as opposed to light trucks) were observed on-road on weekends than on weekdays. Cars measured on weekends have the same on-road HC and CO emissions as cars measured on weekdays; however, cars measured on weekends have consistently, and statistically significant, lower on-road NOx emissions than cars measured on weekdays. Because Caltrans did not allow measurement during certain hours, we were not able to assess how vehicle activity and emissions change during commute and non-commute hours.

Most vehicles observed on road had passed their previous Enhanced Smog Check inspection. About 13% of all I/M-eligible vehicles observed on road failed the initial test in their previous Smog Check cycle; of these, 3% (0.4% of all vehicles) had not passed a retest by the time they were observed on road. We estimate that about 20% of these no-final-pass vehicles continued to be driven in Enhanced Smog Check areas one year, and 10% continued to be driven two years, after failing their previous initial Smog Check test. These estimates are comparable to similar estimates using remote sensing data in Phoenix and Denver. Vehicles that failed their initial test, and passed a retest, in their previous Smog Check cycle (fail-pass vehicles) had significantly higher on-road emissions by model year than vehicles that had passed their initial test in their previous Smog Check cycle (initial-pass vehicles). This is likely because the emissions of fail-pass vehicles deteriorated faster after their previous Smog Check cycle than the emissions of the initial-pass vehicles.

We compared the emissions of vehicles measured on road shortly before their next Smog Check inspection with those of vehicles measured shortly after their previous Smog Check, in order to estimate the effectiveness of the Enhanced Smog Check program in each air basin. There were a sufficient number of on-road measurements for this analysis only for vehicles registered in the South Coast air basin. For vehicles measured on-road within three months before or after their Smog Check, CO and NOx emissions were reduced, by about 10% for cars, and 12% (CO) to 15% (NOx) for light trucks; the differences in HC emissions were not statistically significant. For vehicles measured within one year before or after their Smog Check, light truck emissions were reduced by 12% for HC, 9% for CO and 7% for NOx, while car emissions were reduced by 7% for NOx only (reductions in car HC and CO were not statistically significant). The analysis indicates that emission reductions decrease as vehicles get further from their previous Smog Check. Emission reduction percentages tend to be larger for older model year vehicles; however, because there are fewer of these older vehicles on road, and they are driven fewer miles, this does not necessarily translate into larger absolute emission reductions.

We used the remote sensing data to make two estimates of the light-duty vehicle emissions inventory for the South Coast air basin. Both estimates use the same set of gram per gallon emission factors from the remote sensing measurements. We used two sources of vehicle activity for each estimate: the number of vehicles, average annual miles driven, and average fuel economy, by vehicle type and model, from the EMFAC model; and estimated total gasoline use statewide, from fuel tax receipts reported by the California Board of Equalization. For HC and CO, the fuel-based inventory is almost identical to that estimated using EMFAC; however, the fuel-based inventory estimates 16% more NOx emissions than when we use EMFAC assumptions regarding vehicle use and fuel economy. Our results indicate that gram per gallon emission factors, obtained from remote sensing measurements, can be used to estimate the light-duty vehicle emission inventory using fuel sales, without having to estimate the number of vehicles, annual vehicle miles driven, and vehicle fuel economy.

1. Description of data

In this section we describe the remote sensing measurements made and how individual vehicles were identified using vehicle registration data.

1.1. Vehicle data

A dataset of nearly 2.2 million remote sensing records was provided; Table 1.1 summarizes the reduction of the remote sensing data for use in this analysis. 71% of the total records were successfully merged with registration data from the California Department of Motor Vehicles (DMV), using the vehicle license plate, in order to obtain the vehicle identification number (VIN) and zip code in which the vehicle was last registered. The merging occurred throughout the data collection period, roughly 1 to 4 months after the remote sensing measurements were made; therefore the registration information for a VIN may not reflect the registration information at the time the remote sensing measurement was made.[1] Visual inspection of the video of a sample of the vehicles indicated that the majority of remote sensing records that could not be merged with registration data had obstructed license plates (by a trailer or hitch) or unreadable license plates (because of lighting or glare); an unknown number of the remote sensing records were of non-California license plates, or California license plates that were not in the DMV registration database. The last column of Table 1.1 shows the percent of the previous category; for example, 55% of vehicles with useable VSP (between 5 and 25kW/tonne) also had a previous Enhanced Smog Check record. These vehicles represent 15% of all raw measurements (55% * 58% * 65% * 71% = 15%). the table indicates that about 65% of the remote sensing measurements were flagged as valid (valid gas, speed, and acceleration results). This fraction also applies to the raw measurements, so about 1.4 million of the raw measurements were flagged as valid (not shown in Table 1.1).

Table 1.1. Reduction in remote sensing measurements for analysis

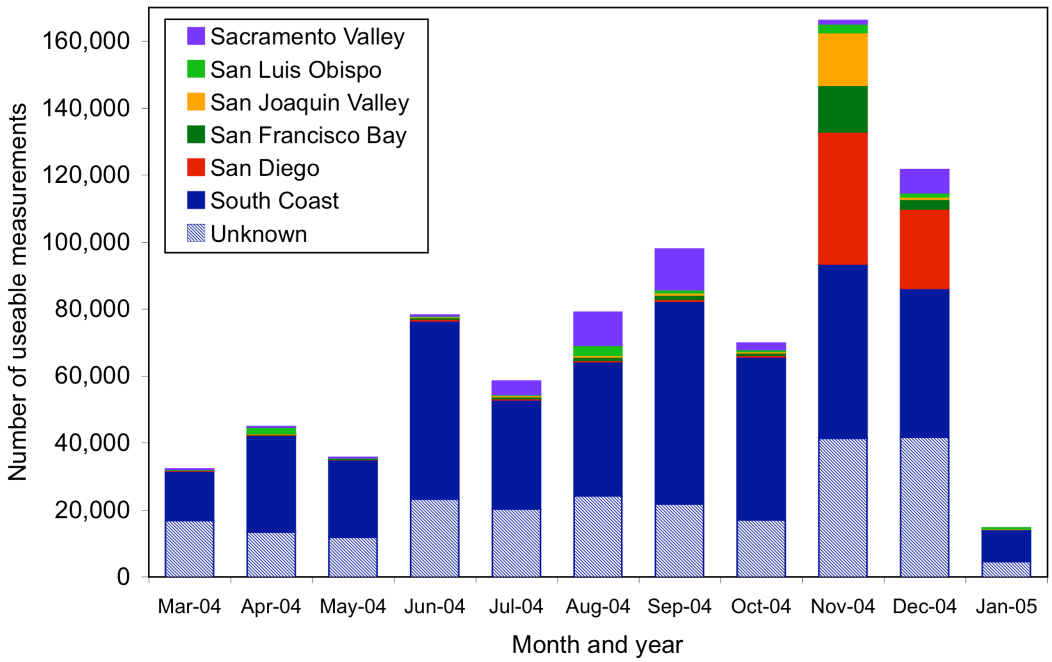
	Number	Percent of total	Percent of previous category
Raw measurements	2,196,274	100%	NA
Matched with registration data	1,562,618	71%	71%
Valid emissions measurement	1,010,794	46%	65%
VSP within 5 and 25 kW/tonne	587,973	27%	58%
With previous Enhanced Smog Check	323,662	15%	55%

We then merged the remote sensing records with a database provided by BAR that listed the zip codes in each county, air basin, and Smog Check area (Enhanced, Basic, and Change of Ownership), by the zip code at which the on-road measurement was made and in which the vehicle was registered. Figure 1.1 shows the distribution of all remote sensing records by the air

[1] In California the license plate stays with the vehicle when it is sold, so there is no problem with vehicles that were sold between the time the remote sensing measurement was made and the registration data was obtained being misidentified, as in other states where the owner keeps the license plate when he or she sells their vehicle; however, a small number of vehicle owners may purchase an environmental license plate in this time period, resulting in the license plate on the vehicle at the time of the on-road measurement not being in the DMV database.

basin in which the vehicle was registered, by the month of measurement. As mentioned above, 29% of all remote sensing records could not be matched with registration data; these are the "unknown" category in the figure. The figure shows that on-road measurement of vehicles registered in the South Coast and Sacramento air basins occurred throughout the analysis period, whereas the measurement of vehicles registered in the San Diego, San Francisco Bay, and San Joaquin Valley basins occurred mostly in November and December 2004. A small number of vehicles registered in other air basins were also measured on road.

Figure 1.1. Number of useable remote sensing measurements (valid emissions and VSP between 5 and 25 kW/tonne), by month and basin in which vehicle is registered

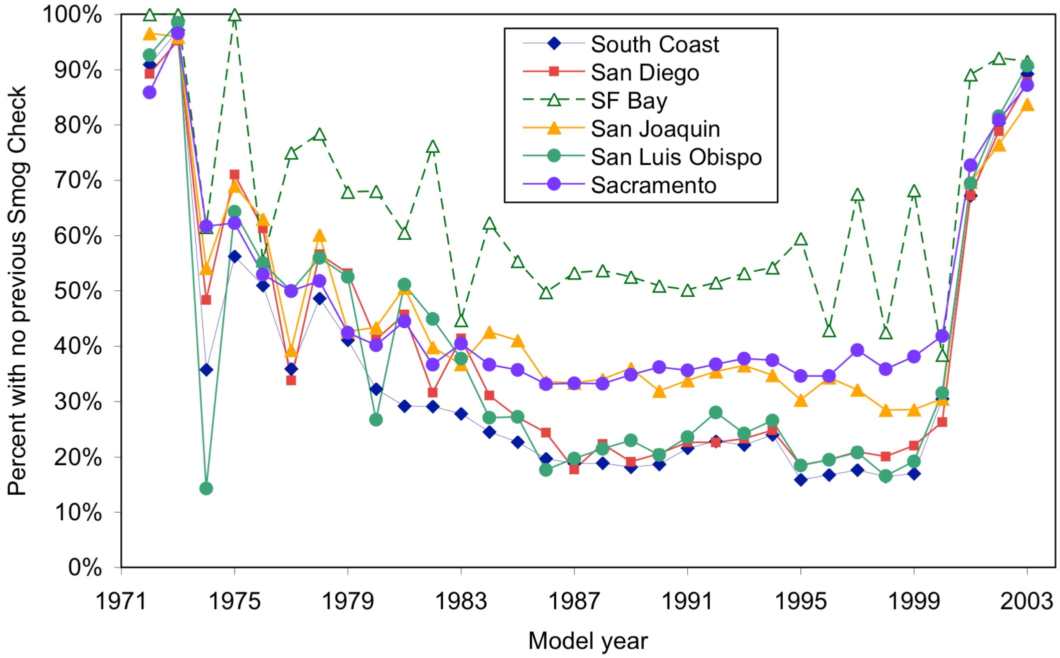


ERG merged the remote sensing records with Enhanced Smog Check records from the Vehicle Inspection Database (VID), using the VIN obtained from DMV. VID data from the start of the Enhanced program (mid-1998) through May 2005 were used. All VID records for each VIN were retained, and the Enhanced Smog Check history was determined for each vehicle; i.e., whether the VID record was an initial test or a retest, the reason for inspection (including official pretests), and the result of the inspection cycle (e.g., initial-pass, fail-pass, fail-no-final-pass, etc.). The VID record previous to each on-road measurement was retained, and the number of days between the previous VID record and the on-road measurement was determined. The resulting database includes one record for each remote sensing measurement, including the date, time, result, and sequence of the previous Enhanced Smog Check test.

About 60% of the on-road measurements with a VIN could not be matched to an Enhanced Smog Check record. This is in part because newer model years are exempted from the Smog Check program; 80% of exempted model years (in 2004, 1975 and older, and 2001 and newer) had no matching Enhanced Smog Check record, while only 24% of non-exempted model years (in 2004, 1976 to 2000) had no matching VID record. The exempted model years had a VID record because they were required to get an inspection prior to either a change in ownership or initial registration in California. Non-exempted model years may not have had a VID record either because: they could not be tested on the Enhanced Smog Check dynamometer (four-wheel drive or diesel vehicles); are registered in a Smog Check area that previously was a Basic area (San Francisco Bay area) and had not yet been subject to an Enhanced Smog Check inspection; or recently were re-registered from the San Francisco Bay area or a Basic or Change of Ownership Smog Check area. Figure 1.2 shows the fraction of vehicles measured on road that had no Enhanced Smog Check record in the VID prior to measurement, by the basin in which they were registered. Note that slightly more than half of the non-exempt vehicles in the San Francisco Bay area had no previous Enhanced Smog Check record; this is likely because at the time of remote sensing measurement in that basin, November 2004, only about half of the fleet had been subjected to the Enhanced Smog Check. About 20% of the non-exempt vehicles in the South Coast and San Diego basins did not have a previous Enhanced Smog Check record, either because they could not be tested on the dynamometer used for the Enhanced test (and received a Basic two-speed idle test instead), or had re-registered from a Basic or Change of Ownership Smog Check area in the state. Nearly 40% of the non-exempt vehicles in the San Joaquin and Sacramento basins did not have a previous Enhanced Smog Check record; we suspect that many of these vehicles recently re-registered in these basins from Basic or Change of Ownership Smog Check areas, or the San Francisco Bay basin, which converted from a Basic area to an Enhanced area in October 2003.

We decoded vehicle VINs to determine which vehicles measured on road had four-wheel drive trains that prevented them from being tested on the ASM dynamometer, and would explain why there was no record of an Enhanced Smog Check. These vehicles are required to receive a Basic Smog Check, including a two-speed idle test; however, we did not have access to the Basic Smog Check test results. We found that essentially no cars, and 8% of all light-duty trucks (12% of all SUVs, 2% of all pickups, and 16% of all vans), were identified as having four-wheel drive trains. However, 60% of the light-duty trucks identified as having four-wheel drive had an Enhanced Smog Check test record, compared with 75% of light-duty trucks (and 80% of cars) suspected of having two-wheel drive. A previous analysis found that about 10% of all light-duty vehicles in the South Coast basin received a Basic Smog Check, because they were either four-wheel drive or diesel vehicles that could not be tested on the Enhanced Smog Check dynamometer. We believe that the remaining 10% to 30% of the on-road vehicles with no previous Enhanced Smog Check recently re-registered from Basic or Change-of-Ownership Smog Areas of the state. This should be confirmed by more in-depth analysis of DMV registration data.

Figure 1.2. Fraction of on-road vehicles with no previous Enhanced Smog Check record, by model year and basin in which registered



1.2. Emission measurements

Remote sensing measurements are basically measurements of the molar ratio of pollutants to CO2 in the exhaust. Using calculations based upon the basic combustion equation of gasoline (and diesel), the results are converted to be expressed in terms of concentration in the vehicle exhaust (parts per million, or ppm, HC and NOx, percent CO and CO2). ESP instrumentation applies filters to identify emission, speed and acceleration values that fall outside of acceptable ranges; Table 1.1 above indicates that about 35% of the emissions measurements were not valid, leaving 65% valid measurements for analysis. This ratio is somewhat lower than the 75% to 80% typically observed in other studies. This is because a significant fraction of measurements in this project were taken on surface street sites, versus practically all freeway ramps in other studies. When only the freeway ramp sites used in this study are considered, the fraction of valid measurements increases to 71%.

Vehicle emissions can vary substantially based on the engine load at which the vehicle is operating when its emissions are measured. All vehicles can temporarily emit relatively high concentrations of pollutants. For example, when a vehicle undergoes a hard acceleration at moderate speed, the emission control system may go “open loop”, with the fuel-air ratio substantially increased (or “enriched”) to obtain additional power. Engine operation in enrichment mode can result in extremely high CO and HC emissions. As another example, when a vehicle decelerates it may emit a high concentration of HC; however, the total exhaust flow during deceleration is quite low, so the actual grams of HC emitted during deceleration also are quite low. Because vehicle accelerations and decelerations are not representative of average driving behavior or average on-road emissions, remote sensing sites typically are selected to avoid such operating modes. In addition, analysis of remote sensing data typically use the vehicle specific power (VSP) to characterize the approximate engine load at about the time of measurement, and screen out these operating modes. VSP is calculated using the following formula:

$$VSP = (4.39 * \sin(G)) * (V + 0.22 * V * A) + (0.0954 * V) + (0.0000272 * V^3)$$

where G is the grade of the road (in degrees) at which the measurement is made, V is vehicle velocity (miles per hour), and A is vehicle acceleration (miles per hour per second).

Typically VSP in the range of 5 to 25 kW per tonne (i.e., metric ton or Mega-gram) are used to minimize the effect of engine load on measured emissions. Table 1.1 indicates that about 60% of the valid emissions measurements were within the acceptable VSP range of 5 to 25 kW per tonne.

Remote sensing sites are selected to maximize the number of valid emissions measurements in the useable VSP range. Table 1.2 indicates that the efficiency of the remote sensing sites used in this study varied by air basin. While 38% of all the raw remote sensing measurements had valid emissions and acceptable VSP, the fraction with valid emissions and acceptable VSP ranged from under 30% for sites used in the San Luis Obispo and Sacramento basins, to over 60% for the sites used in the San Diego basin. Freeway ramps are often ideal sites for remote sensing measurements: they often have curved geometry and a grade, which requires drivers to operate their vehicles under a controlled, moderate acceleration. Table 1.2 also shows the fraction of measurements made on freeway ramps, by basin. Almost all of the measurements in the San Francisco basin, and none of the measurements in the San Joaquin and San Luis Obispo basins, were made on freeway ramps; the remaining measurements were made on surface streets. Considering only sites on freeway ramps, 71% of the raw measurements have valid emissions, and 39% have valid emissions and acceptable VSP. San Diego is the basin with the highest fraction of valid (78%) and valid and useable (62%) measurements; when we consider San Diego sites on freeway ramps only, these fractions increase to 95% valid and 81% valid and useable. One reason that there are relatively few measurements at freeway ramps is that Caltrans did not allow us to measure vehicles during morning and evening rush hours, when ramps are heavily used.

Table 1.2. Percent of remote sensing measurements of vehicles matched to DMV registration data with valid emissions and acceptable VSP, by air basin in which measurement was made

Air basin in which remote sensing measurement was made	Percent of remote sensing measurements of vehicles matched to DMV registration data		
	on freeway ramps	with valid emissions	with valid emissions and 5<=VSP<=25 kW/tonne
Unknown	NA	62%	38%
South Coast	13%	63%	37%
San Diego	11%	78%	62%
San Francisco	98%	71%	35%
San Joaquin	0%	67%	38%
San Luis Obispo	0%	55%	24%
Sacramento	68%	70%	29%
All	21%	65%	38%

Previous remote sensing analyses have found that the individual sensors can produce biased measurements, probably because of day-to-day variability in how they are set-up and because of differing ambient conditions (Bishop et al., 2004; ERG, 2002). In the past, adjustment factors have been used to correct for this bias. Lately the factors have been based on the median emissions for the newest vehicles measured, from all instruments and sites in the study. (This assumes that the median results from new vehicles should not vary from site to site or day to day.) The factors are then either added or subtracted from the raw measurements. ERG calculated adjustment factors for each of the four pollutants, for each instrument/site/day combination, based on the median emissions for the four newest model years measured at all instruments, sites and days in the study. Table 1.3 shows the average adjustment factor (weighted by the number of measurements) for each van site-day, as well as the range in factors, for each pollutant. Figures 1.3 through 1.5 show the distribution of adjustment factors for each pollutant, by the basin in which the site was located and site-day. For example, Figure 1.3 shows that the vast majority of HC correction factors fall between -80 ppm and 80 ppm. Correction factors for other pollutants have similar distributions. Note that there are some extreme NOx correction factors, greater than 300 ppm (Figure 1.5). Figure 1.6 shows the percent roadway grade of each site used in each air basin.

Table 1.3. Average and range in emission adjustment factors for van site-days, by air basin

Air basin	Number of van site-days	Number of measurements	Weighted average HC	Weighted average CO	Weighted average NOx	Range HC	Range CO	Range NOx
Missing	27	42,933	2.3	0.00	-32.4	-90 to 65	-0.08 to 0.02	-1172 to 23
South Coast	527	1,579,527	-2.7	0.00	-1.6	-296 to 77	-0.24 to 0.03	-365 to 40
San Diego	33	159,226	-5.3	0.00	3.4	-16 to 12	-0.06 to 0.01	-16 to 11
San Francisco	41	55,977	-5.5	-0.01	-10.6	-29 to 7	-0.05 to 0.01	-853 to 97
San Joaquin	19	60,341	-10.8	0.00	1.8	-50 to 16	0 to 0.01	-14 to 11
San Luis Obispo	12	39,540	-5.2	0.00	5.2	-83 to 126	-0.01 to 0.01	-10 to 29
Sacramento	129	258,730	-0.6	0.00	-3.9	-103 to 99	-0.05 to 0.03	-84 to 57

