Filling the gaps: Estimating roadway emissions using inconsistent traffic measurements in Las Vegas, Nevada near-road field study.

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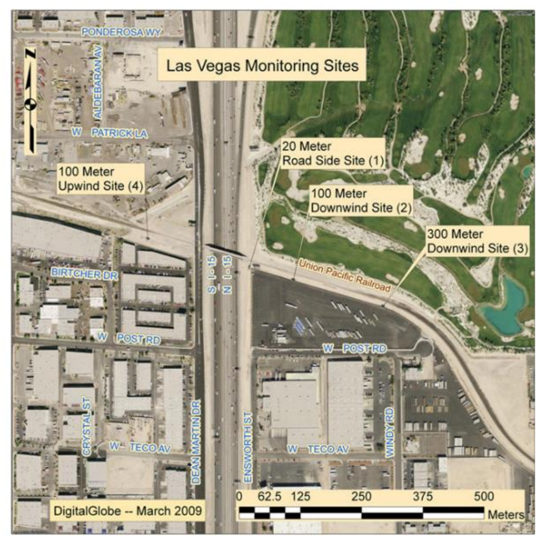
ABSTRACT

The accuracy of air quality modeling is reliant on the validity of model input. For modeling projects that include emissions from mobile sources, real-time traffic measurements of volume, speed, and vehicle type are needed to determine emissions from a roadway. Traffic measurements, like all measurements, can have uncertainties, inaccuracies, and errors. However, unlike many other measurements, there are fewer standards for calibration and QA. Thus, when there are unexpected changes in traffic, such as lane shifts or instrument error resulting in missing data, they are often undiagnosed. As a result, inaccurate traffic measurements misrepresent true roadway conditions and hinder the ability to produce reasonable emissions estimates for an air-quality model. In the Las Vegas near-road field study, missing traffic measurements and measurements with suspiciously low volumes and speeds were identified for significant periods in the yearlong study. In this work, we leverage near-by and on-site traffic measurements to fill the gaps when traffic measurements are suspicious or missing. We examine traffic volume and speed patterns across multiple measurement locations and develop a methodology to determine the most accurate estimates of traffic volume and speeds throughout the Las Vegas near-road field study when traffic measurements are missing or inconsistent. The adjusted traffic estimates will be used in a refined modeling exercise, which will be compared with air quality measurements to determine the importance of accurate traffic estimates in the air quality modeling process.

TRAFFIC MEASUREMENTS

EPA Measurement Location



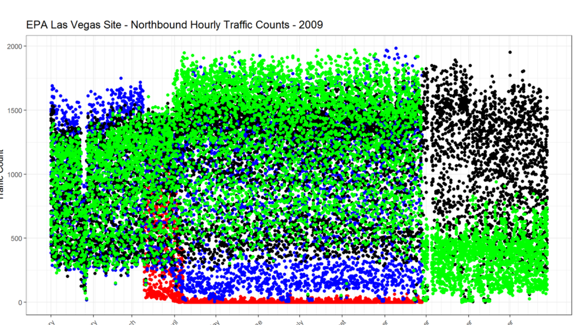
- Las Vegas, Nevada with an estimated 206,000 Average Annual Daily Traffic (AADT) traveling on Interstate 15 (North-South).
- Traffic measurements of volume, length, and speeds for each lane of Northbound (NB) and Southbound (SB) traffic.
- Measurements from December 2008 – January 2010. We focus on 2009 measurements only.
- Measured lengths >= 30m are assumed to be Heavy-Duty (HD) vehicles. All others assumed to be Light-Duty (LD) vehicles.
- Recreational destination with inter- and intrastate traffic patterns and a trade corridor.

Kimbrough, S. et. al. 2013. Long-term continuous measurement of near-road air pollution in Las Vegas: seasonal variability in traffic emissions impact on local air quality. *Air Quality, Atmosphere & Health*, *6*(1), pp.295-305.