Figure 1.3. Van site-day HC adjustment factors, in ascending order by air basin

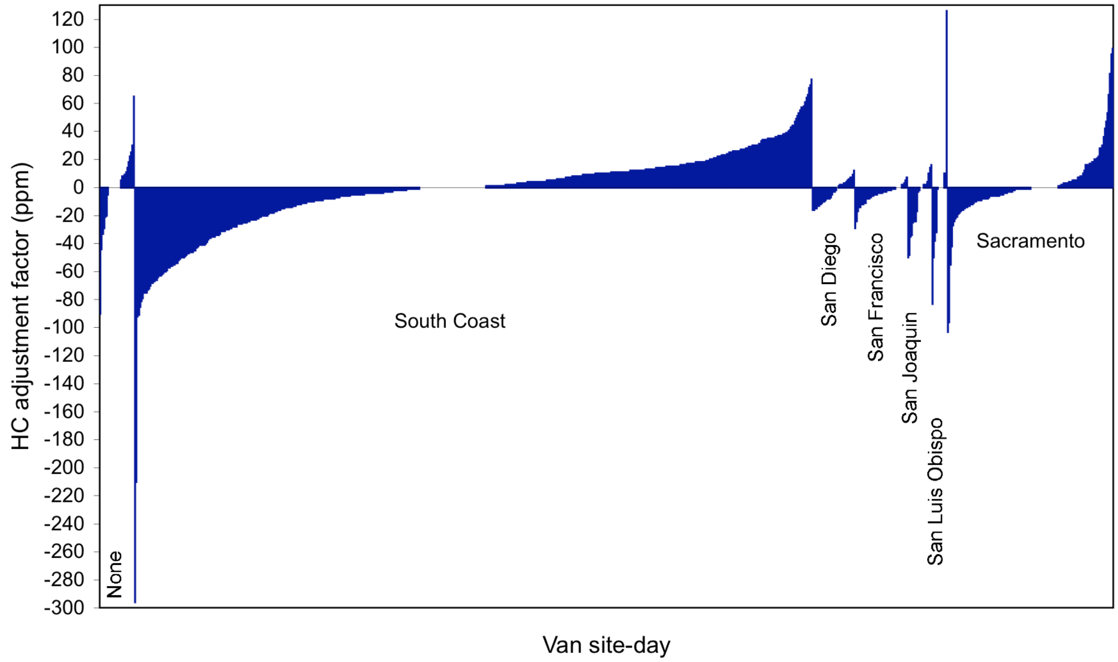


Figure 1.4. Van site-day CO adjustment factors, in ascending order by air basin

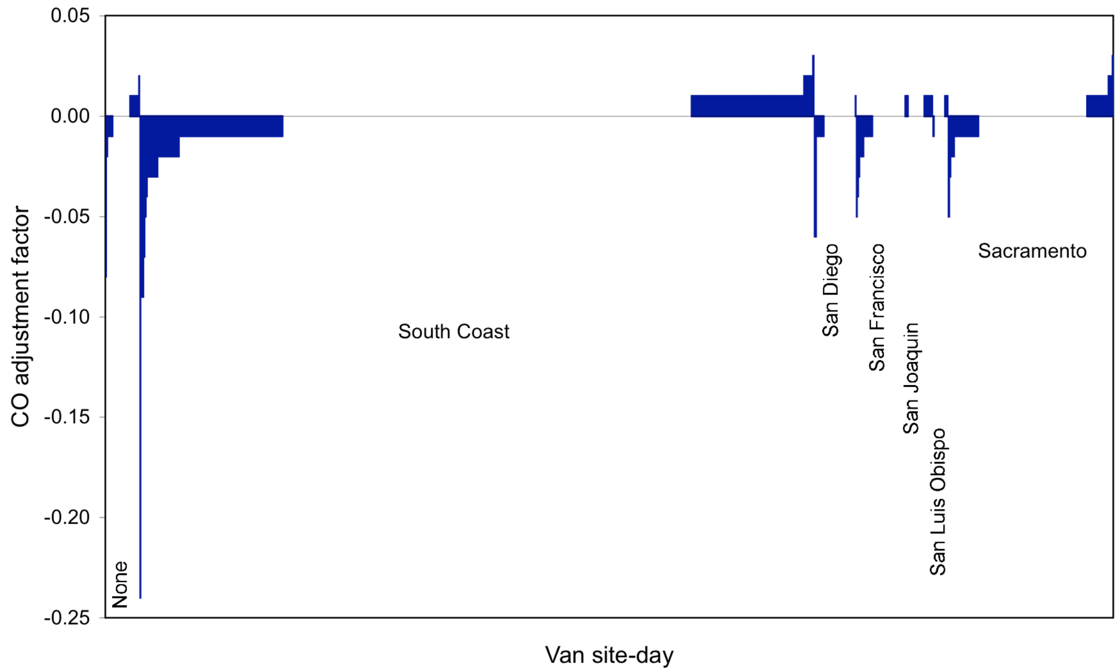


Figure 1.5. Van site-day NOx adjustment factors, in ascending order by air basin

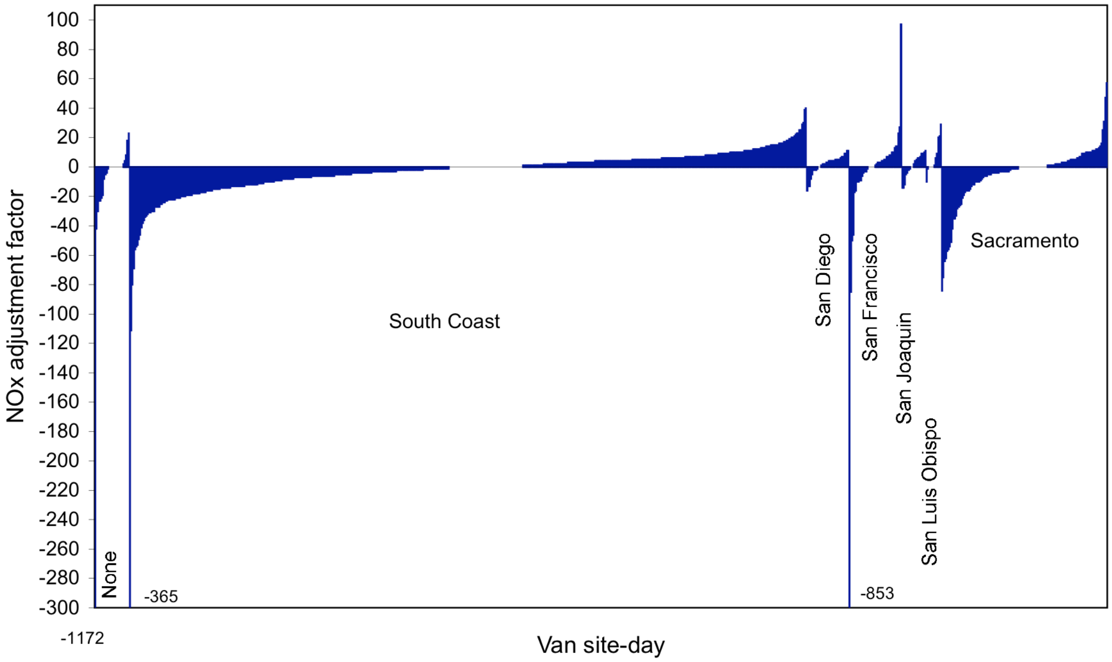
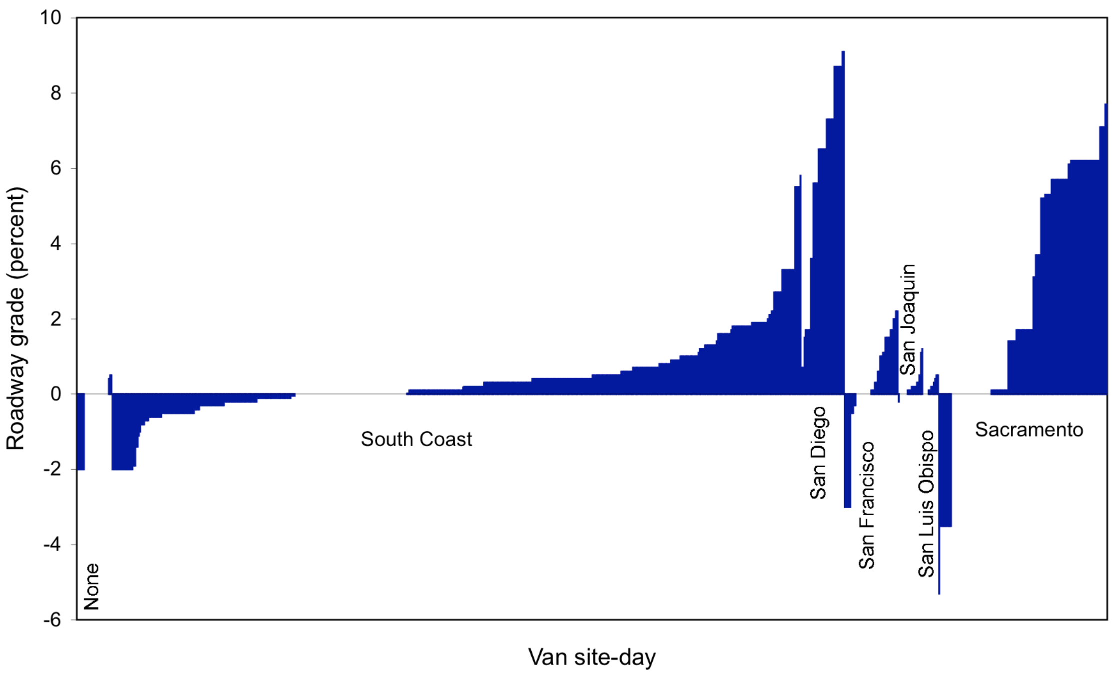


Figure 1.6. Van site-day roadway grade, in ascending order by air basin



We analyzed both the raw and site-adjusted remote sensing measurements. One potential problem with these adjustment factors is that they might reduce the influence of actual difference in emissions by assuming that all new vehicles should have the same median emissions, regardless of the site or vehicle population measured at the site. It is possible that subtle differences in sites, and traffic patterns at sites, might result in lower or higher emissions than at a measurement site a short distance away. And differences in the population of vehicles measured at a site, in terms of vehicle type (car vs. light-truck), make/model, or even owner maintenance practices, may also result in actual differences in measured emissions of new vehicles. Wherever possible, we corrected for the fleet differences by normalizing to the patterns that were observed in the South Coast region. In other words, we corrected fleet-average emissions for differences in model-year distributions. It may be appropriate to make similar adjustments to normalize emissions to the same distribution of VSP; however, this is not practical in this study given the relatively small number of measurements in many of the air basins.

To investigate the possible influence of actual variations in driving patterns from site to site, we looked at actual differences in the way vehicles are driven from one area to another. Figure 1.7 compares the distribution of VSP across air basins. The figure indicates that the distributions of VSP for the sites used in the South Coast and San Joaquin basins are similar, perhaps because most of the measurements in these two basins were made at sites on surface roads (Table 1.2). However, the vehicles measured at the San Diego sites have a much higher distribution of VSP, even though almost all of those vehicles were measured at sites on surface roads as well. The VSP distributions for vehicles measured in San Francisco and Sacramento are similar, with a higher fraction of vehicles under deceleration; this is likely because a majority of vehicles measured in these basins (98% in San Francisco, 68% in Sacramento) were measured on freeway ramps. The dramatic differences in the VSP distributions across air basins may account for some of the differences observed in emissions across air basins. Figure 1.8 shows the distribution of useable VSP (that is, VSP between 5 and 25 kW per tonne) for each air basin. Again, San Diego vehicles have substantially higher VSP than those in other basins.

Figure 1.7. Distribution of vehicle specific power, by air basin

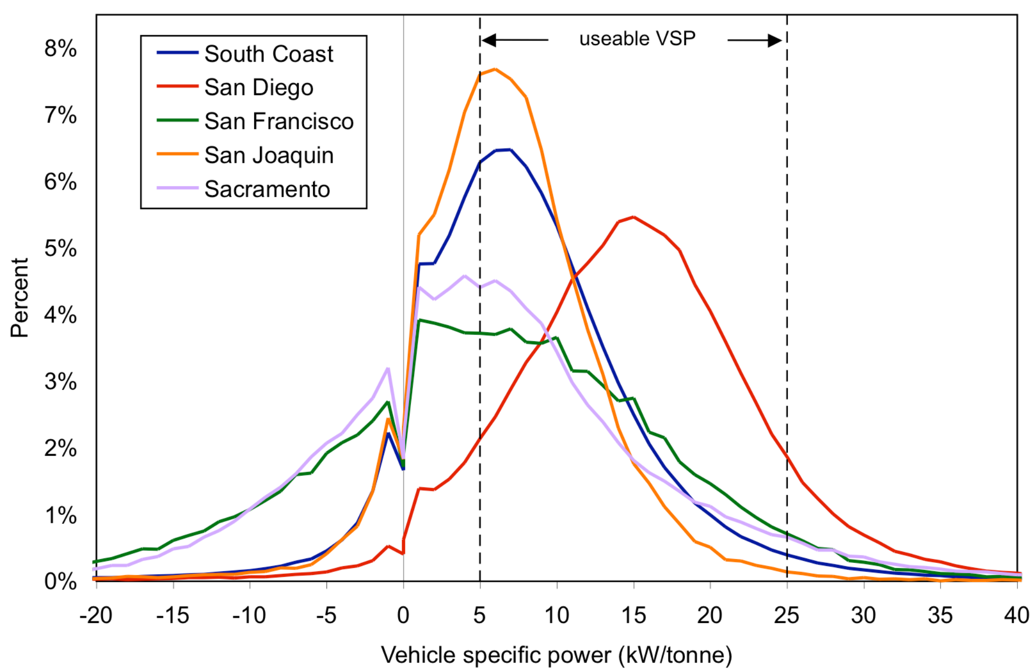


Figure 1.8. Distribution of useable vehicle specific power (between 5 and 25 kW per tonne), by air basin

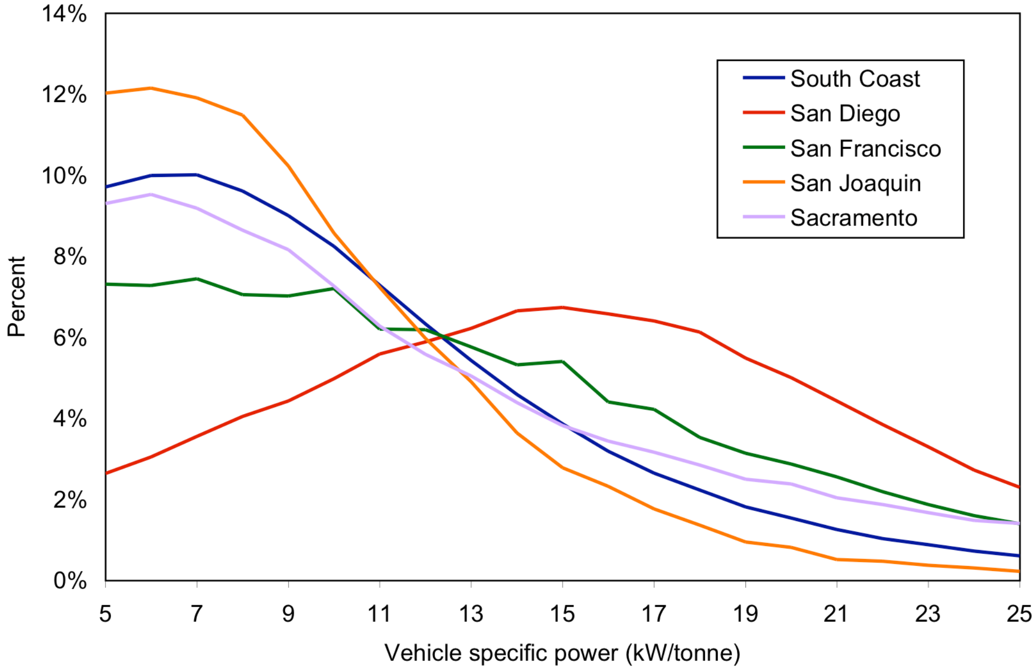
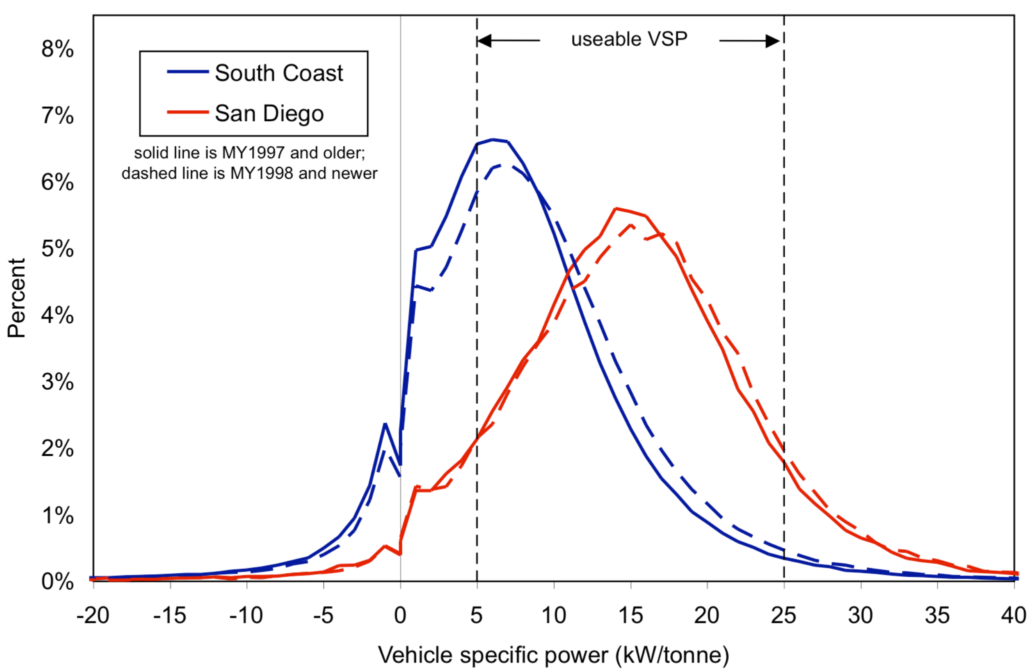


Figure 1.9 shows that 1998 and newer vehicles tend to have slightly higher VSP than 1997 and older vehicles, at both the South Coast and San Diego sites. These differences are not large enough to require that VSP be held constant when comparing emissions by model year across different air basins.

Figure 1.9. Distribution of vehicle specific power, by vehicle model year and air basin



On the other hand, Figures 1.10 and 1.11 show that vehicles measured traveling over 30 miles per hour (dashed lines in the figure) have substantially higher VSP distributions than vehicles traveling less than 30 miles per hour (solid lines). Note that, in Figure 1.8, vehicles measured in the South Coast (blue) and Sacramento (violet) air basins have similar VSP distributions, with South Coast vehicles having slightly lower VSP than Sacramento vehicles. Figure 1.11 shows that vehicles measured at low speeds also have a similar VSP distribution (although low-speed South Coast vehicles now have slightly higher VSP than low-speed Sacramento vehicles), while vehicles measured at high speeds have rather different VSP distributions. We did not have a sufficient number of remote sensing measurements in two basins to test whether the difference in VSP-speed distributions have an effect on average emissions. Further work is required to test whether this difference in VSP distributions at different speeds results in significant differences in average emissions; if so, emissions should be adjusted to a common VSP and speed distribution, in addition to a common model year distribution, when comparing average emissions between different groups of vehicles.

Figure 1.10. Distribution of vehicle specific power, by speed and air basin

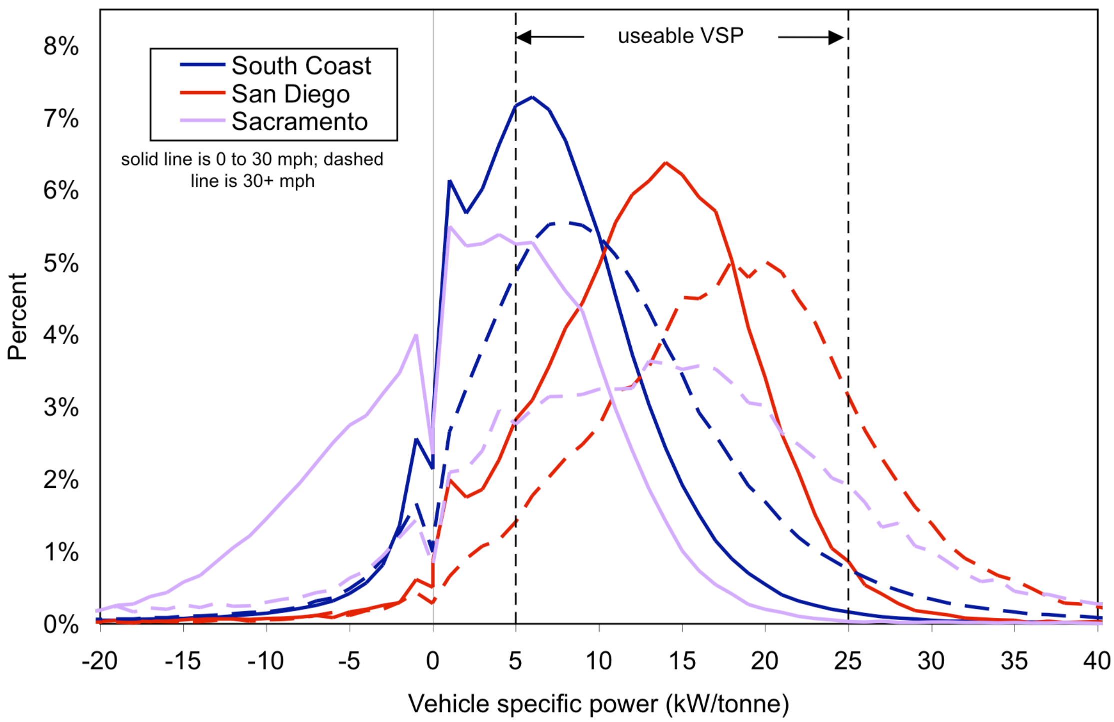
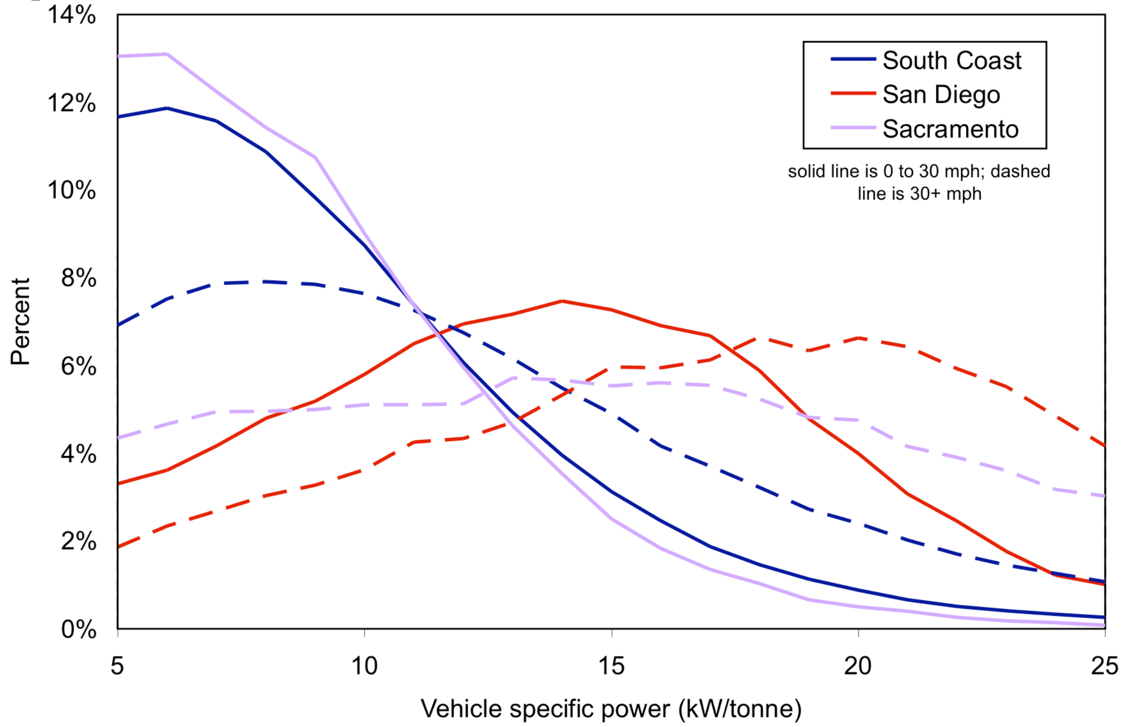


Figure 1.1. Distribution of useable vehicle specific power (between 5 and 25 kW per tonne), by speed and air basin



In order to use remote sensing concentration measurements to estimate mass emissions, the raw or adjusted measurements first must be converted. We used standard combustion equations to convert the remote sensing concentration emission factors into gram per gallon of fuel emission factors:

$$\text{HC grams / gallon} = (2 * 8644 * \%HC) / (15 + (0.285 * \%CO) + (2 * 2.87 * \%HC))$$
$$\text{CO grams / gallon} = (5506 * \%CO) / (15 + (0.285 * \%CO) + (2 * 2.87 * \%HC))$$
$$\text{NOx grams / gallon} = (5900 * \%NOx) / (15 + (0.285 * \%CO) + (2 * 2.87 * \%HC))$$

where %HC and %NOx are expressed in percent, rather than ppm. Note that HC emissions are multiplied by an additional factor of two to account for the HC species in the exhaust that are not measured by remote sensing (Singer et al., 1998). This adjustment brings fleet-average remote sensing HC measurements to an approximately equal basis of TOC (total organic carbon) measured using other methods. The gram per gallon emission factors can be multiplied by an estimate of fuel use to obtain mass emissions.

In all of the following analyses, we used the raw concentration, adjusted concentration, and mass emissions to test the sensitivity of our results to the emission units. Therefore, all of the emissions in this report refer to the raw concentration measurements. We did use the gram per gallon emission factors to calculate total mass emissions in Section 4, however.

2. Characterizing the on-road fleet

One question arising from the objectives of this project is whether remote sensing measurements of on-road vehicles can be used to characterize the fleet of vehicles operating on-road in a particular area. In this section we analyze the distribution of on-road vehicles, and their emissions, by: the basin in which they were registered; vehicle type and model year; day and time of day observed; and the result of each vehicle's previous Enhanced Smog Check test.

2.1. On-road fleet by vehicle type

Table 2.1 shows the distribution by vehicle type in each basin. This type of data comes from the video records taken with remote sensing measurements, so it can also be obtained from other video data of on-road fleets, such as traffic cameras and parking lot cameras. The San Francisco basin has a higher percentage of cars (60%), and the San Joaquin basin a lower percentage of cars (52%), in their light-duty on-road fleet than the other basins. Figure 2.1 shows the percent of on-road light-duty vehicles that are cars by basin and model year. The figure indicates that the San Francisco Bay Area has a consistently higher percentage, and San Joaquin Valley a consistently lower percentage, of cars than the other basins. The figure also indicates that the fraction of cars is decreasing with each successive model year, in each basin; for example, in the San Francisco basin, while 75% of model year 1988 vehicles are cars, only 55% of the 2004 model year are. This decline is mostly attributable to the increasing popularity of light trucks (pickups, SUVs, and minivans) over the past 15 years or so.

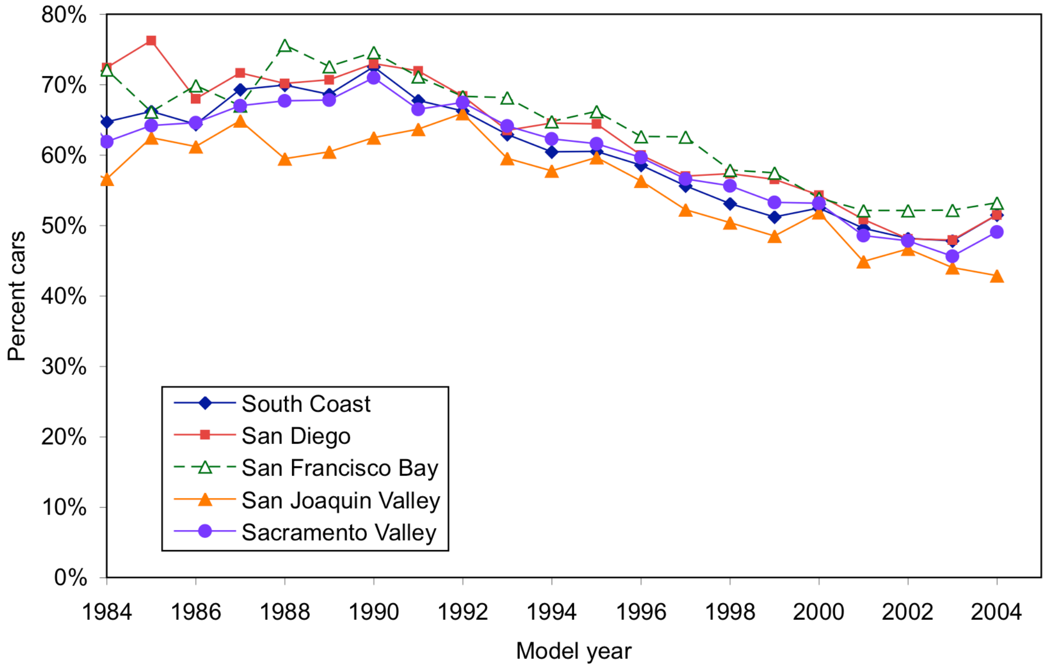
In subsequent analyses we combine pickups, SUVs, vans and minivans as light trucks, and exclude buses and incomplete vehicles from the analysis.