EPA Traffic Volume Measurements

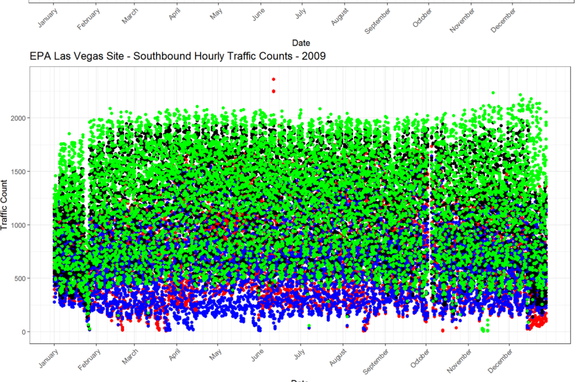
Northbound hourly measurements:

- Traffic for all lanes have discontinuities in March and October.
- Lane 1 traffic counts reduce to nearly zero April – October, then missing.
- Lane 2 missing October – December.
- Lane 3 maintains the most "steady" volume throughout the year.

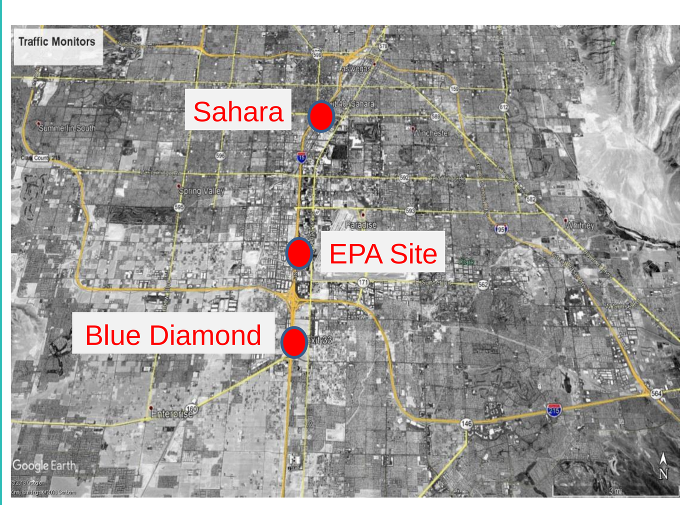


Southbound hourly measurements:

- All Lanes have "steady" traffic volumes throughout the year.
- The spread of hourly measurements is consistent throughout all lanes and throughout the year, suggesting similar diurnal patterns throughout the year.



Supplemental Traffic Measurements from Nevada DOT



Sahara

- About 5.3 miles north of the EPA site.
- No interchanges with expressways, only arterials, between measurement and EPA site.
- 2009 AADT: 233,000.
- NB and SB volume only

Blue Diamond

- About 3.3 miles south of the EPA site.
- Measurement on the other side of I-215 interchange.
- 2009 AADT: 102,000.
- NB and SB volume, plus aggregated diurnal hourly speeds by month.

FILLING THE GAPS

In an effort to replace missing traffic volume and speed measurements we used data from each lane at the EPA site as well as the Nevada DOT sites. We examine normalized traffic volume patterns for each site and determine similarities and differences in traffic patterns when measurements exist. From these patterns we make recommendations to replace missing traffic volume and speed data so we have complete time-period coverage.

Normalized AADT

Monthly:

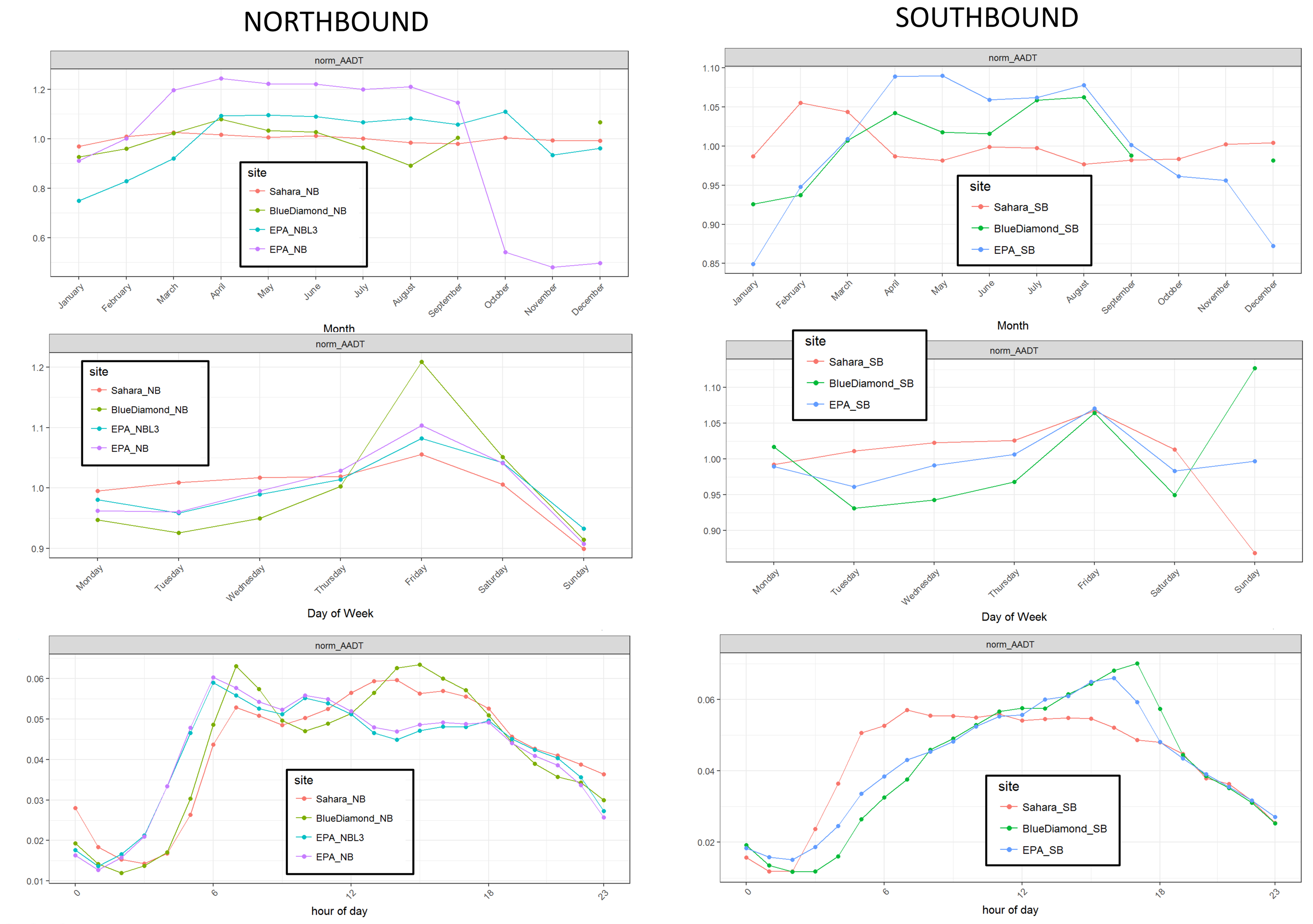
- Blue Diamond is missing Oct. and Nov.
- Noticeable drop in EPA_NB measurements (this drop is not present in EPA_NBL3).
- The drop in EPA_NB in Oct. & Nov. causes normalized trend to be higher in other months.

Weekly:

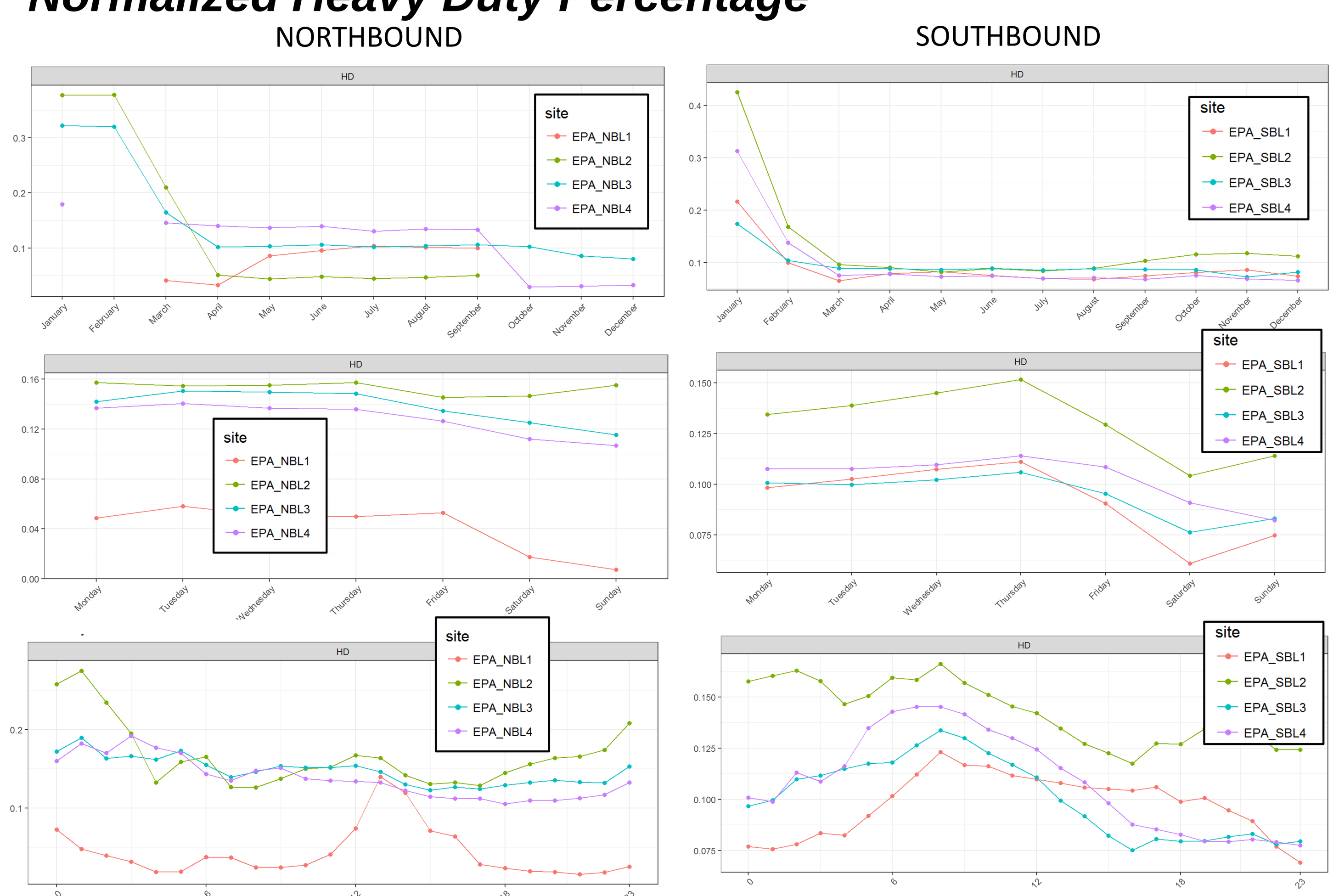
- EPA_SB shows trends between Blue Diamond and Sahara.
- EPA_NB and EPA_NBL3 trends are in-between Blue Diamond and Sahara.

Diurnal:

- Separate patterns for weekday (shown), Saturday (not shown) and Sunday (not shown).
- EPA_SB shows trends in-between Blue Diamond and Sahara.
- EPA_NB and EPA_NBL3 trends are very similar, showing a sustained mid-day volume.
- Blue Diamond and Sahara have an AM and PM rush (although PM is sustained longer), a bi-modal weekday trend.



Normalized Heavy Duty Percentage



Only EPA NB & SB measurements available.

Monthly:

- Jan. and Feb. NB measurements missing for some lanes in Jan. Feb., Mar., Oct., Nov., and Dec.
- HD percentage increase in Jan. and Feb. for NB & SB measurements.
- Monthly variability (past Mar.) is not pronounced, NBL3 & NBL4 show decrease in HD and all SBL2 shows increase for Oct. – Dec.

Weekly:

- HD traffic decreases in NB and SB during the weekend, more pronounced in SB.
- SB shows highest HD fraction on Wednesdays, lowest on Saturdays.

Diurnal:

- Separate patterns for weekday (shown), Saturday (not shown) and Sunday (not shown).
- NBL1 is very suspicious. NBL2, 3, & 4 have similar patterns.
- Most SB Lanes show increase in HD fraction in middle of the day, NB does not.
- All lanes show similar Saturday and Sunday patterns, although NB and SB are quite different.

Traffic Recommendations:

- **Use EPA_NB with monthly, weekly, and diurnal normalized AADT profiles and HD percentages from EPA_NBL3 for all EPA_NB lanes (modeling as 1 source).**
- **Use EPA_SB normalized AADT profiles and HD percentages (no adjustment!).**