Table 2.1. Distribution of on-road vehicles by type, by air basin

Air basin	Bus	Car	Incomplete *	SUV	Pickup	Van
Missing	0.3%	58%	1.2%	17%	17%	6%
South Coast	0.2%	56%	1.3%	18%	17%	7%
San Diego	0.2%	57%	0.6%	19%	15%	8%
San Francisco	0.2%	60%	1.1%	17%	16%	6%
San Joaquin	0.2%	52%	1.2%	17%	24%	6%
San Luis Obispo	0.2%	56%	0.9%	19%	17%	7%
Sacramento	0.2%	56%	1.3%	17%	20%	6%
All	0.2%	56%	1.2%	18%	17%	7%

* Incomplete is a vehicle that was manufactured for further modification outside of the factory; wreckers, for example.

Figure 2.1. Percent of on-road light-duty vehicles that are cars, by model year and basin in which registered



2.2. On-road fleet emissions by air basin and vehicle type and model year

Even when correcting for differences in the fleet make-up, on-road emissions can vary substantially by the air basin in which vehicles are registered. Table 2.2 shows the number of measurements average vehicle model year and average emissions of cars, and Table 2.3 of light trucks, by air basin. The average emissions and standard error in each basin are shown weighted by the model year distribution of vehicles in that basin; the average emissions normalized the model year distribution of vehicles in the South Coast basin, are also shown to account for differences in the model year distribution of vehicles in each basin. Table 2.4 indicates that, for the most part, the other basins have substantially lower on-road emissions than the South Coast, after accounting for vehicle type and model year; the exceptions are NOx emissions in San Diego and San Francisco, and HC emissions in San Joaquin (in bold italics in the table). The South Coast car fleet is older than the car fleet in other air basins. Therefore, adjusting the average emissions in each basin to the model year distribution in the South Coast basin increases their emissions somewhat. However, even after this adjustment, vehicles in the South Coast basin have statistically significantly higher emissions than vehicles in the Sacramento basin. (The values for the San Francisco and San Joaquin basins are shown in grey because the relatively small number of measurements of vehicles in these basins increases the statistical uncertainty of their estimated average emissions.)

Table 2.2. Average on-road car emissions by air basin (HC and NOx in ppm, CO in percent)

Air basin	Number	Average model year	Average emissions based on South Coast MY distribution			Average emissions based on actual MY distribution			Standard error based on actual MY distribution		
			HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
South Coast	212,974	1996.8	76.3	0.26	243.7	76.3	0.26	243.7	1.0	0.002	1.1
San Diego	35,697	1997.0	66.4	0.23	274.7	61.1	0.22	259.0	1.8	0.004	3.0
San Francisco	13,433	1997.2	62.0	0.22	249.2	55.8	0.21	232.5	2.4	0.006	4.1
San Joaquin	9,633	1996.9	78.4	0.22	219.8	74.9	0.22	211.5	3.3	0.008	4.7
Sacramento	25,576	1997.0	48.5	0.21	202.6	42.4	0.19	190.1	2.2	0.004	2.7

Table 2.3. Average on-road light truck emissions by air basin (HC and NOx in ppm, CO in percent)

Air basin	Number	Average model year	Average emissions based on South Coast MY distribution			Average emissions based on actual MY distribution			Standard error based on actual MY distribution		
			HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
South Coast	188,342	1998.2	66.7	0.19	233.7	66.7	0.19	233.7	0.8	0.002	1.2
San Diego	29,387	1998.6	48.9	0.18	264.5	42.4	0.16	240.8	1.2	0.004	3.1
San Francisco	8,426	1998.4	62.7	0.18	246.6	58.1	0.17	234.4	7.4	0.007	5.7
San Joaquin	8,911	1998.1	72.6	0.17	222.9	74.3	0.17	225.1	4.1	0.007	5.1
Sacramento	21,217	1998.4	42.9	0.15	227.7	39.8	0.14	219.1	1.7	0.004	3.3

Table 2.4. Difference in average emissions from South Coast by vehicle type and air basin

Air basin	Difference from South Coast					
	Cars			Light trucks		
	HC	CO	NOx	HC	CO	NOx
South Coast	NA	NA	NA	NA	NA	NA
San Diego	-13%	-10%	***13%***	-27%	-7%	***13%***
San Francisco	-19%	-13%	***2%***	-6%	-8%	***6%***
San Joaquin	***3%***	-13%	-10%	***9%***	-14%	-5%
Sacramento	-36%	-20%	-17%	-36%	-22%	-3%

The results above are very similar when we use adjusted concentrations or mass (gram per gallon) emissions. The one exception is HC emissions in the San Joaquin basin; when we use site-adjusted emissions, San Joaquin emissions are 15% lower for cars, and 3% lower for light trucks, than those in the South Coast basin (as opposed to 3% and 9% higher, in the tables above). This might be the result of the relatively few on-road measurements of vehicles registered in the San Joaquin basin.

Note that on-road emissions in the Sacramento basin in Tables 2.2 and 2.3 are substantially lower than those in the South Coast basin. Figures 2.2 through 2.4 show car emissions in all basins by pollutant. Figures 2.5 through 2.7 explicitly compare on-road emissions in the South Coast and Sacramento basins; the error bars represent the standard error of the mean emissions for each model year. Figures 2.5 and 2.7 indicate that the difference in the South Coast and Sacramento on-road car emissions are statistically significant for most model years. Note that Figure 2.5 indicates that HC emissions for 2000 and newer cars in the Sacramento basin are substantially lower than in the South Coast basin. We get the same result when we use the site-adjusted emissions. Because the site adjustment factors are based on median emission values, they correct for biases in the data, without masking any real difference in average emissions, which may be due to a few super emitters.

Figure 2.2. Average car remote sensing HC emissions, by model year and basin in which registered

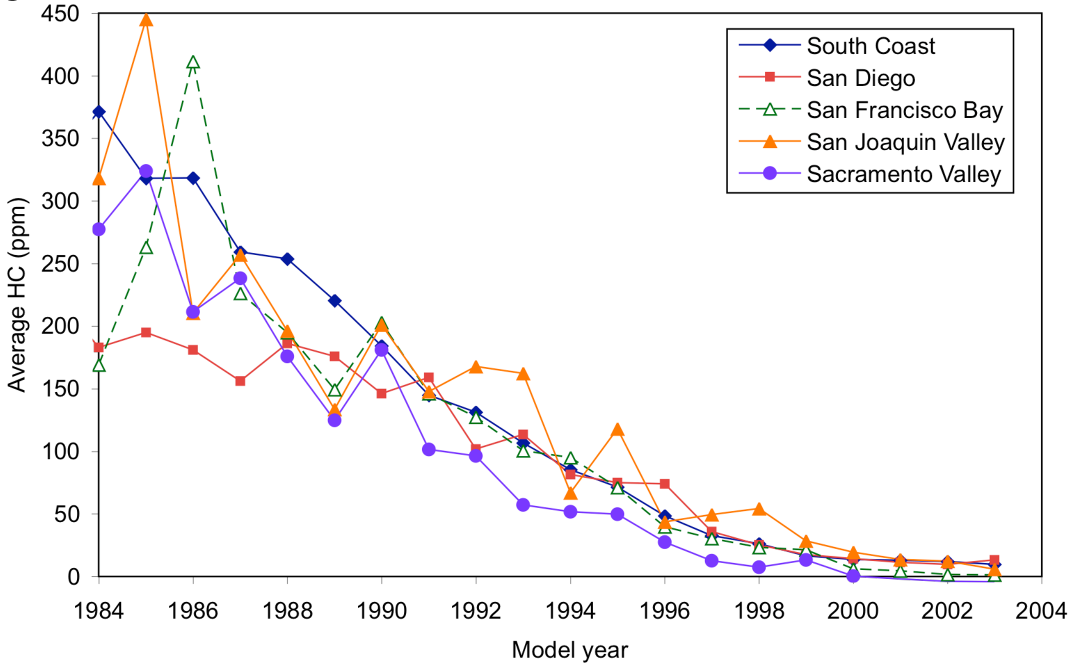


Figure 2.3. Average car remote sensing CO emissions, by model year and basin in which registered

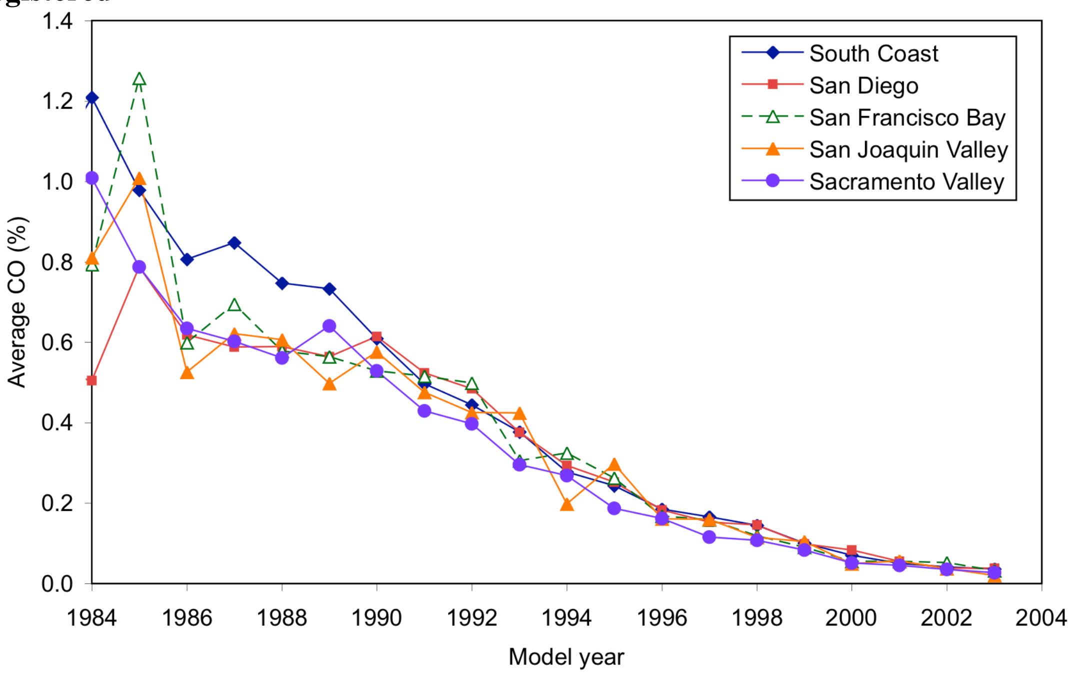


Figure 2.4. Average car remote sensing NOx emissions, by model year and basin in which registered

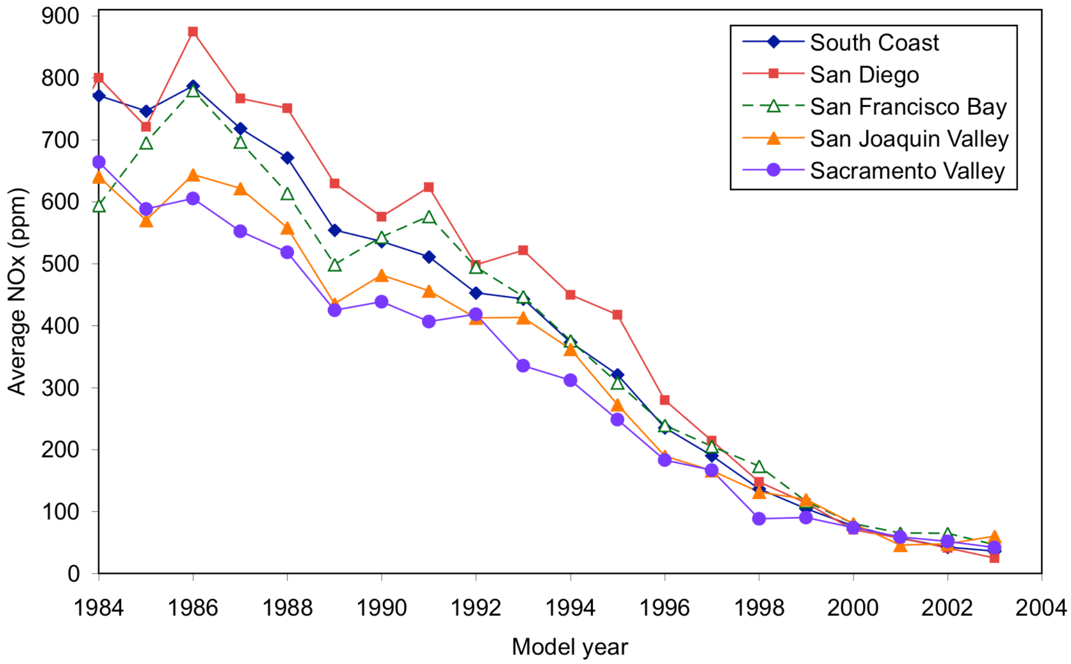


Figure 2.5. Average car remote sensing HC emissions in South Coast and Sacramento basins, by model year

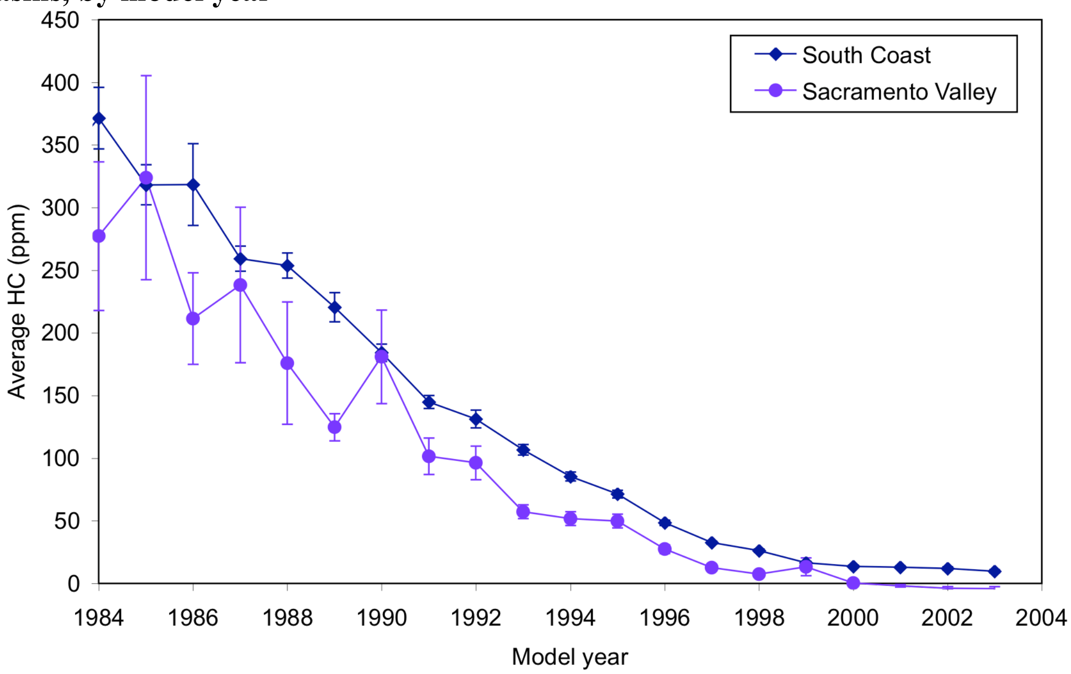


Figure 2.6. Average car remote sensing CO emissions in South Coast and Sacramento basins, by model year

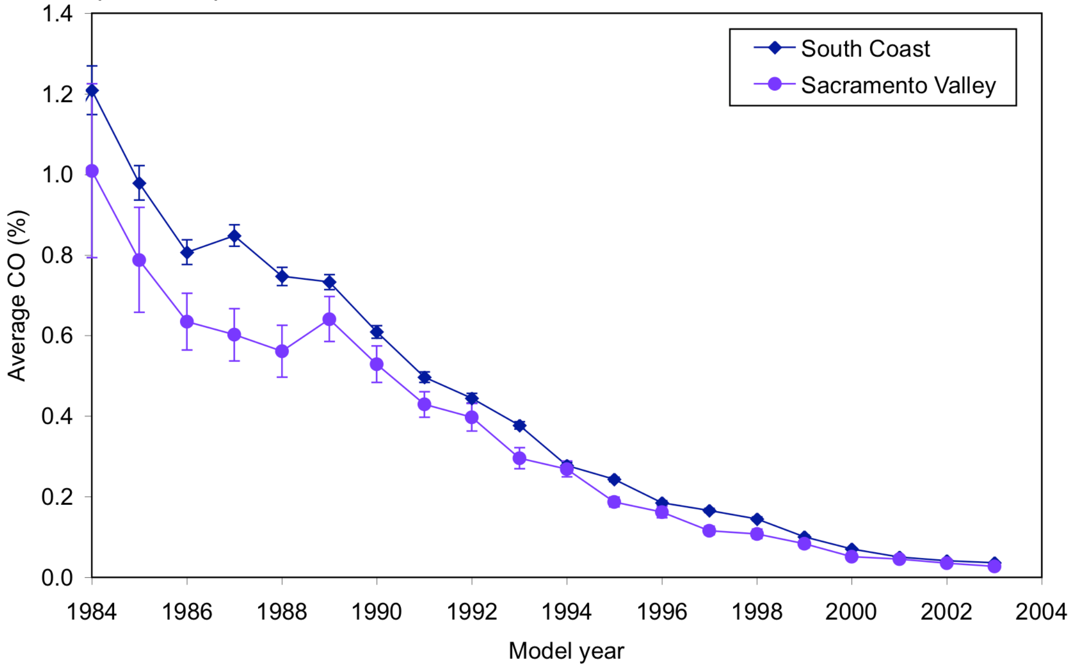
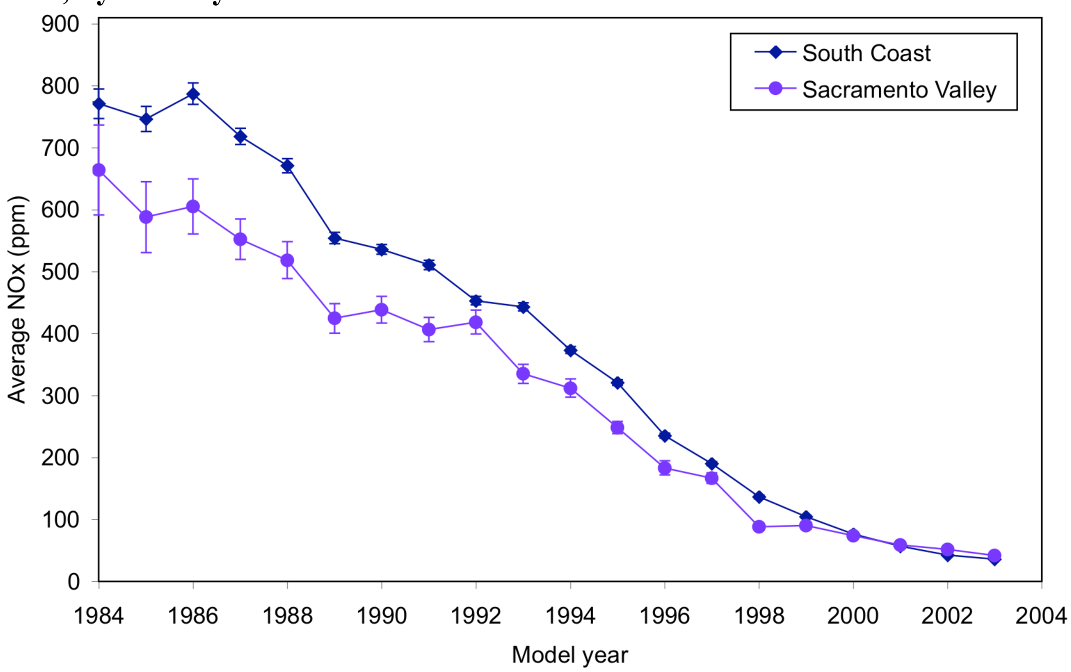


Figure 2.7. Average car remote sensing NOx emissions in South Coast and Sacramento basins, by model year



Remember that vehicles in four of the five basins have similar VSP distributions; San Joaquin vehicles have somewhat lower, and San Francisco and Sacramento vehicles somewhat higher, VSP than South Coast vehicles (Figures 1.7 and 1.8). However, San Diego vehicles have substantially higher VSP than South Coast vehicles. Ideally, the average emissions in each basin should be adjusted to the same VSP distribution, just as the emissions are adjusted to the same model year distribution. Figures 2.8 through 2.10 show average emissions of South Coast cars by model year, for four VSP bins; error bars in the figures represent the standard error of the means, and are shown for the lowest and highest VSP bins only. In general, emissions by model year increase with increasing VSP. CO and HC (for newer cars) increase only after VSP of about 20 kW/tonne, which is consistent with increasing emissions due to fuel enrichment at higher engine loads. NOx consistently increases with increasing VSP for all model years, which is due to increased NOx at higher engine temperatures. However, the increase in NOx at the highest VSP bin is muted, perhaps due to the coooling effect fuel enrichment has in the combustion chamber, which suppresses NOx formation.

Note that HC emissions from 1994 and older cars are relatively high at the lowest VSP range (blue diamonds in figure); we would expect HC emissions from these vehicles to be similar up to VSP of about 20 kW per tonne.

Figure 2.8. Average car remote sensing HC emissions in South Coast, by VSP range and model year

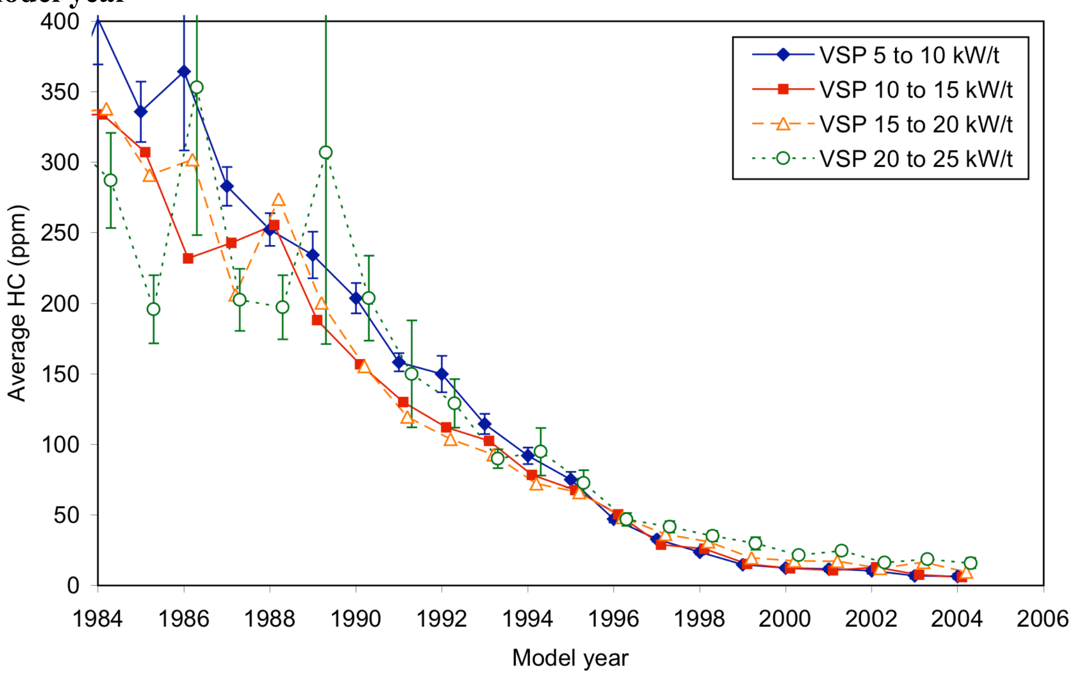


Figure 2.9. Average car remote sensing CO emissions in South Coast, by VSP range and model year

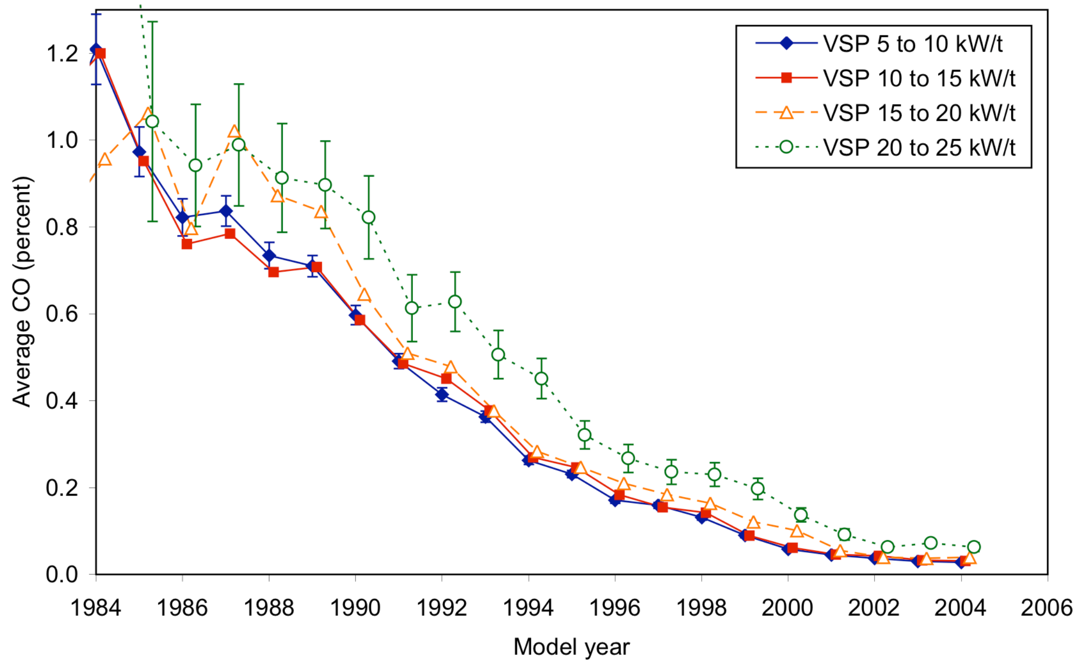
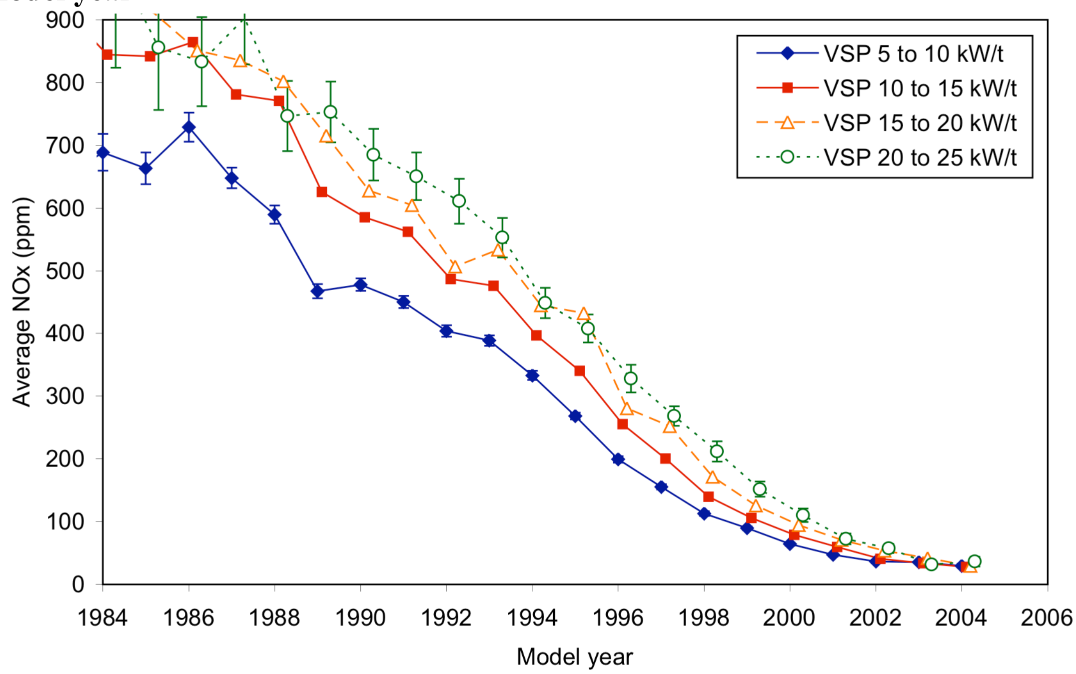


Figure 2.10. Average car remote sensing NOx emissions in South Coast, by VSP range and model year



We tested what effect adjusting to the (higher) VSP distribution of San Diego cars would have on the emissions of South Coast cars, by weighting the average South Coast emissions by VSP bin for each model year by the distribution of San Diego cars in each VSP bin. Figures 2.11 through 2.13 compare the actual average emissions by model year of South Coast and San Diego cars, with the average emissions of South Coast cars adjusted to the same VSP distribution as the

San Diego cars. The figures indicate that that VSP-adjusted HC and CO emissions for each model year are within the uncertainty of the unadjusted averages (Figures 2.11 and 2.12), which, for 1989 and older cars, are statistically higher than those for San Diego cars. However, adjusting South Coast NOx emissions to the San Diego VSP distribution significantly increases the NOx emissions of all South Coast cars; adjusting to the same distribution of VSP makes the average NOx emissions of South Coast cars comparable to those of San Diego cars, for most model years.

Figure 2.11. Average car remote sensing HC emissions in South Coast and San Diego basins, by model year

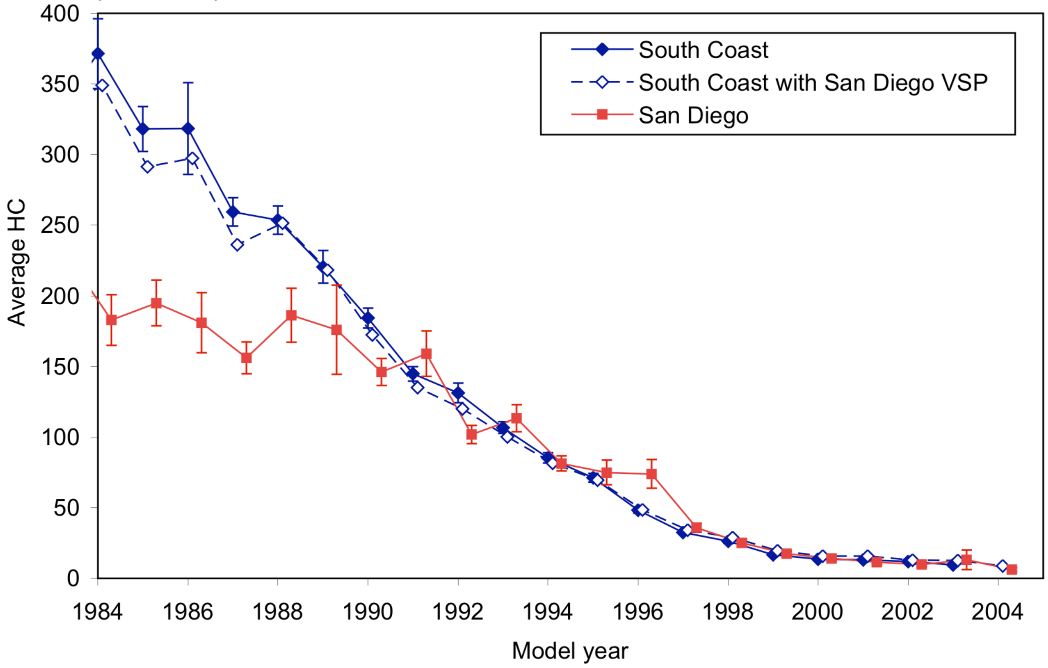


Figure 2.12. Average car remote sensing CO emissions in South Coast and San Diego basins, by model year

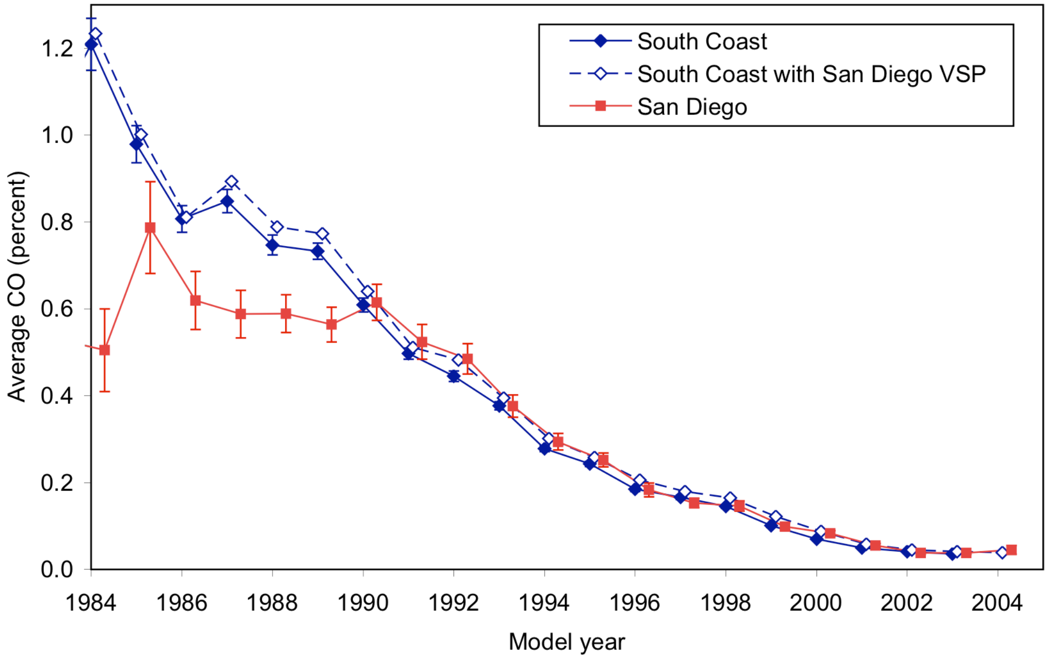
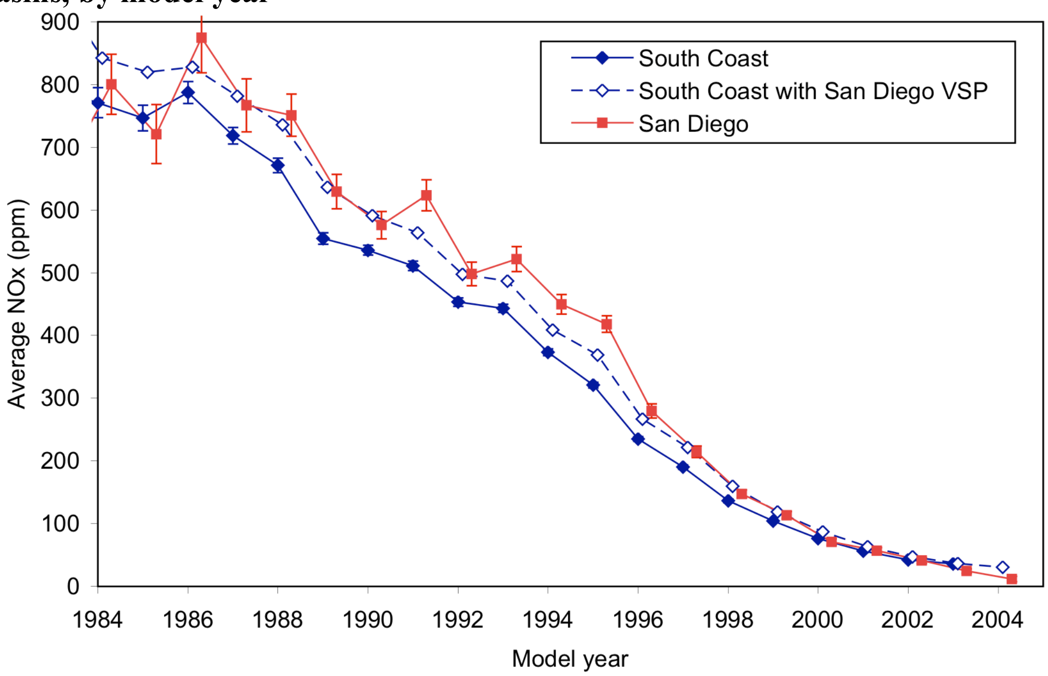


Figure 2.13. Average car remote sensing NOx emissions in South Coast and San Diego basins, by model year



The large difference in VSP distribution between cars measured in the South Coast and San Diego air basins appears to have little effect on relative HC and CO emissions, but has a statistically significant effect on relative NOx emissions. We recommend that, when VSP distributions between groups of vehicles are substantially different, researchers adjust for those differences when comparing emissions of the vehicle groups, particularly NOx emissions.

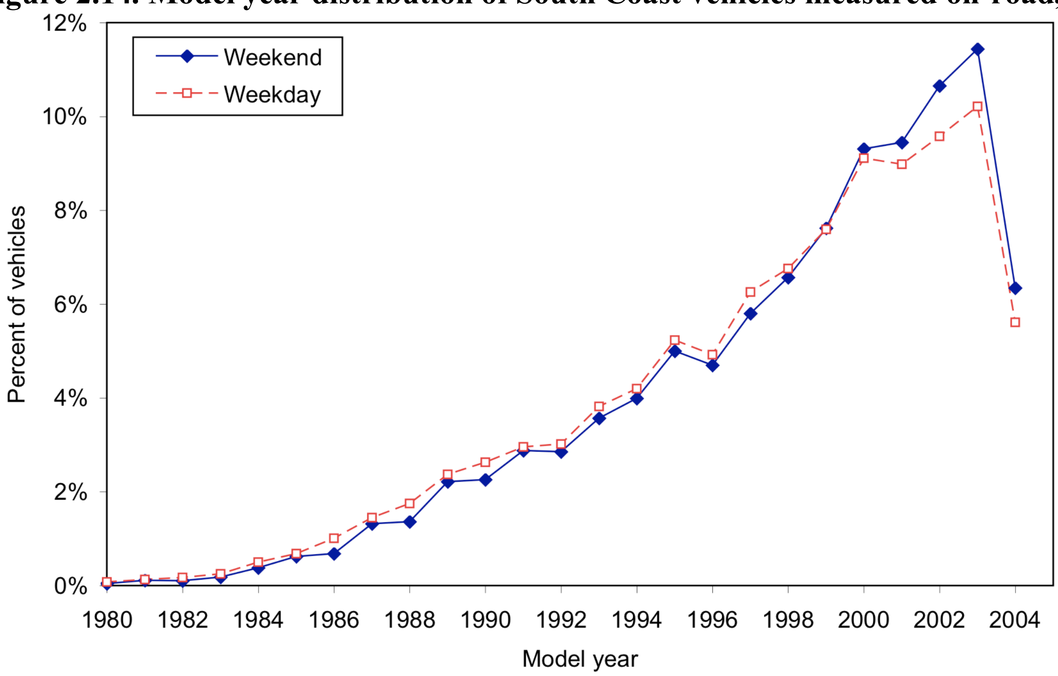
Note that HC and CO emissions from 1989 and older cars in San Diego are significantly lower than from those in the South Coast, even after adjusting the emissions of South Coast cars to the higher VSP distribution in San Diego. One possibility for this discrepancy is that the sample of San Diego vehicles measured on road is a better-maintained fleet than the sample of South Coast vehicles measured on road. However, the San Diego vehicles had the same, or slighlty higher, failure rate by model year on their previous Enhanced Smog Check test than the South Coast vehicles. This suggests that older vehicles in the South Coast undergo a higher rate of emissions deterioration after their previous Enhanced Smog Check than older vehicles in San Diego.

Figures 1.10 and 1.11 (above) indicate that vehicles measured in two areas (South Coast and Sacramento) can have similar overall VSP distributions, but the VSP distributions within speed groups can be substantially different. It may be desirable to adjust emission rates to a common distribution of VSP and speed when comparing average emissions across geographical areas; however, there were not enough remote sensing measurements of Sacramento vehicles in this study to attempt such an adjustment.

2.3. On-road fleet by day

For this study most of the remote sensing vans were deployed on weekdays; however, about 7% of the vehicles measured on-road were observed on weekends as opposed to weekdays. Figure 2.14 compares the model year distribution of on-road vehicles registered in the South Coast basin, by the day observed on road. The figure indicates that the model year distribution of vehicles observed on the road on weekends is very similar to that of vehicles observed on road on weekdays, with the weekend fleet slightly, but statistically, younger.

Figure 2.14. Model year distribution of South Coast vehicles measured on-road, by day



Figures 2.15 through 2.17 show the average emissions of on-road vehicles registered in the South Coast basin, by model year. Vehicles measured on weekends have the same HC and CO emissions as vehicles measured on weekdays; however, vehicles measured on weekends have consistently lower NOx emissions than vehicles measured on weekdays.

Figure 2.15. Average on-road HC emissions of vehicles measured on weekdays and weekends, by model year

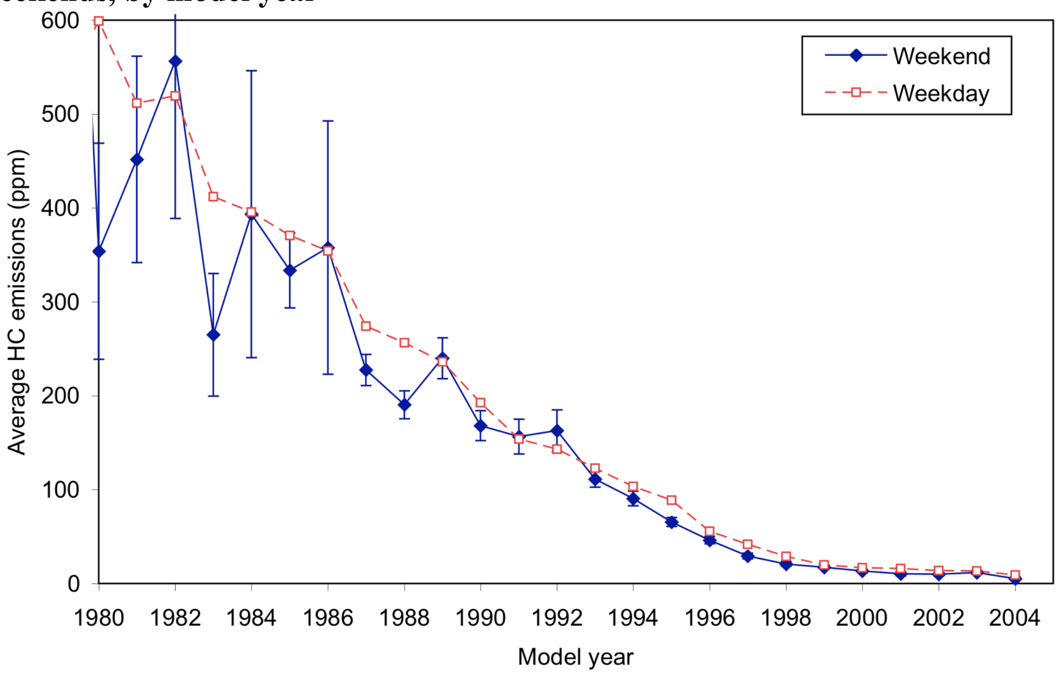


Figure 2.16. Average on-road CO emissions of vehicles measured on weekdays and weekends, by model year

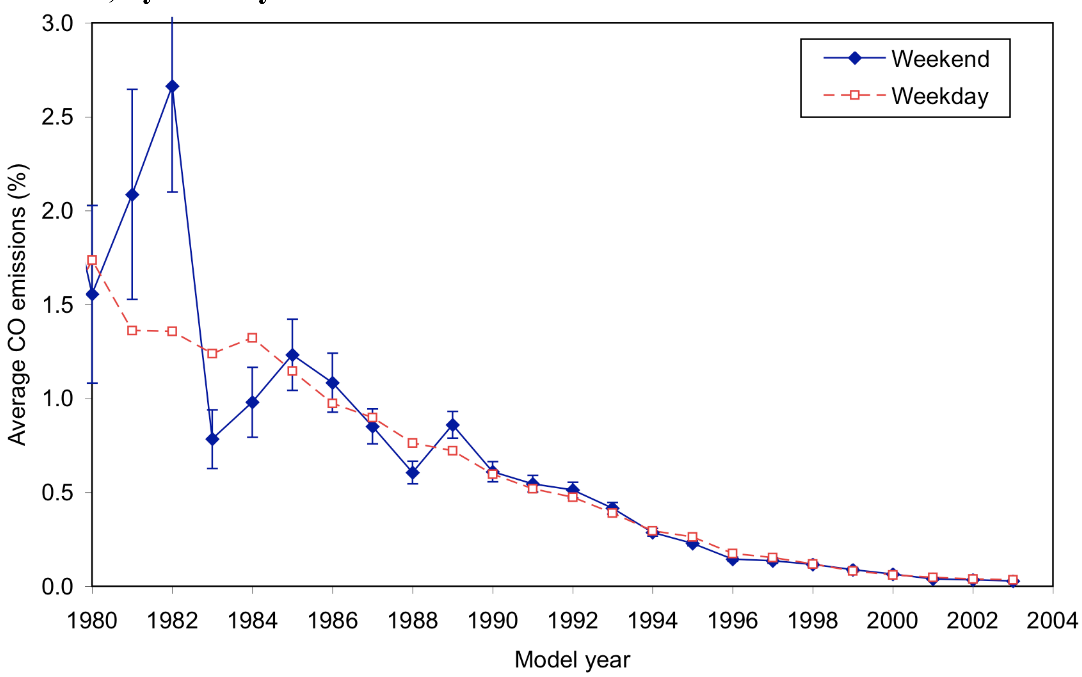
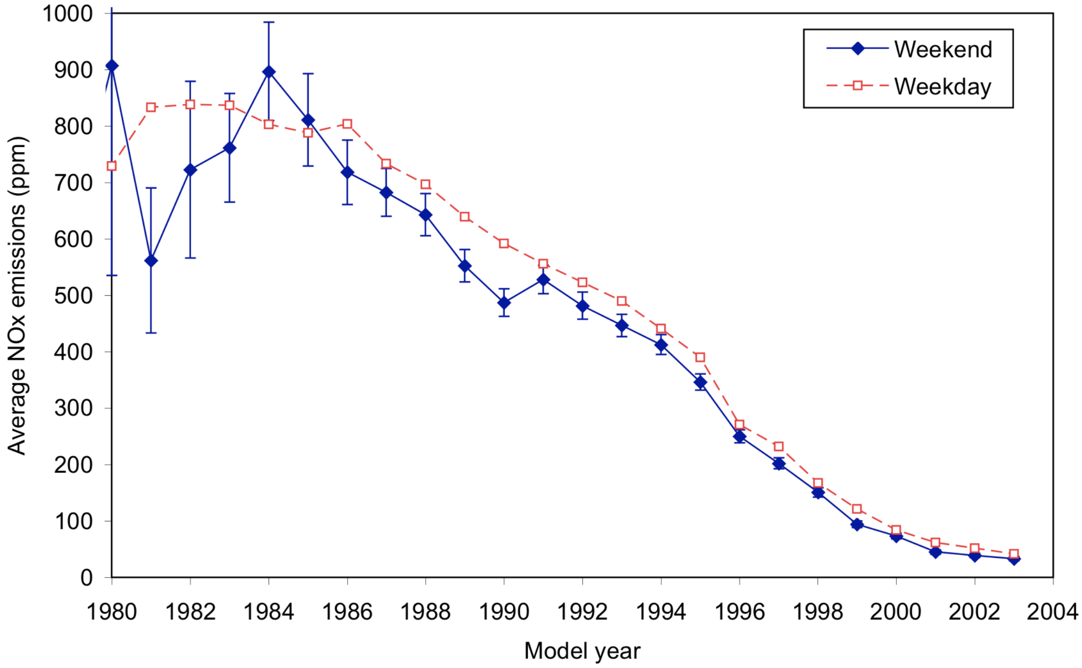


Figure 2.17. Average on-road NOx emissions of vehicles measured on weekdays and weekends, by model year



It has been postulated that lower NOx during the weekends leads to higher ozone because of the chemical kinetics of how ozone is formed. (Ambient HC/NOx ratio differences can produce condtions that either promote or inhibit the formation of ozone.) Lower weekend NOx emissions are speculated to be the result of less commerical (i.e. diesel) traffic, less than average aggressive driving, and more use of "fun" vehicles (such as motorcycles, restored classics, etc.) on weekends. Figure 2.18 indicates that the VSP distributions on weekdays and weekends are similar, suggesting that driving differences are not the cause of lower weekend NOx emissions. Figure 2.19 indicates that the fraction of on-road vehicles that are cars is consistently slightly lower on weekends than on weekdays; however, Figure 2.20 shows that average NOx emissions of cars only are consistently slightly lower on weekends than on weekdays.

Figure 2.18. Distribution of vehicle specific power of vehicles measured on weekdays and weekends

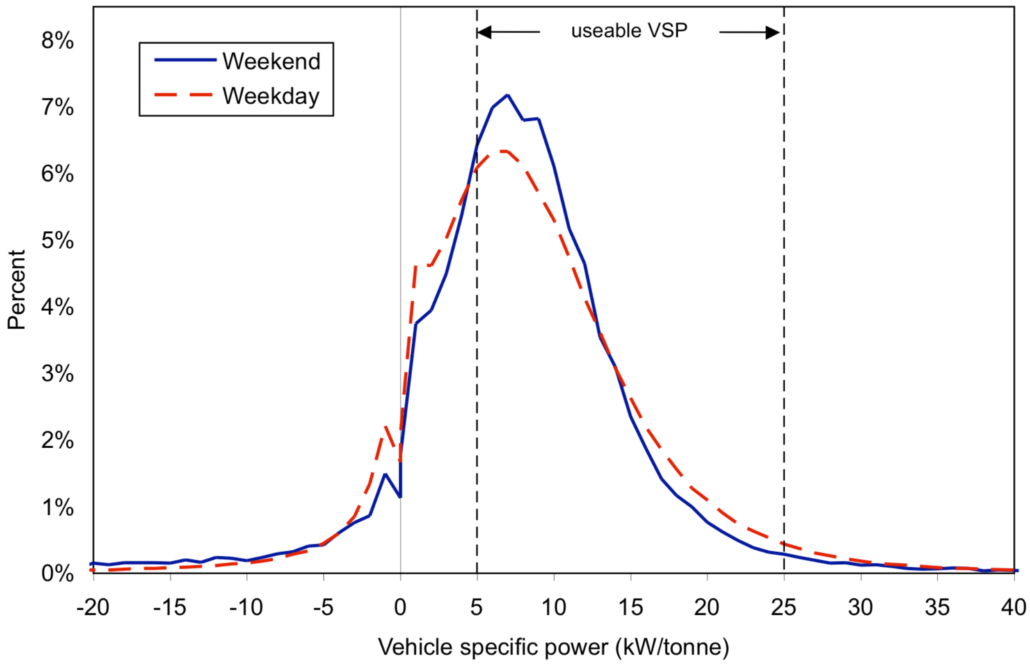


Figure 2.19. Fraction of vehicles measured on weekdays and weekends that are cars, by model year

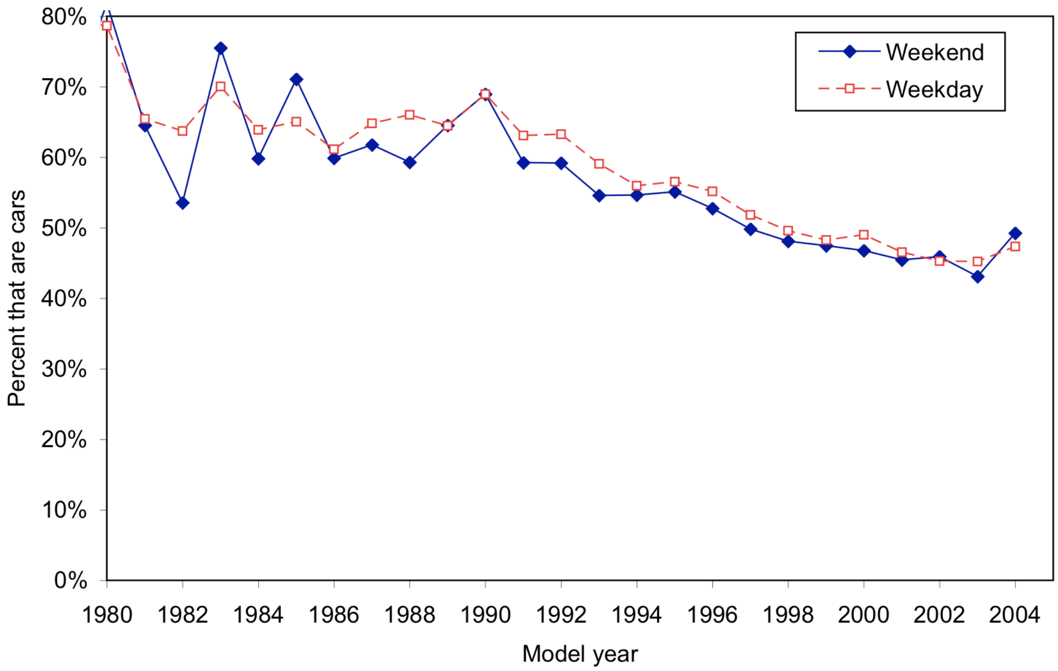
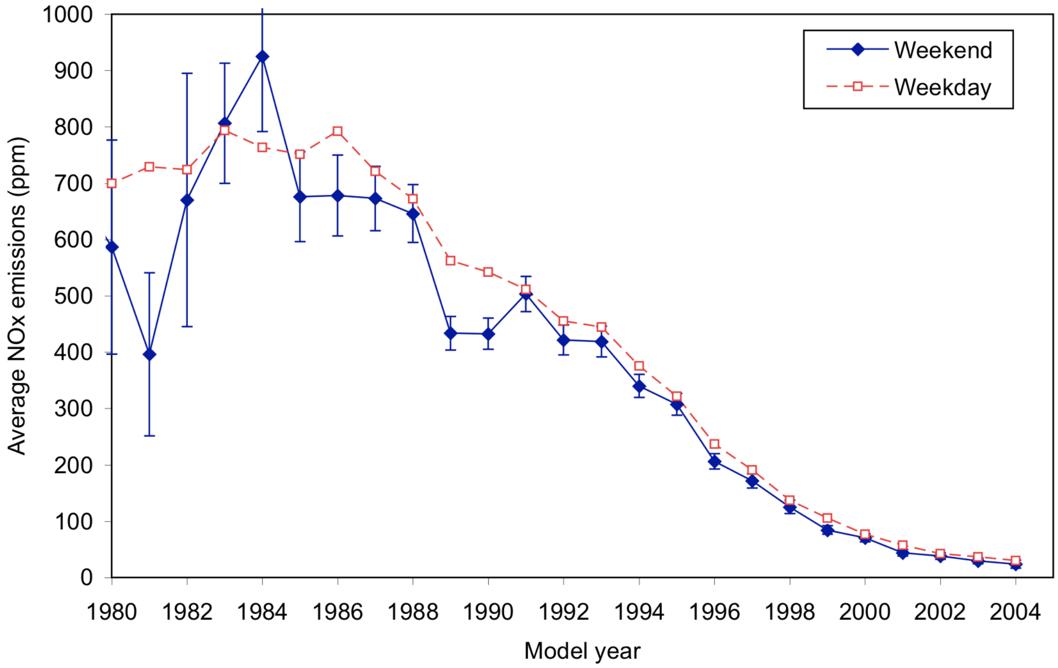


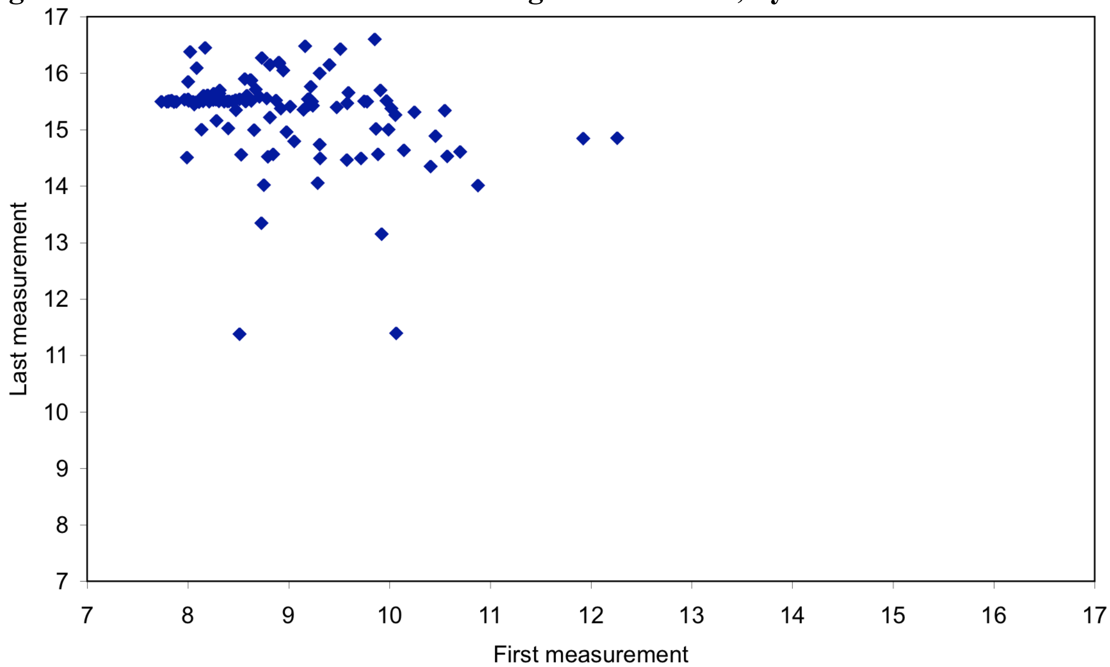
Figure 2.20. Average on-road NOx emissions of cars measured on weekdays and weekends, by model year



2.4. On-road fleet by time of day

In theory, remote sensing can also be used to compare the vehicles on-road during commute hours and non-commute hours. However, in this study the remote sensing vans were not consistently set up and recording information early enough to capture the morning rush hour, or late enough to capture the evening rush hour. Figure 2.21 indicates that only a few of the South Coast basin sites were operational before 7 am, and nearly half of the sites were not operational before 9 am. On the other hand, no sites were operational after 5 pm, with most operating until only 3:30 pm at the latest. Therefore we were not able to analyze vehicle distributions and emissions by time of day.

Figure 2.21. First and last remote sensing measurement, by site



2.5. On-road fleet by result of previous Enhanced Smog Check

Table 2.4 shows the number of measurements with valid emissions measurements and useable VSP readings, by the result of the current Smog Check cycle of each vehicle. Most vehicles were measured on-road after completing their previous Smog Check cycle; however, a small number of vehicles were measured on-road between the initial and final inspection in their Smog Check cycle. For example, only 3% of all fail-pass vehicles were measured on-road between their initial (failed) test and their final passing retest. However, about one-third of fail-fail vehicles, and one-quarter of pass-fail vehicles, were measured on-road between their initial and final test. Pass-pass and pass-fail vehicles passed their initial Smog Check test; however, because this was an official pretest, they had to pass a subsequent test.

Table 2.5. Number of measurements by Smog Check status and air basin

Result of Smog Check cycle	South Coast	San Diego	San Francisco	San Joaquin	Sacramento
Initial-pass	203,590	33,585	6,038	8,104	14,834
Pass-pass*	2,533	517	74	127	265
Fail-pass	28,738	3,589	648	1,162	1,541
Fail-no retest	461	122	27	38	62
Fail-fail	232	59	10	14	27
Pass-fail*	100	8	0	11	48
Undetermined	340	45	18	20	37
Total	235,994	37,925	6,815	9,476	16,814

* initial passing test is an official pretest.

Table 2.5 shows the distribution of on-road measurements by Smog Check status for each air basin. The bottom of the table indicates that between 2% and 8% of the on-road measurements are of vehicles that failed their initial test and either did not receive a subsequent retest or did not pass a subsequent retest ("no-final-pass" vehicles).

Table 2.6. Distribution of measurements by Smog Check status and air basin

Result of Smog Check cycle	South Coast	San Diego	San Francisco	San Joaquin	Sacramento
Initial-pass	86.3%	88.6%	88.6%	85.5%	88.2%
Pass-pass*	1.1%	1.4%	1.1%	1.3%	1.6%
Fail-pass	12.2%	9.5%	9.5%	12.3%	9.2%
Fail-no retest	0.2%	0.3%	0.4%	0.4%	0.4%
Fail-fail	0.1%	0.2%	0.1%	0.1%	0.2%
Pass-fail*	0.0%	0.0%	0.0%	0.1%	0.3%
Undetermined	0.1%	0.1%	0.3%	0.2%	0.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%
Fail rate	12.7%	10.1%	10.3%	13.1%	10.2%
No-final-pass rate (percent of initial fails)	2.7%	4.9%	5.3%	5.1%	8.0%

* initial passing test is an official pretest.

No-final-pass vehicles exist in all I/M programs. How these vehicles are ultimately disposed of can greatly affect estimates of the effectiveness of the I/M program. If most of these vehicles are permanently removed from the I/M program area, either through relocation, resale, or retirement, this is an often unquantified benefit of the program. However, if most of these vehicles continue to be driven regularly in the area, without fulfilling I/M requirements, they continue to contribute excess emissions to the emissions inventory. A previous analysis of the Enhanced Smog Check program indicated that about 1.3% of all vehicles, and 10% of initial fail vehicles, in 1998 and 1999 failed their initial test and did not pass a retest (Wenzel et al., 2000).

Previous studies have used a large number of remote sensing measurements to estimate the fraction of no-final-pass vehicles that continue to be driven in an I/M area (Wenzel et al., 2000; ENVIRON, 2003; ERG, 2005). We calculated the fraction of South Coast no-final-pass vehicles of all vehicles observed on-road, as a function of time since their last Smog Check test. Then we multiplied this percentage in each time period by the 1.3% of all vehicles that were no-final-pass. Figure 2.22 shows our estimate of the fraction of South Coast no-final-pass vehicles that continue to be driven in the South Coast. The figure suggests that about 20% of no-final-pass vehicles continue to be driven in the South Coast area one year after failing their initial Smog Check test, and about 10% continue to be driven two years after failing their initial Smog Check test. These percentages are very similar to estimates made for Phoenix (ERG, 2005) and Denver (ENVIRON, 2003), using remote sensing data. The registration status of these vehicles could be tracked to determine what fraction are chronically unregistered versus permanently removed from California.

Figure 2.22. Estimated fraction of South Coast no-final-pass vehicles still on road, by time since failed previous Smog Check

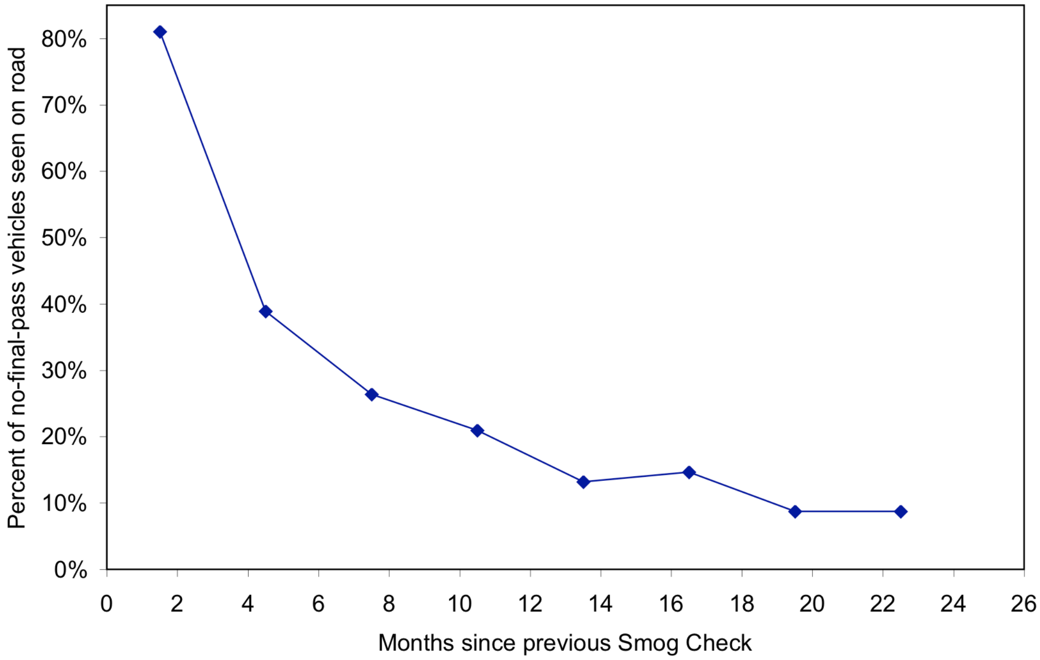
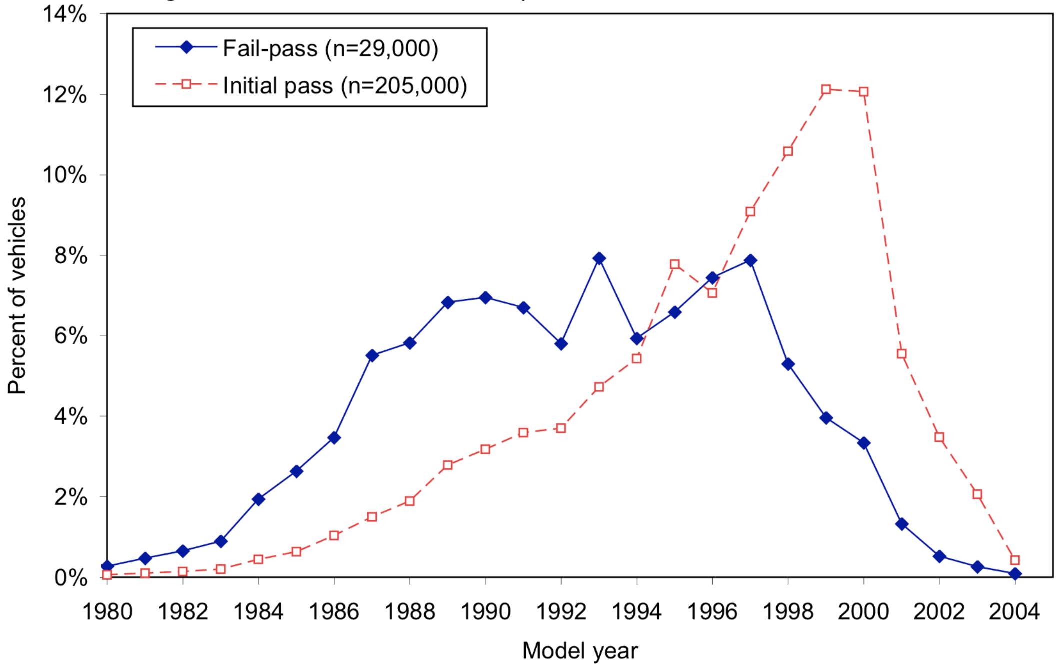


Figure 2.23 shows the model year distribution of on-road measurements of vehicles registered in the South Coast basin, by Smog Check status. As expected, vehicles that pass the initial inspection in their previous Smog Check cycle tend to be newer than vehicles that fail their initial inspection.

Figure 2.23. Model year distribution of South Coast vehicles measured on-road, by previous Smog Check result and model year



Figures 2.24 through 2.26 compare the average remote sensing emissions of initial-pass and fail-pass vehicles. The figures indicate that fail-pass vehicles have consistently, significantly higher on-road emissions than initial-pass vehicles. Previous analysis of VID data indicates that fail-pass vehicles have about the same, or slightly higher, emissions on their passing retest as initial-pass vehicles (Wenzel et al., 2000). The fail-pass vehicles have higher on-road emissions than the initial-pass vehicles because the remote sensing measurement is often made several months after the vehicle passed its retest, and thus includes some emission deterioration that occurs after repairs are made and the vehicle passes Smog Check. The difference in emissions of initial-pass and fail-pass vehicles in their previous Smog Check is greater for NOx than for HC or CO.

Figure 2.24. Average on-road HC emissions of South Coast vehicles, by previous Smog Check result and model year

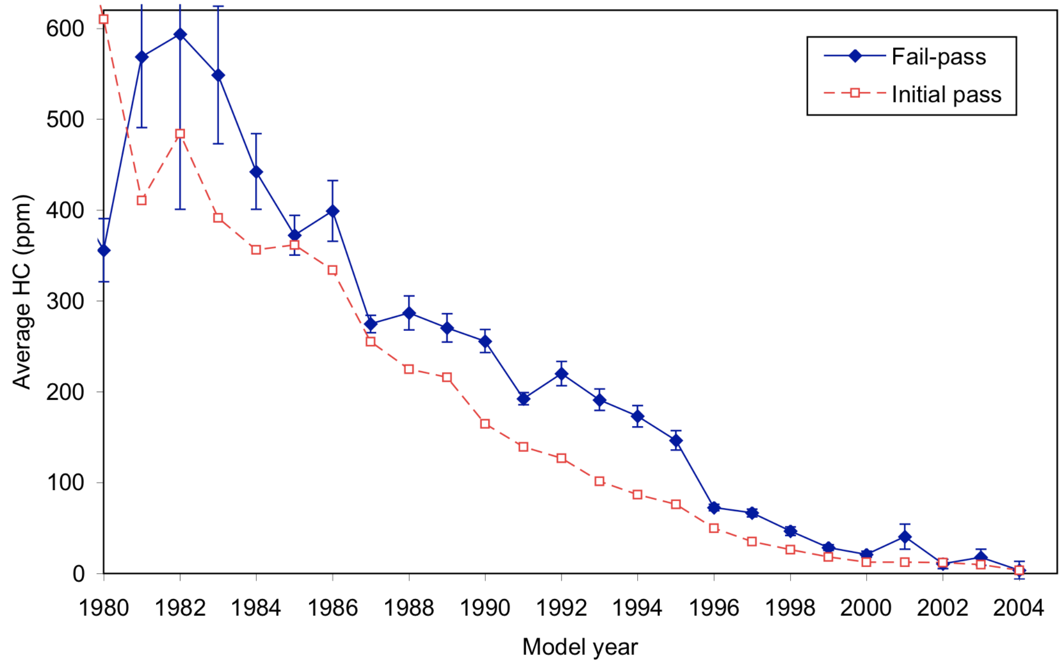


Figure 2.25. Average on-road CO emissions of South Coast vehicles, by previous Smog Check result and model year

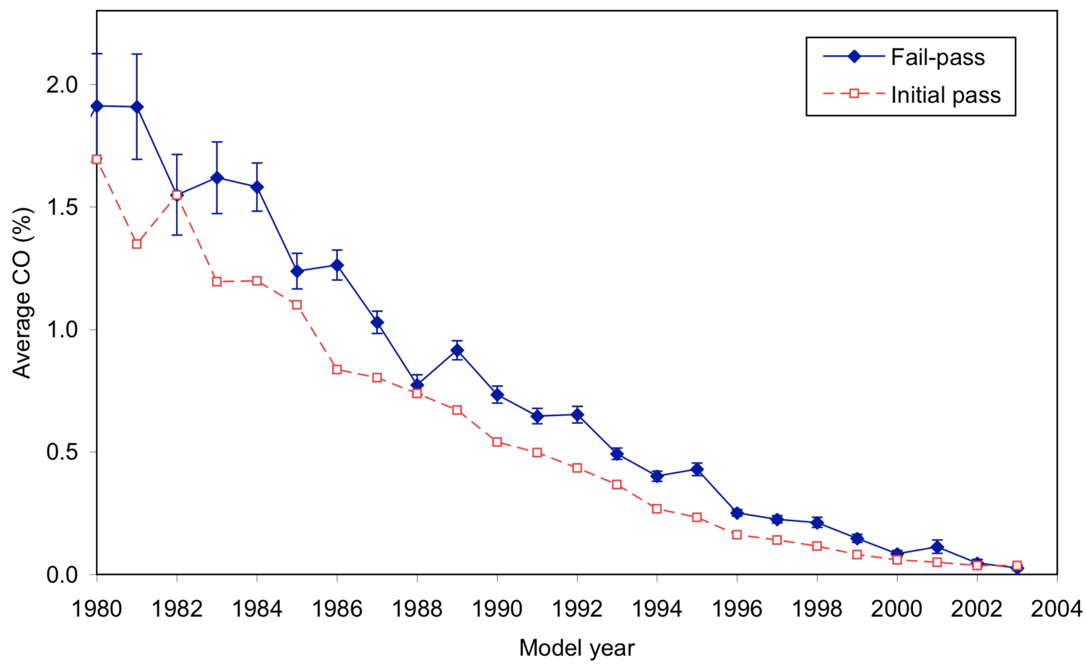
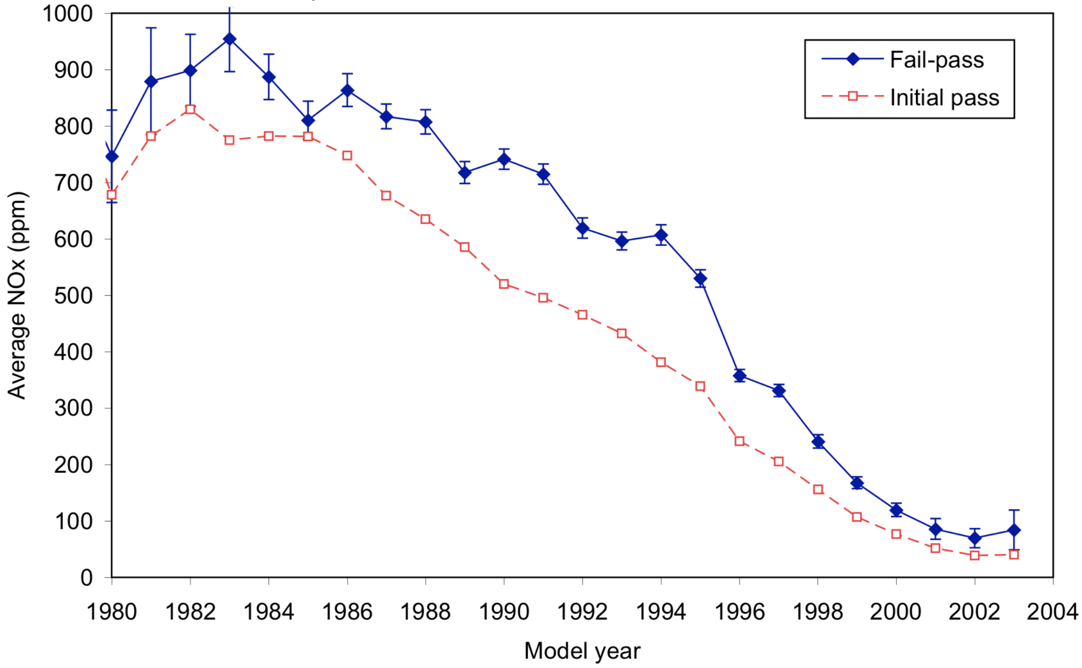


Figure 2.26. Average on-road NOx emissions of South Coast vehicles, by previous Smog Check result and model year



2.6. On-road fleet by median owner income (by zip code)

Vehicle distributions and on-road emissions can also be analyzed by the income of the vehicle owner. The median household income for the zip code in which each vehicle is registered can be readily obtained from the latest US Census, and used to approximate the income of the vehicle owner. Analysis by income was outside the scope of the current contract.

3. Estimate emission reductions of the Enhanced Smog Check program

One question arising from the objectives of this project is whether remote sensing data can be used to independently estimate the effectiveness of an I/M program. USEPA has published a guidance document summarizing three methods to estimate I/M benefits: the step method, that compares on-road emissions before and after a change in an I/M program; the comprehensive method, that compares on-road emissions as a function of time before and after I/M testing; and the reference method, that compares on-road emissions of vehicles in an I/M area with those of vehicles in a non-I/M area (USEPA, 2004; Wenzel, 2003). Since EPA has issued guidance on this use of RSD for this purpose, states are allowed to do so. Because all of the remote sensing sites used in the study were located in, and nearly all vehicles measured on road were registered in, enhanced areas of the state, this analysis estimates emission reductions from the Enhanced Smog Check program, using a combination of the step and comprehensive methods. We also estimate the incremental benefit from changing the Basic program in the San Francisco Bay Area to an Enhanced program.

Previous research has demonstrated that emission reduction benefits are largest immediately after vehicles pass their I/M inspection, since emissions tend to increase shortly thereafter (Wenzel et al., 2003; Wenzel, 2004). Figures 3.1 through 3.3 show average emissions for cars registered in the South Coast and San Diego basins (including initial-pass and fail-pass vehicles), as a function of time since their previous I/M test. (The heavy lines in the figures are averaged over three-month time periods rather than one-month time periods.) The figures indicate that, for all pollutants, on-road emissions decrease in the first six months after Smog Check, then gradually increase.

Figure 3.1. Average HC emissions of cars registered in South Coast and San Diego, as a function of time since previous I/M test

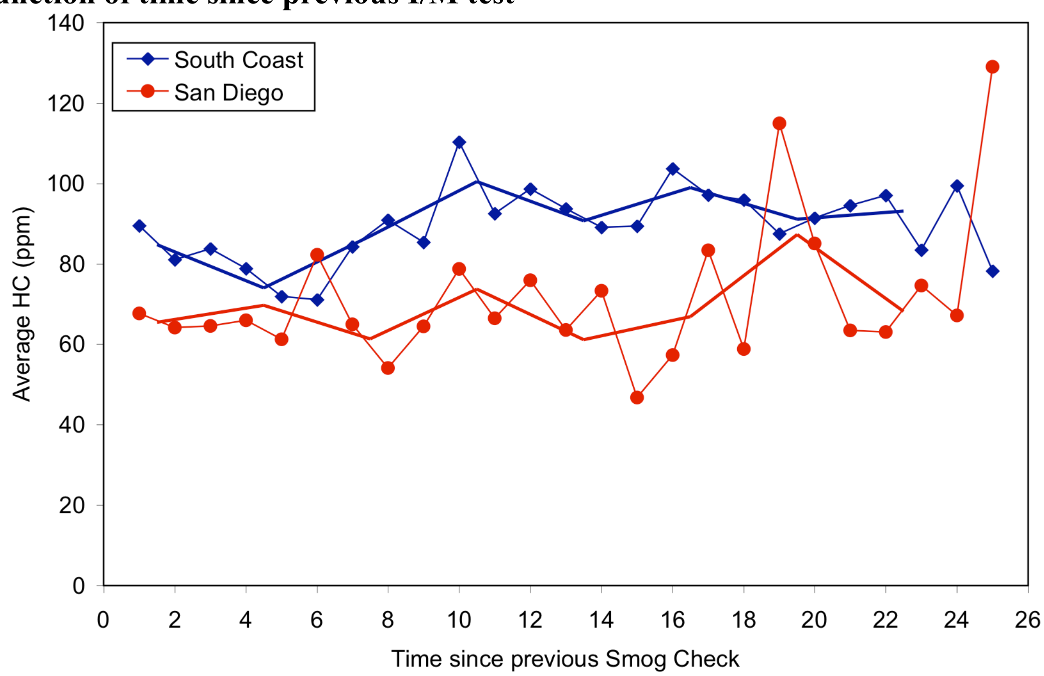


Figure 3.2. Average CO emissions of cars registered in South Coast and San Diego, as a function of time since previous I/M test

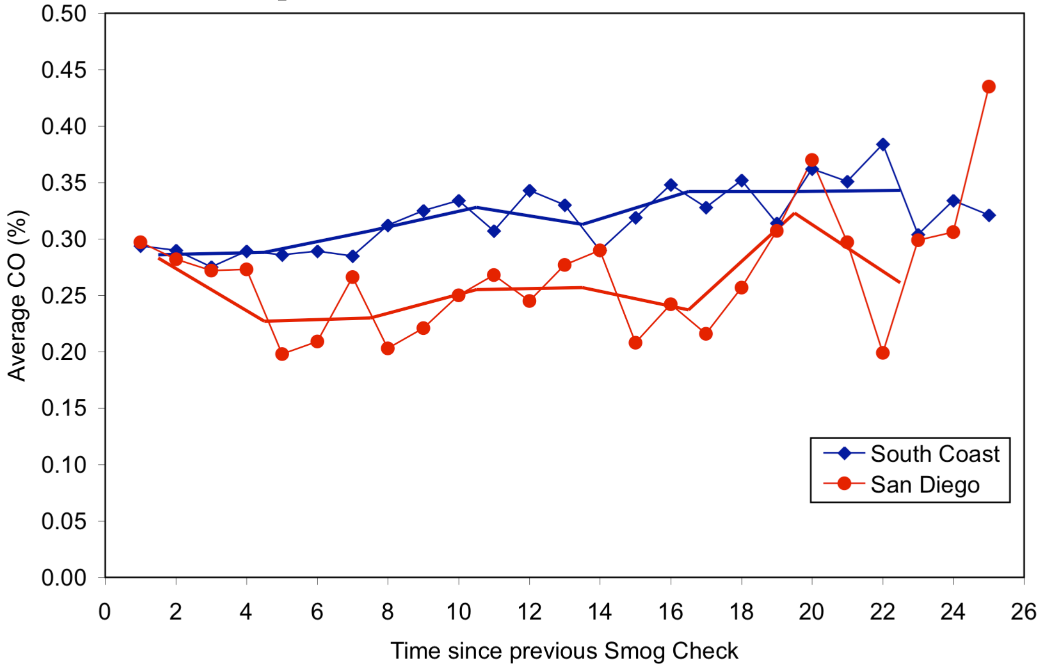
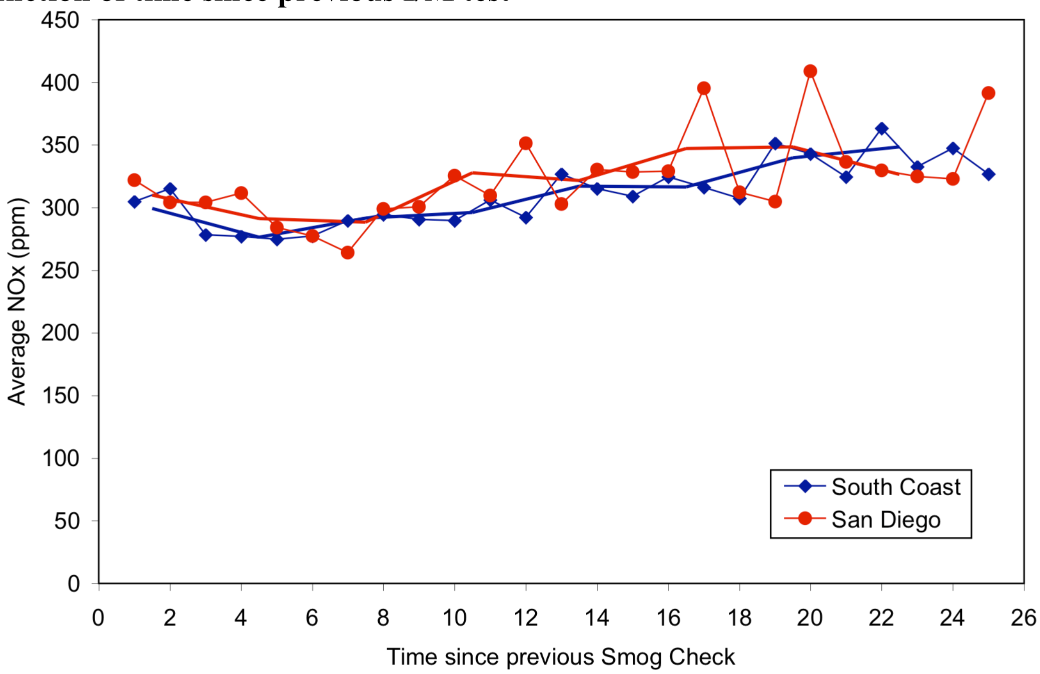


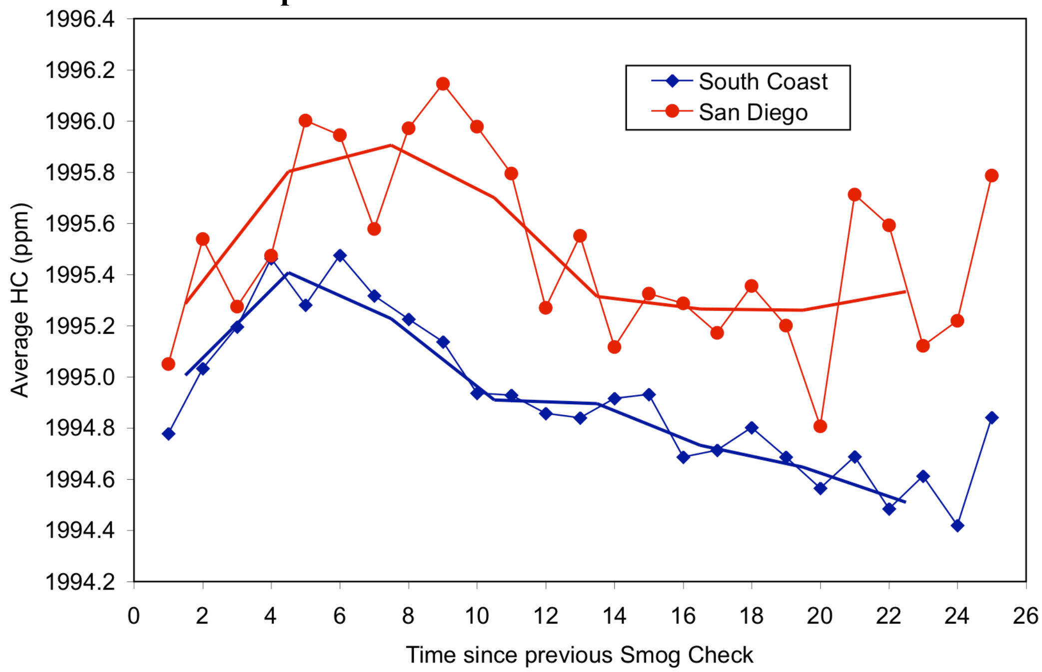
Figure 3.3. Average NOx emissions of cars registered in South Coast and San Diego, as a function of time since previous I/M test



One reason for the lack of a consistent trend is that a different set of vehicles is tested at each time period; Figure 3.4 shows that the cars in each basin tested one month after their previous Smog Check are about one year older than the cars tested about six months after their previous Smog Check. This may be a result of older vehicles being permanently removed from the Smog

Check areas in the first few months after they pass their Smog Check. Thus vehicle age may partially account for the decrease in emissions in the first six months after the previous Smog Check, in Figures 3.1 through 3.3. Normalizing for the same model year distribution in each time period may reduce the fluctuation in emissions seen in Figures 3.1 through 3.3. We do this in the following analysis for the South Coast air basin.

Figure 3.4. Average model year of cars registered in South Coast and San Diego, as a function of time since previous I/M test



Since emissions tend to increase as a function of time since the last Smog Check inspection, the estimated benefit of Smog Check will change depending on when vehicles are measured on-road. To estimate the percent reduction from the Smog Check program, we compared two sets of vehicles in each basin: vehicles measured on-road up to three months (on average 1.5 months) after their previous Smog Check with those measured on-road up to three months before their next Smog Check (or 21 to 24 months after their previous Smog Check); and vehicles measured on-road up to one year (on average 6 months) after their previous Smog Check with those measured on-road up to one year before their next Smog Check (or 12 to 24 months after their previous Smog Check). If emissions increase consistently as a function of time since the previous Smog Check, one would expect the difference in before and after emissions to be greater for the "up to three month" analysis than for the "up to one year" analysis.

The following three tables (3.1 through 3.3) summarize our analysis of the effectiveness of the Enhanced Smog Check program in the South Coast air basin, using concentration, site-adjusted concentration, and gram per gallon emissions. Average emissions are weighted by the model year distribution of vehicles measured on-road after the previous Smog Check; the reason for the normalization is shown in Figure 3.4.

Several observations can be made about Tables 3.1 through 3.3:

- Although the absolute emissions levels vary depending on which measurement (raw concentrations, site-adjusted concentrations, or grams per gallon) is used, the percent changes in emissions are very consistent between Tables 3.1, 3.2, and 3.3.
- In virtually all cases emissions after Enhanced Smog Check are lower than emissions before Enhanced Smog Check, resulting in emission reductions. However, only CO and NOx emission reductions in the 3-month analysis, and car NOx reductions and light truck reductions for all three pollutants in the 12-month analysis, are statistically significant (differences that are not statistically significant at the 95% confidence interval are shown in gray).
- Light trucks have consistently lower emissions, but larger emission reductions, than cars. This is because the light truck on road fleet tends to be newer than that for cars. For the most part, average emissions by model year are higher for light trucks than for cars (see Figures 3-13 through 3-16).
- Including the older model years (1972 to 1983) in the analysis increases the absolute emissions, but has little impact on the percent emission reductions.
- Percent emission reductions using on-road measurements up to 3 months before and after Enhanced Smog Check are larger than when using measurements up to 12 months before and after; the exception is for HC emissions, particularly for light trucks, where the 3-month analysis shows 3% reductions but the 12-month analysis shows a 12% reduction.

Table 3.1. Average remote sensing concentration emissions of South Coast light-duty vehicles, by vehicle type and relation to previous Enhanced Smog Check

Time period	Model years	Vehicle type	Before HC	Before CO	Before NOx	After HC	After CO	After NOx	Difference HC	Difference CO	Difference NOx
3 month	1984-03	Cars	81	0.31	329	80	0.28	295	-1.9%	-9.3%	-10.5%
		LDTs	76	0.25	320	74	0.22	272	-2.7%	-12.4%	-15.0%
	1972-03	Cars	85	0.32	334	86	0.29	303	0.4%	-10.0%	-9.5%
		LDTs	81	0.26	325	78	0.23	277	-3.9%	-11.8%	-14.9%
12 month	1984-03	Cars	82	0.30	306	81	0.29	286	-0.8%	-2.9%	-6.6%
		LDTs	81	0.25	297	72	0.22	277	-11.6%	-8.7%	-6.9%
	1972-03	Cars	88	0.31	313	87	0.30	293	-1.0%	-3.6%	-6.4%
		LDTs	86	0.26	304	77	0.24	283	-10.5%	-6.9%	-7.0%

Table 3.2. Average remote sensing site-adjusted concentration emissions of South Coast light-duty vehicles, by vehicle type and relation to previous Enhanced Smog Check

Time period	Model years	Vehicle type	Before HC	Before CO	Before NOx	After HC	After CO	After NOx	Difference HC	Difference CO	Difference NOx
3 month	1984-03	Cars	80	0.31	328	79	0.28	294	-1.7%	-9.3%	-10.5%
		LDTs	76	0.25	319	73	0.22	271	-4.0%	-12.4%	-15.1%
	1972-03	Cars	84	0.32	333	84	0.29	302	0.6%	-10.1%	-9.5%
		LDTs	81	0.26	324	77	0.23	275	-5.1%	-11.9%	-15.1%
12 month	1984-03	Cars	81	0.30	305	80	0.29	285	-0.9%	-2.9%	-6.6%
		LDTs	80	0.25	297	70	0.22	276	-11.8%	-8.6%	-6.9%
	1972-03	Cars	86	0.31	312	86	0.30	292	-1.1%	-3.6%	-6.4%
		LDTs	84	0.26	303	75	0.24	282	-10.7%	-6.8%	-7.1%

Table 3.3. Average remote sensing gram per gallon emissions of South Coast light-duty vehicles, by vehicle type and relation to previous Enhanced Smog Check

Time period	Model years	Vehicle type	Before HC	Before CO	Before NOx	After HC	After CO	After NOx	Difference HC	Difference CO	Difference NOx
3 month	1984-03	Cars	8.7	104.5	12.8	8.6	95.6	11.4	-1.9%	-8.6%	-10.5%
		LDTs	8.2	85.1	12.4	7.9	75.0	10.6	-4.0%	-11.9%	-14.9%
	1972-03	Cars	9.2	109.7	13.0	9.1	99.5	11.7	-0.3%	-9.2%	-9.5%
		LDTs	8.7	89.1	12.6	8.3	79.0	10.7	-4.1%	-11.3%	-14.9%
12 month	1984-03	Cars	8.7	101.8	11.9	8.6	99.1	11.1	-2.0%	-2.7%	-6.6%
		LDTs	8.7	83.9	11.5	7.7	77.1	10.8	-10.7%	-8.0%	-6.7%
	1972-03	Cars	9.3	107.3	12.1	9.1	103.7	11.3	-1.9%	-3.3%	-6.4%
		LDTs	9.1	87.9	11.8	8.2	82.2	11.0	-9.8%	-6.4%	-6.9%

Tables 3.4 through 3.6 show comparable results for vehicles registered in the San Diego air basin:

- The percent changes in emissions are fairly consistent between Tables 3.4, 3.5, and 3.6.
- In most cases emissions after Enhanced Smog Check are lower than emissions before Enhanced Smog Check, resulting in emission reductions; however, this is not the case for car CO and light truck HC in the 3-month analysis, or car HC in the 12-month analysis. However, none of the emission reductions in Tables 3.4 through 3.6 are statistically significant (differences that are not statistically significant at the 95% confidence interval are shown in gray).
- Light trucks have lower HC and CO emissions, but higher NOx emissions, than cars. Light trucks have larger emission reductions than cars in all cases except for HC in the 3-month analysis. Again, this is because the average age of the on-road light truck fleet is younger than that of the on-road car fleet; emissions by model year are higher for light trucks than for cars (see Figures 3-13 through 3-16).
- Including the older model years (1972 to 1983) lowers the emission reductions for car HC and light truck CO in the 3-month analysis.
- Emission reductions in the 3-month analysis are larger than in the 12-month analysis, with the exceptions of car CO and light truck HC.

Table 3.4. Average remote sensing concentration emissions of San Diego light-duty vehicles, by vehicle type and relation to previous Enhanced Smog Check

Time period	Model years	Vehicle type	Before HC	Before CO	Before NOx	After HC	After CO	After NOx	Difference HC	Difference CO	Difference NOx
3 month	1984-03	Cars	66	0.25	315	63	0.28	304	-5.4%	10.9%	-3.4%
		LDTs	59	0.25	354	61	0.22	324	3.0%	-13.7%	-8.4%
	1972-03	Cars	66	0.25	314	66	0.28	310	-0.4%	14.0%	-1.3%
		LDTs	60	0.25	355	64	0.23	328	5.6%	-7.3%	-7.4%
12 month	1984-03	Cars	64	0.26	308	64	0.24	299	0.9%	-4.8%	-3.2%
		LDTs	54	0.21	319	53	0.20	307	-1.7%	-6.4%	-3.6%
	1972-03	Cars	66	0.26	314	68	0.25	305	2.1%	-4.8%	-2.9%
		LDTs	57	0.22	324	56	0.21	312	-2.3%	-4.3%	-3.8%

Table 3.5. Average remote sensing site-adjusted concentration emissions of San Diego light-duty vehicles, by vehicle type and relation to previous Enhanced Smog Check

Time period	Model years	Vehicle type	Before HC	Before CO	Before NOx	After HC	After CO	After NOx	Difference HC	Difference CO	Difference NOx
3 month	1984-03	Cars	60	0.25	318	57	0.28	307	-5.1%	11.1%	-3.4%
		LDTs	54	0.25	357	56	0.21	327	4.7%	-13.9%	-8.5%
	1972-03	Cars	59	0.25	318	60	0.28	314	0.4%	14.2%	-1.3%
		LDTs	55	0.25	358	59	0.23	331	7.4%	-7.5%	-7.5%
12 month	1984-03	Cars	57	0.26	312	58	0.24	302	1.4%	-5.0%	-3.2%
		LDTs	49	0.21	322	48	0.20	310	-1.2%	-6.5%	-3.7%
	1972-03	Cars	60	0.26	318	62	0.25	308	2.8%	-5.0%	-2.9%
		LDTs	52	0.22	327	51	0.21	315	-1.8%	-4.4%	-3.9%

Table 3.6. Average remote sensing gram per gallon emissions of San Diego light-duty vehicles, by vehicle type and relation to previous Enhanced Smog Check

Time period	Model years	Vehicle type	Before HC	Before CO	Before NOx	After HC	After CO	After NOx	Difference HC	Difference CO	Difference NOx
3 month	1984-03	Cars	7.3	86.7	12.2	6.8	94.9	11.8	-6.3%	9.4%	-3.4%
		LDTs	6.6	85.4	13.8	6.7	74.1	12.6	2.1%	-13.3%	-8.3%
	1972-03	Cars	7.3	86.4	12.2	7.2	97.2	12.1	-1.4%	12.5%	-1.3%
		LDTs	6.7	86.5	13.8	7.0	80.3	12.8	4.5%	-7.1%	-7.3%
12 month	1984-03	Cars	6.9	88.2	12.0	6.9	84.0	11.6	-0.1%	-4.7%	-3.1%
		LDTs	6.0	72.8	12.4	5.9	68.0	12.0	-1.9%	-6.7%	-3.6%
	1972-03	Cars	7.2	89.9	12.2	7.3	85.8	11.8	1.2%	-4.5%	-2.9%
		LDTs	6.3	74.5	12.6	6.1	71.0	12.1	-2.2%	-4.7%	-3.8%

Table 3.7 compares the on-road emissions of vehicles measured up to 12 months after Enhanced Smog Check with those vehicles with no Enhanced Smog Check record. The analysis is made using the raw emissions concentrations, and includes the San Francisco air basin. The table indicates that, in the South Coast basin, vehicles that had not yet received an Enhanced Smog Check have higher HC and NOx (especially for light trucks), but the same or lower CO, than vehicles that were measured on-road after an Enhanced Smog Check. For San Diego vehicles, vehicles without an Enhanced Smog Check inspection have higher HC and CO, but lower NOx, than vehicles that had received an Enhanced Smog Check.

Because the San Francisco air basin went from a Basic to an Enhanced Smog Check program in October 2003 there are very few vehicles registered in that basin that had an Enhanced Smog Check 12 to 24 months prior to the on-road measurement in November 2004. Therefore, we had to compare San Francisco basin vehicles that were measured on road up to 12 months after an Enhanced Smog Check with vehicles that had not yet received an Enhanced Smog Check. Table 3.7 indicates that, for vehicles registered in the San Francisco basin:

- The percent changes in emissions are fairly consistent regardless of which of the three emission measurements are used; however, light truck HC emission reductions are 27% using raw or adjusted concentration emissions, but only 16% when using gram per gallon emissions (not shown).

- Light truck emissions after Enhanced Smog Check are much lower (27% lower HC, 18% lower CO, and 14% lower NOx) than trucks not given an Enhanced Smog Check; however, car emissions after Enhanced Smog Check are higher (6% higher HC, 7% higher CO, and 3% higher NOx) than cars not given an Enhanced Smog Check. However, only the NOx emission reduction for light trucks is statistically significant (differences that are not statistically significant at the 95% confidence interval are shown in gray).
- Light trucks without an Enhanced Smog Check have the same or higher emissions (especially HC and NOx) than cars, but consistently lower emissions after Enhanced Smog Check than cars.
- Including the older model years (1972 to 1983) in the analysis little impact on the emission reductions.

Table 3.7. Average remote sensing concentration emissions of light-duty vehicles measured on-road up to one year after Enhanced Smog Check and with no previous Enhanced Smog Check, by air basin and vehicle type

Air basin	Model years	Number	No Smog Check HC	No Smog Check CO	No Smog Check NOx	After HC	After CO	After NOx	Difference HC	Difference CO	Difference NOx
South Coast	1984-03	Cars	88	0.28	295	81	0.29	286	-7.6%	1.4%	-3.1%
		LDTs	84	0.23	358	72	0.22	277	-14.0%	-1.6%	-22.6%
	1972-03	Cars	93	0.30	301	87	0.30	293	-7.1%	1.9%	-2.7%
		LDTs	89	0.24	364	77	0.24	283	-13.4%	-0.6%	-22.3%
San Diego	1984-03	Cars	64	0.24	309	64	0.24	299	0.5%	0.6%	-3.3%
		LDTs	50	0.18	346	53	0.20	307	5.9%	8.2%	-11.1%
	1972-03	Cars	67	0.25	312	68	0.25	305	1.5%	1.3%	-2.5%
		LDTs	53	0.19	350	56	0.21	312	5.5%	8.7%	-11.0%
San Francisco	1984-03	Cars	69	0.24	281	73	0.26	285	5.8%	6.7%	1.6%
		LDTs	83	0.23	321	60	0.20	269	-27.4%	-15.1%	-16.0%
	1972-03	Cars	70	0.24	284	74	0.26	292	5.9%	7.2%	3.0%
		LDTs	86	0.24	333	63	0.21	273	-26.8%	-13.9%	-17.9%

Figure 3.5 shows the model year distribution of on-road vehicles registered in the South Coast basin, by the relationship of their measurement on-road to their Enhanced Smog Check inspection. The figure indicates that, starting in model year 1995, Smog Check testing appears to be on an even-odd model year cycle in each calendar year, with even model years tested in even calendar years. The figure also indicates that most of the vehicles with no previous Smog Check inspection are exempted model years (model years 2001 and newer in 2004). Figure 3.6 shows the model year distribution for vehicles registered in the San Francisco Basin. Here, the even-odd model year cycle is more severe, and the distribution of vehicles not yet given an Enhanced Smog Check is much less skewed to the newer model years, as expected.

Figure 3.5. Model year distribution of cars registered in South Coast basin by relation to Enhanced Smog Check test

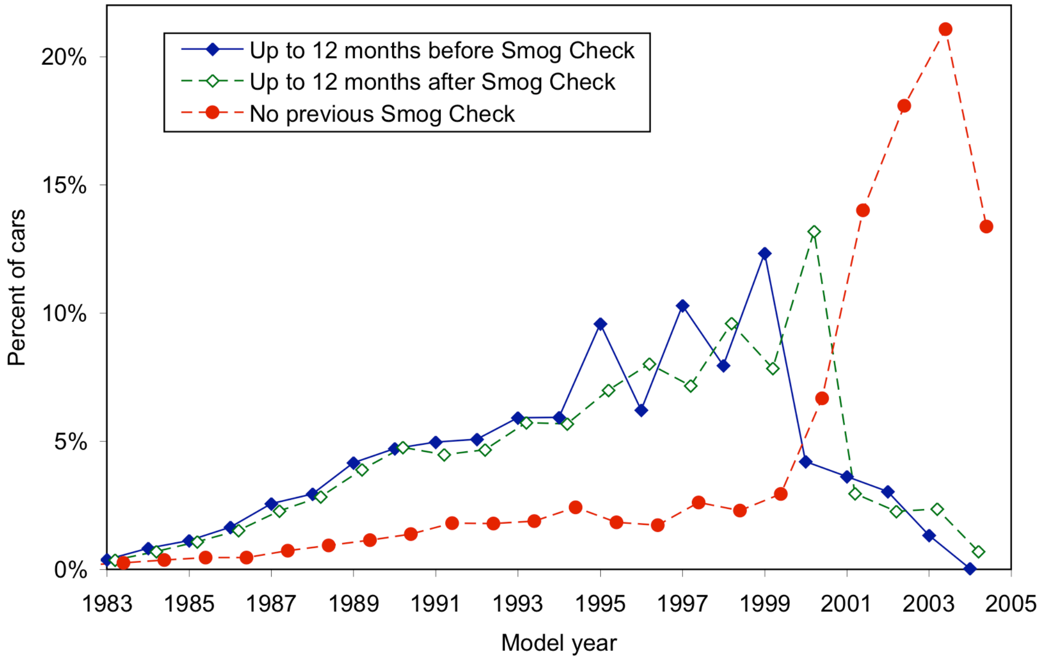
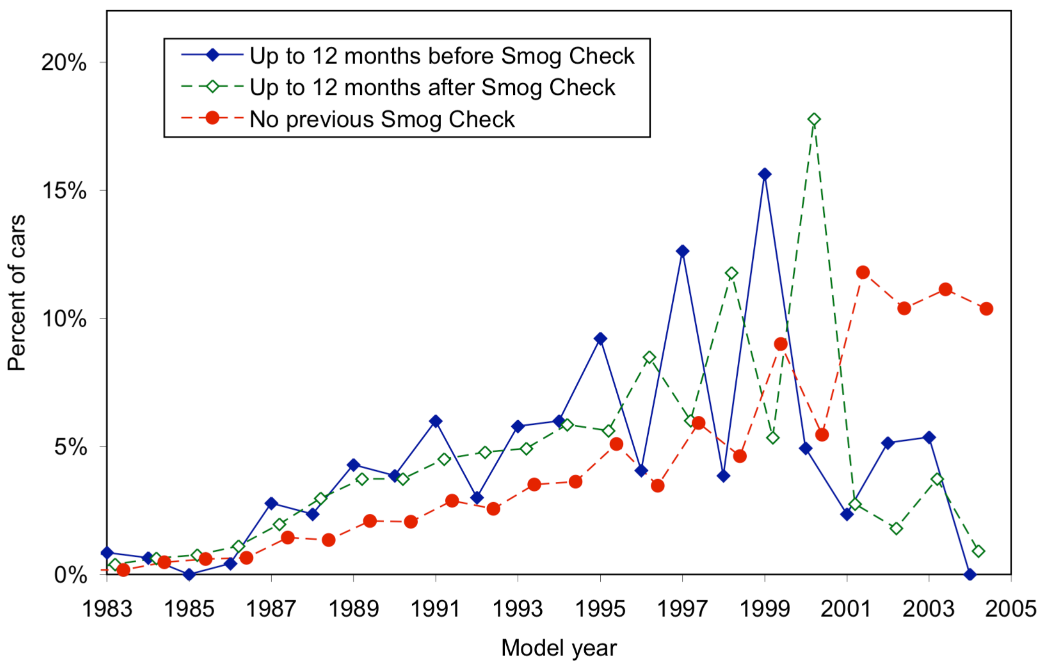


Figure 3.6. Model year distribution of cars registered in San Francisco basin by relation to Enhanced Smog Check test



Figures 3.7 through 3.12 show selected comparisons of raw remote sensing emission concentrations by model year and relation to Enhanced Smog Check, for vehicles registered in the South Coast basin. Figures 3.7 and 3.8 present the 3- and 12-month analyses for car HC emissions, Figures 3.9 and 3.10 the 3- and 12-month analyses for car NOx emissions, and

Figures 3.11 and 12 the 3- and 12-month analyses for light truck NOx emissions. The bars in each figure represent the standard error of each mean emission value.

In Table 3.1 there is an overall 1.9% reduction in car HC emissions; however, this difference is not statistically significant. Figure 3.7 shows that there is no consistent difference in the emissions by model year. Note that the 2001 and newer cars measured up to 3 months before Enhanced Smog Check have consistently substantially lower emissions than cars measured up to 3 months after Enhanced Smog Check. We obtained the same result when we used the site-adjusted emission concentrations.

In Table 3.7, cars measured on road up to 12 months after Enhanced Smog Check have HC emissions 7.6% lower overall than those with no Enhanced Smog Check; this difference is statistically significant. Figure 3.8 shows that most of this difference is from big differences in a few model years (1987 through 1989, and 1995).

Figure 3.7. Average South Coast car remote sensing HC emissions by model year, in relation to Enhanced Smog Check test (measured on road up to three months before or after Enhanced Smog Check)

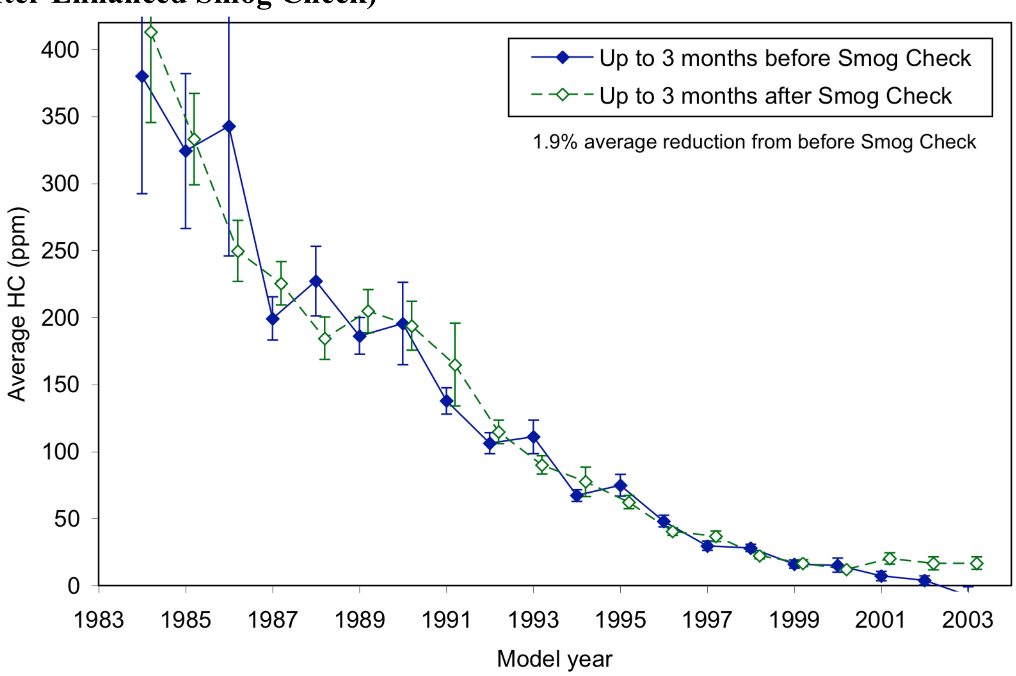
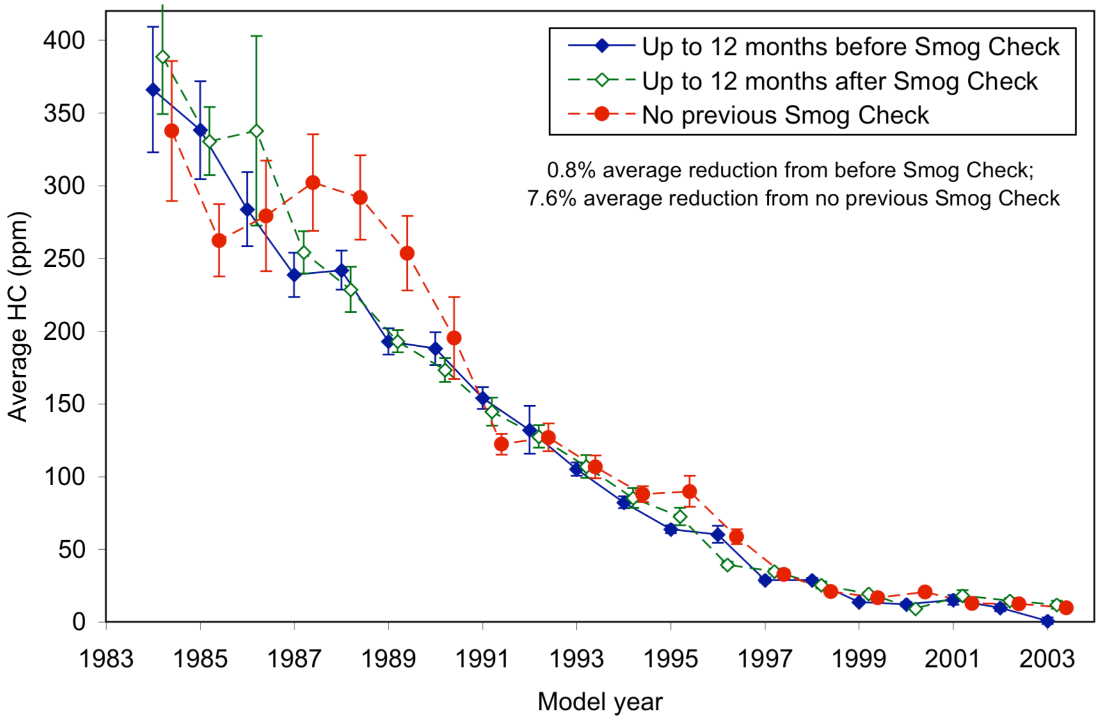


Figure 3.8. Average South Coast car remote sensing HC emissions by model year, in relation to Enhanced Smog Check test (measured on road up to twelve months before or after Enhanced Smog Check, or no previous Enhanced Smog Check)



Figures 3.9 and 3.10 show similar results for car NOx emissions; although the overall emissions reductions are substantial and statistically significant (10.5% in Figure 3.9 and 3.1% in Figure 3.10), emissions are not reduced consistently for all model years, with most of the reduction from substantial (and statistically significant) reductions in a handful of model years (1989, 1990, 1992, 1993, and 2000 in Figure 3.9; 1994, 1995, and 1997 in Figure 3.10).

Figure 3.9. Average South Coast car remote sensing NOx emissions by model year, in relation to Enhanced Smog Check test (measured on road up to three months before or after Enhanced Smog Check)

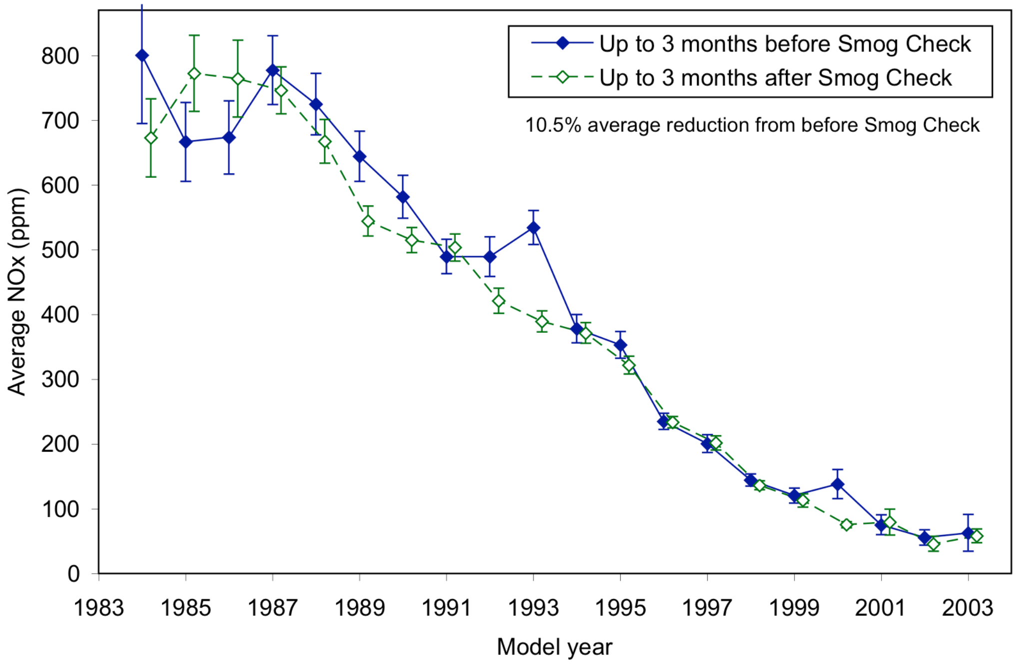
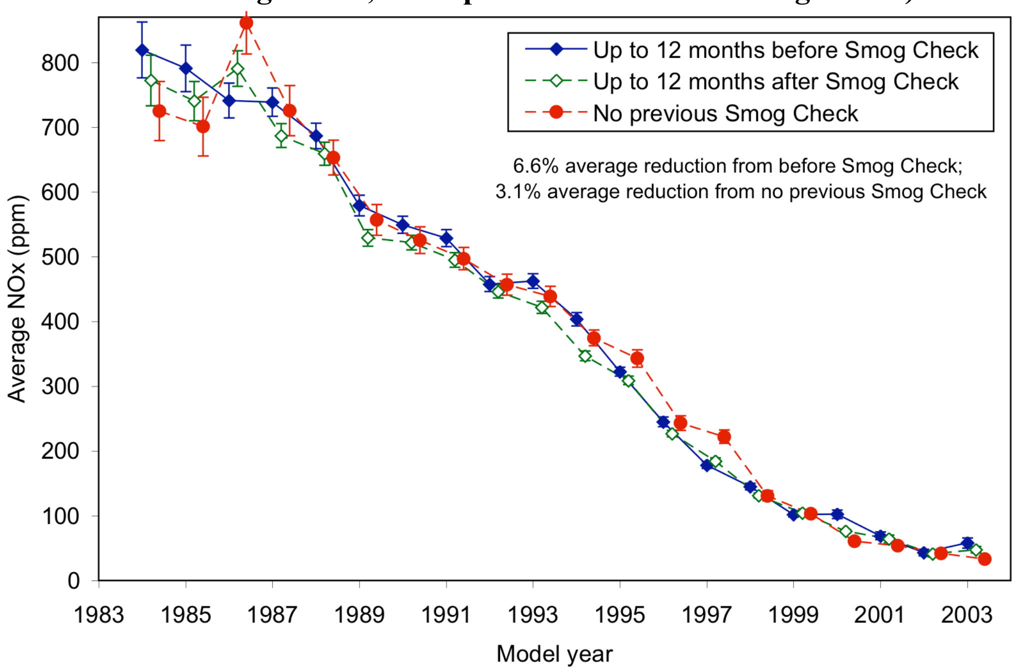


Figure 3.10. Average South Coast car remote sensing NOx emissions by model year, in relation to Enhanced Smog Check test (measured on road up to twelve months before or after Enhanced Smog Check, or no previous Enhanced Smog Check)



The largest emission reductions in Tables 3.1 and 3.7 are for NOx emissions from light trucks; these reductions are statistically significant. Figures 3.11 and 3.12 show that the NOx emission reductions are consistent and statistically significant for most model years.

Figure 3.11. Average South Coast light truck remote sensing NOx emissions by model year, in relation to Enhanced Smog Check test (measured on road up to three months before or after Enhanced Smog Check)

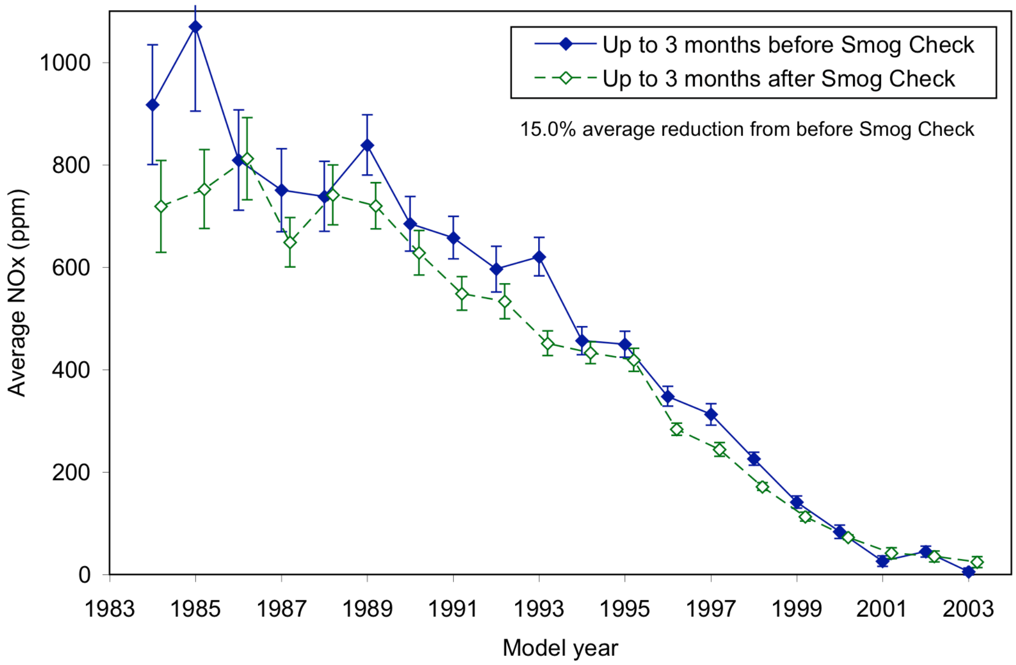
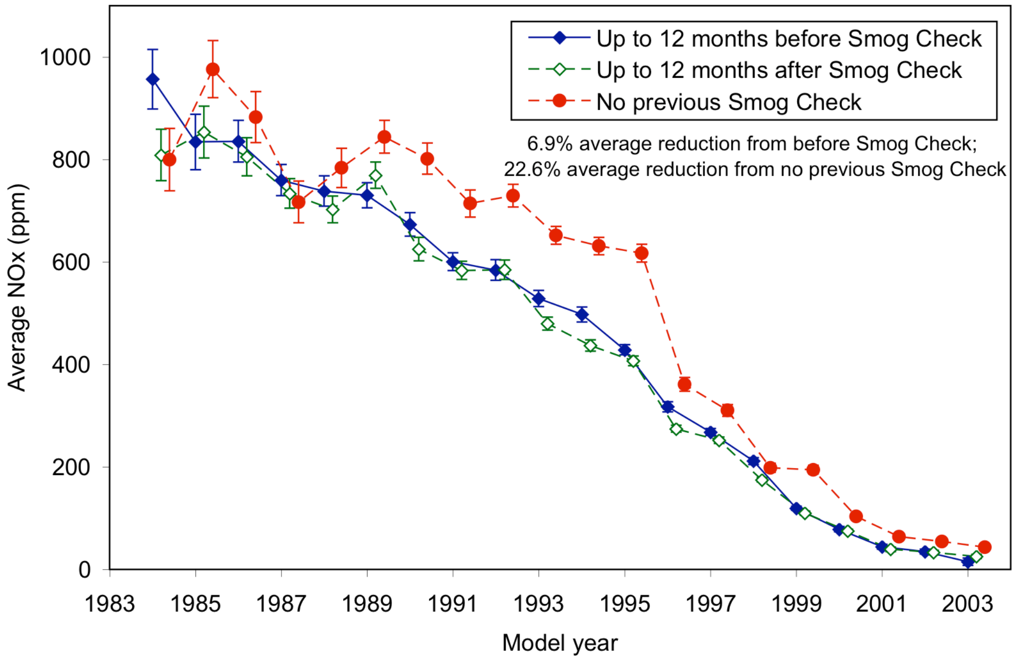


Figure 3.12. Average South Coast light truck remote sensing NOx emissions by model year, in relation to Enhanced Smog Check test (measured on road up to twelve months before or after Enhanced Smog Check, or no previous Enhanced Smog Check)



The analysis above indicates that, if measured soon before or after Smog Check, on-road emissions indicate a larger benefit from the program than if vehicles are measured further before or after Smog Check. This is consistent with previous analyses that suggest that emissions increase substantially shortly after vehicles pass their I/M inspection. The on-road measurements indicate that emission benefits tend to be greater for light trucks than for cars; this may be a result of the stringency of Enhanced Smog Check cut points for light trucks relative to those for cars. Finally, for the San Diego and San Francisco air basins, the results are not consistent for both cars and light trucks, or for all pollutants. There were not enough on-road measurements of vehicles registered in these basins to estimate the effectiveness of the Enhanced Smog Check program in these basins. Table 3.8 shows the number of on-road measurements with valid emissions values and useable vehicle specific power (between 5 and 25 kW per tonne), by air basin, vehicle type and relation to Enhanced Smog Check. It appears that at least 10,000, and perhaps as many as 20,000, measurements of cars from I/M-eligible model years are needed both before and after Smog Check to get consistent results by model year. Because cars represent more than half of the light-duty fleet, at least 20,000 to 40,000 measurements of light-duty vehicles are required.

Table 3.8. Number of on-road measurements, by air basin, vehicle type, and relation to Enhanced Smog Check

Air basin	Time period	Vehicle type	Number of useable on-road measurements: Before Smog Check	After Smog Check	No Smog Check
South Coast	3 month	Cars	10,134	19,218	
		LDTs	7,519	14,190	
	12 month	Cars	53,854	72,680	78,099
		LDTs	40,022	53,836	88,267
San Diego	3 month	Cars	1,838	2,985	
		LDTs	1,195	1,939	
	12 month	Cars	9,364	11,743	13,051
		LDTs	6,101	7,906	14,299
San Francisco	12 month	Cars	467	4,067	8,750
		LDTs	242	1,961	6,161

Figures 3.13 through 3.16 compare the model year distribution and average emissions of cars and light trucks, for South Coast vehicles measured on road up to three months before or after Enhanced Smog Check. Figure 3-13 indicates that on-road light trucks are younger (on average, one year younger) than on-road cars; this is a result of the increasing popularity of SUVs and pickup trucks. Figures 3-14 through 3-16 show that average emissions by model year are consistently higher for light trucks than for cars; this is particularly true for NOx, and for older model years.

Figure 3.13. Model year distribution of South Coast vehicles, by vehicle type and model year (measured on road up to three months before or after Enhanced Smog Check)

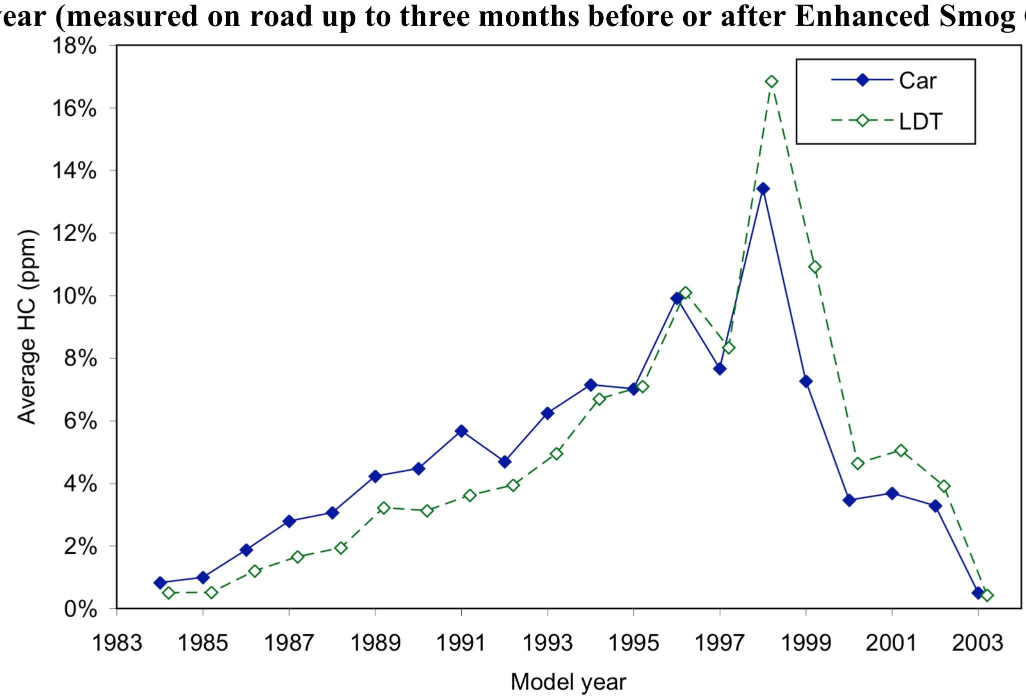


Figure 3.14. Average South Coast remote sensing HC emissions by vehicle type and model year (measured on road up to three months before or after Enhanced Smog Check)

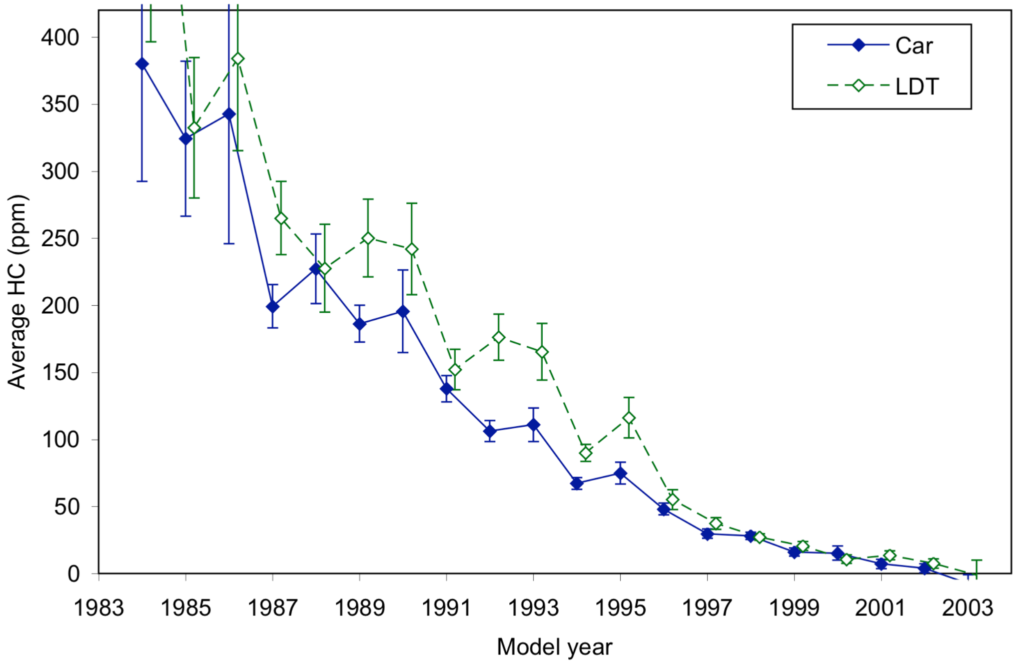


Figure 3.15. Average South Coast remote sensing CO emissions by vehicle type and model year (measured on road up to three months before or after Enhanced Smog Check)

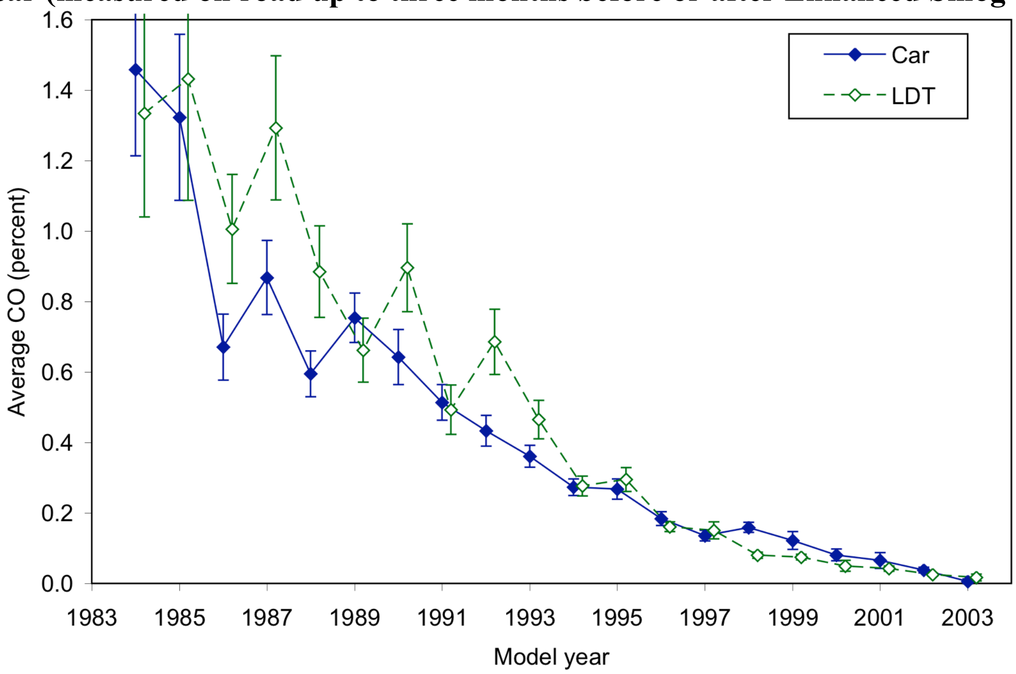
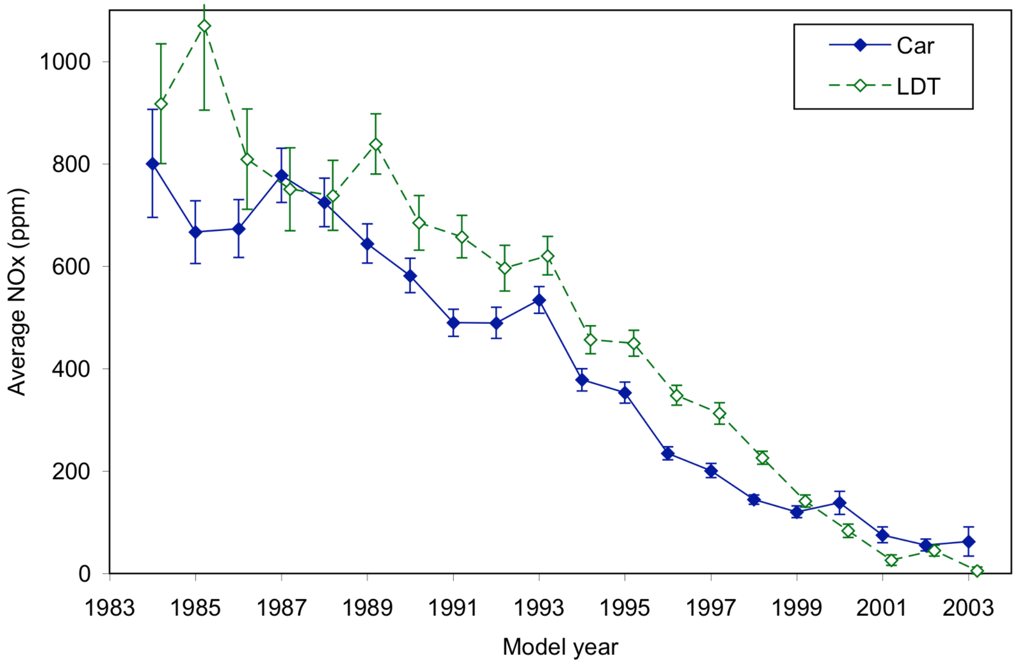


Figure 3.16. Average South Coast remote sensing NOx emissions by vehicle type and model year (measured on road up to three months before or after Enhanced Smog Check)



4. Estimate on-road emissions inventory

The remote sensing measurements can be used as a check on MVEI/EMFAC estimates of the distribution of the number of vehicles, vehicle miles traveled, and total travel fractions by vehicle type and model year. Figure 4.1 shows the distribution of model year 1972 to 2003 cars and light-duty trucks in the South Coast basin by model year. The EMFAC estimates are for 2005, and combine the LDT1 and LDT2 categories for light-trucks. The remote sensing estimates are the number of unique vehicles observed on road. The figure suggests that, based on the remote sensing data, EMFAC understates the fraction of 2000 and newer vehicles, and overstates the fraction of 1990 and older cars and 1995 and older LDTs, in the South Coast basin. Our sample may be biased due to lack of measurements made during the morning and evening rush-hours. Ideally we would want a sample that represents the 24-hour traffic cycle, weighted by hourly traffic volume.

Figure 4.1. South Coast light-duty vehicles by vehicle type and model year, estimated using remote sensing and by EMFAC

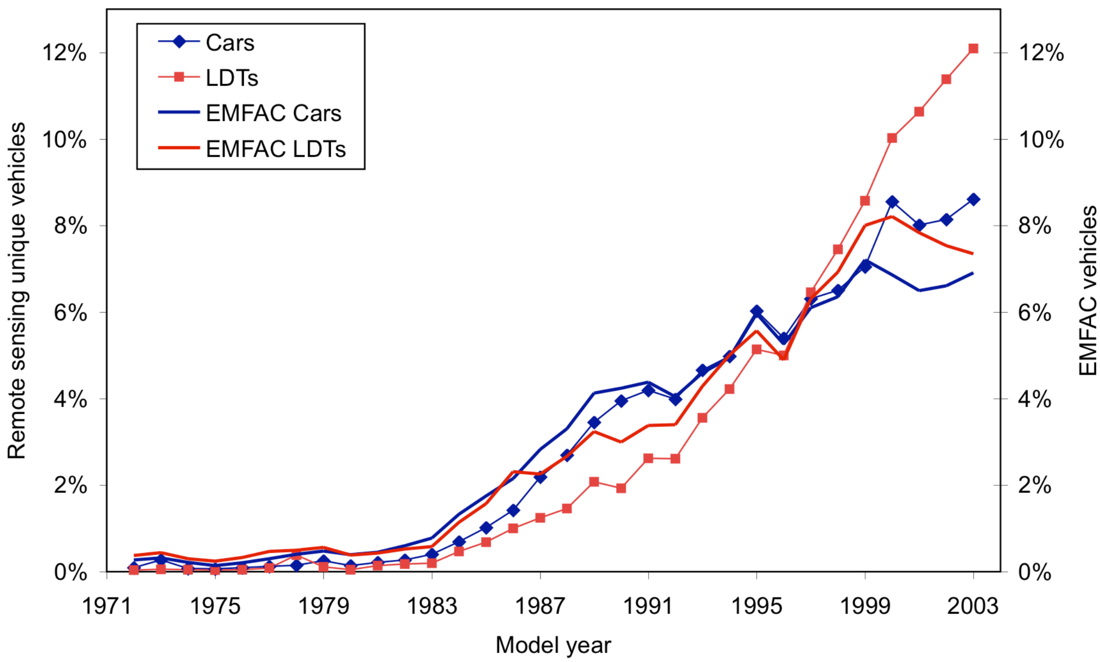


Figure 4.2 shows the average vehicle use from each source. The EMFAC estimates are simply the average annual vehicle miles traveled in the model inputs. The remote sensing estimate is based on the number of days each unique vehicle was observed on road, by vehicle type and model year. Because some remote sensing sites had two units operating at the same time, we used the number of days observed, not simply the number of measurements, per vehicle. The figure indicates that newer cars were observed on road nearly twice as often as older cars were, and that 10-year-old cars (model year 1992) are driven about the same as one-year-old cars (model year 2002). This is in contrast with the annual vehicle miles traveled estimates in EMFAC, which assumes that annual mileage decreases almost linearly with vehicle age. Again, the remote sensing data are biased towards vehicles on road between, and not during, the morning and evening rush-hours. The remote sensing data suggest that light-duty trucks have

the same annual useage pattern by vehicle age as cars, whereas the EMFAC inputs estimate that older trucks are driven more miles than older cars.

Figure 4.2. South Coast light-duty vehicle use by vehicle type and model year, estimated using remote sensing and by EMFAC

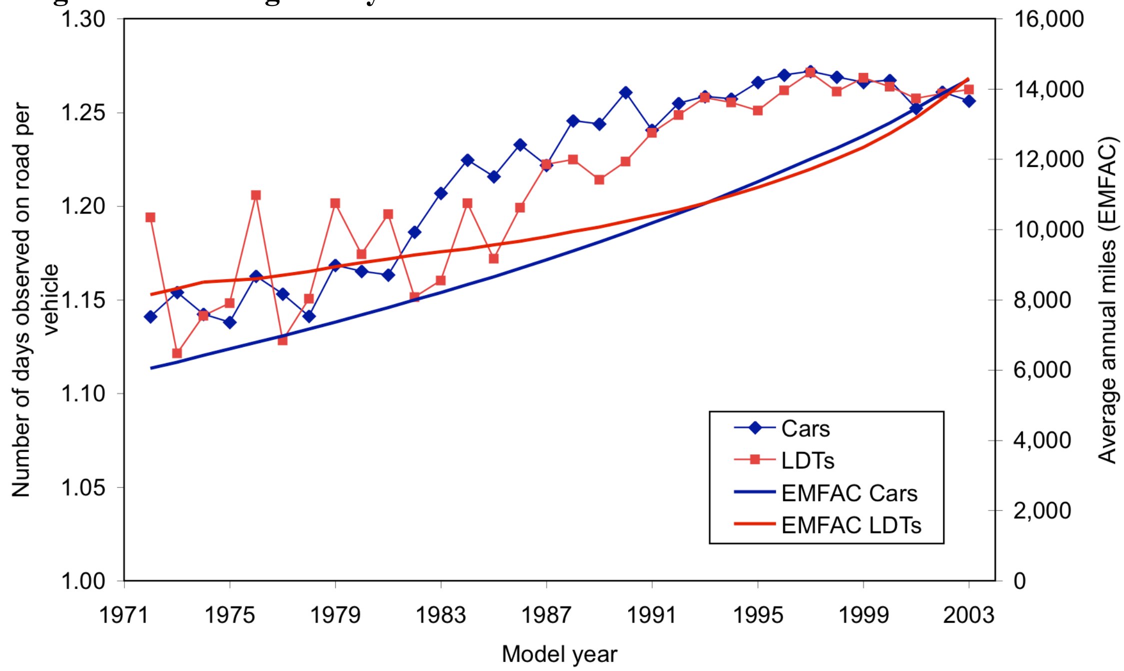
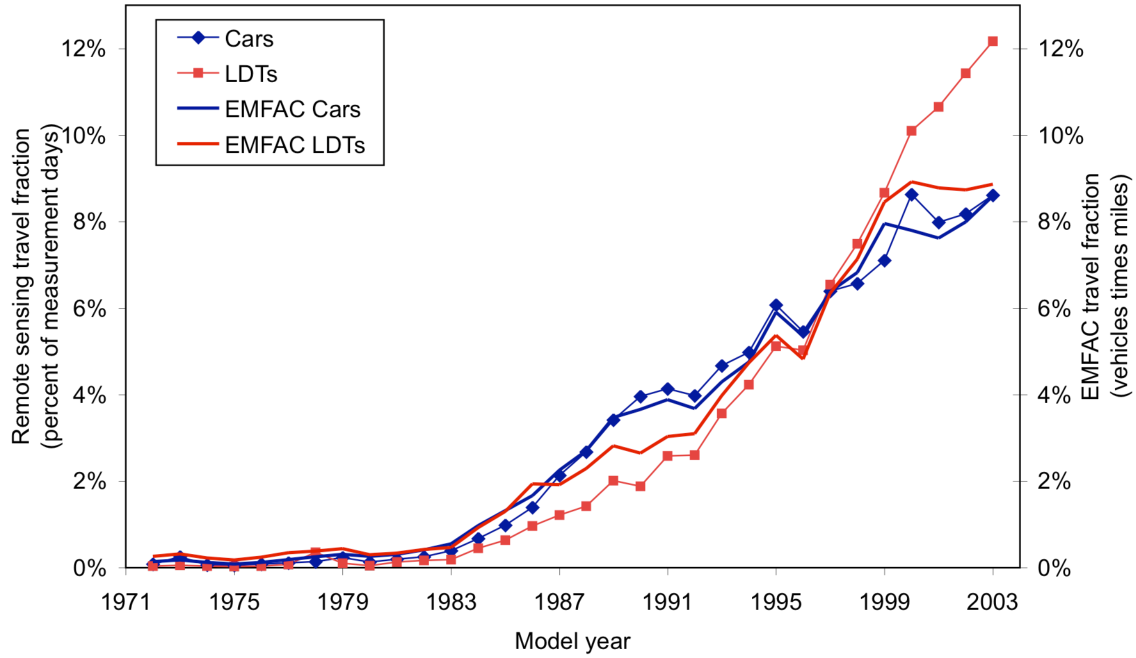


Figure 4.3 combines the distribution of vehicles in Figure 4.1 with the distribution of vehicle use in Figure 4.2, to create distributions of vehicle travel fractions, in EMFAC and based on the remote sensing data. The car travel fractions derived from the remote sensing data are very similar to the EMFAC inputs. However, the travel fractions derived from remote sensing suggest that the EMFAC inputs overstate the travel fraction of older light trucks relative to newer light trucks.

Figure 4.3. South Coast light-duty vehicle travel fractions by vehicle type and model year, estimated using remote sensing and by EMFAC



We estimated the light-duty vehicle emissions inventory for the South Coast air basin using on-road emission factors, from all remote sensing measurements of vehicles registered in the South Coast basin, and two sources of vehicle activity: the number of vehicles, average annual miles driven, and average fuel economy, by vehicle type and model, from the EMFAC model; and estimated total gasoline use statewide, from fuel tax receipts reported by the California Board of Equalization. Both estimates use the same set of emission factors, from the remote sensing measurements; however, the EMFAC-based estimate is disaggregated by vehicle type and model year, and then summed to obtain the emission inventory, while the fuel-based estimate uses the weighted average gram per gallon emission factors for the on-road fleet. The fuel-based estimate multiplies the fleet gram per gallon emission factors (which represent hot stabilized driving, and do not include start or evaporative HC emissions) by the estimated South Coast fraction of statewide fuel consumption (we attributed 39% of statewide fuel consumption to vehicles in the South Coast, based on the South Coast portion of the statewide vehicle population).

Table 4.1 shows the estimated emission inventory for light-duty vehicles under these two methods. For HC and CO, the fuel-based inventory is almost identical to that estimated using EMFAC; however, the fuel-based inventory estimates 16% more NOx emissions than when we use EMFAC assumptions regarding vehicle use and fuel economy. Note that the EMFAC-based estimate only accounts for 1972 through 2004 vehicles; including vehicles older or newer than these model years would increase the estimated emissions inventory. The fuel-based emissions inventory does not account for the small fraction of non-gasoline fuel consumption; previous estimated excluded the roughly 3% of fuel sales attributable to non-gasoline fuels. Excluding non-gasoline fuel use would slightly reduce the fuel-based emission inventory. And the fleet emission factors used for the fuel-based inventory do not include vehicles older than 1972 or newer than 2004.

Nonetheless, the analysis indicates that gram per gallon emission factors, obtained from remote sensing measurements, can be used to estimate the light-duty vehicle emission inventory using fuel sales, without having to estimate the number of vehicles, annual vehicle miles driven, and vehicle fuel economy.

Table 4.1. Estimated inventory of 2004 emissions from light-duty vehicles in the South Coast basin, using remote sensing gram per gallon emission factors and two sources of vehicle activity

	Tons per day		Difference between fuel-based and EMFAC-based estimates
Pollutant	Number of vehicles, vehicle use, and vehicle fuel economy from EMFAC model	Vehicle use from South Coast portion of statewide fuel sales	
HC	143	144	1%
CO	1,480	1,480	0%
NOx	152	177	16%

Table 4.2 compares the fuel consumption based inventory estimated in Table 4.1 with the official 2004 inventory for "hot-stabilized" emissions from light-duty and medium-duty vehicles in the South Coast basin. We use hot-stabilized emissions for comparison because remote sensing only measures the exhaust from warmed-up vehicles. Other emissions, such as cold-start and evaporative HC emissions, can be a substantial portion of the official inventory; since they are not measured by remote sensing we do not include them here. Our estimate for THC is substantially larger (44%) than the official inventory; however, our estimates for CO and NOx are substantially lower (23% and 17%, respectively). The University of Denver estimated the uncertainty of their fuel-based emission inventory using remote sensing data as +/-18% for THC, +/-15% for CO and +/-11% for NOx (Pokharel et al., 2001).[2]

[2] Pokharel et al. estimated the uncertainty in HC and CO emissions factors from fleet average emissions from seven sites outside of Denver, and the uncertainty in NO emission factors from fleet average NO emissions in several other cities. These sites included surface streets as well as freeway ramps, and therefore measured many vehicles in various degrees of cold start, as well as vehicles owned by households with a range of socioeconomic characteristics.

Table 4.2. Comparison of estimated inventory, using remote sensing gram per gallon emission factors and fuel sales, and official inventory, for 2004 South Coast basin light- and medium-duty, gasoline-powered vehicles

	Tons per day		
Estimate	THC	CO	NOx
Estimate using remote sensing and South Coast fuel sales	144 +/-26	1480 +/-220	177 +/-19
Official EMFAC "hot stabilized" emission inventory	99.9	1930	213
Difference (from official EMFAC to fuel-based)	44%	-23%	-17%

The differences between these modeled predictions are significant. To determine whether the differences originate from assumptions in the RSD based inventory or in EMFAC, or in both, would require some research. Sensitivity analyses of assumptions would help pinpoint important assumptions for further research. Tracking these differences over a period of years would also help build experience with the RSD based method and help determine whether the method could be improved with changes in assumptions and/or the way the data are analyzed.

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