Speeds

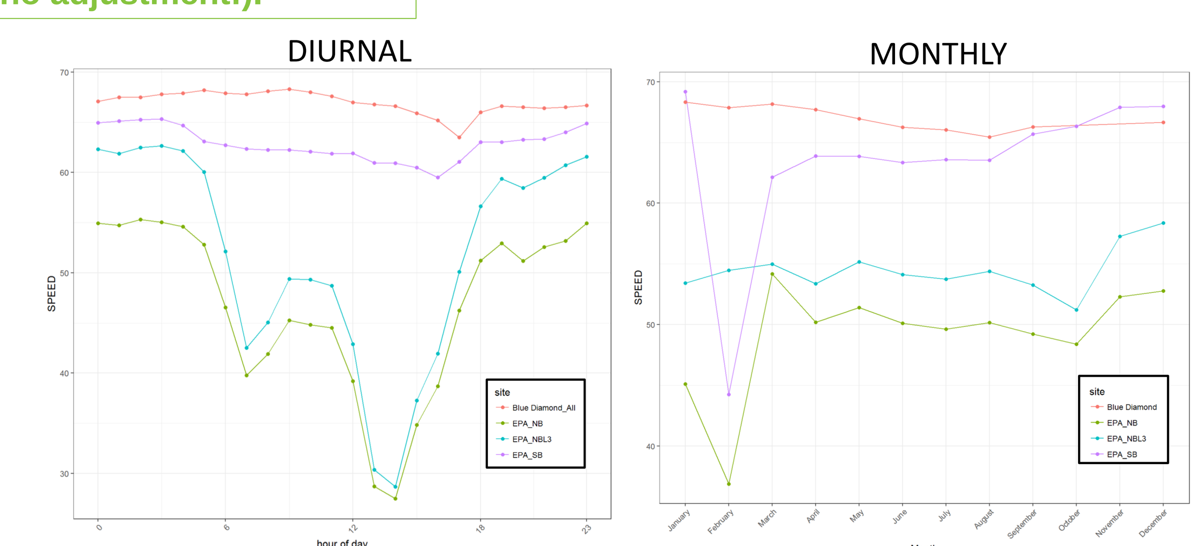
Only EPA NB & SB, and aggregate Blue Diamond measurements available.

Monthly:

- Clear drop in EPA_SB and EPA_NB for Feb. (suspicious), but EPA_NBL3 looks steady.
- Monthly trends show steady speeds, with EPA_NB and EPA_NBL3 being consistently ~10mph slower than Blue Diamond and EPA_SB.

Diurnal:

- Separate diurnal patterns for weekday (shown), Saturday (not shown) and Sunday (not shown).
- Weekday diurnal trends for EPA_NB and EPA_NBL3 show slow downs in the AM and PM peaks, indicative of congestion conditions.
- Diurnal trends for EPA_SB do not show massive slow downs, indicative of free flow traffic.



Speed Recommendations:

- **Ignore monthly variably**
- **Use EPA_NBL3 diurnal speeds for all EPA_NB traffic.**
- **For EPA_SB use diurnal speeds (no adjustment).**

DETERMINING AADT

Once we determined normalized traffic patterns to use for the EPA traffic. We explored four options to estimate the AADT for EPA NB. The options consisted of using the non-suspicious EPA NB lanes, and looking at the ratio of traffic volumes between the NB and SB lanes for the Sahara and Blue Diamond sites and using the EPA SB measured AADT. This AADT will be used with the normalized traffic volume patterns to determine an hourly traffic volumes estimate for the EPA NB source.

```
> agg_volume_bysite
                site     value      AADT
 1:      Sahara_Total 9711.3050 233071.32
 2:         Sahara_NB 4768.1606 114435.85
 3:         Sahara_SB 4943.1444 118635.47
 4: BlueDiamond_Total 4229.1942 101500.66
 5:    BlueDiamond_NB 2100.5793  50413.90
 6:    BlueDiamond_SB 2128.6149  51086.76
 7:          EPA_NBL1  117.4250   2818.20
 8:          EPA_NBL2  939.6179  22550.83
 9:          EPA_NBL3 1058.5642  25405.54
10:          EPA_NBL4  981.8091  23563.42
11:          EPA_SBL1  769.3228  18463.75
12:          EPA_SBL2  696.6520  16719.65
13:          EPA_SBL3 1190.0796  28561.91
14:          EPA_SBL4 1241.7602  29802.25
15:            EPA_NB 2792.6948  67024.68
16:            EPA_SB 3897.3188  93535.65
17:         EPA_Total 6682.2180 160373.23
```

B: Use ratio of Sahara NB to SB volumes
Sahara NB/SB = 0.9646
New EPA_NB = 0.9646 * EPA_SB = 90224.56

C: Use ratio of Blue Diamond NB to SB volumes
Blue Diamond NB/SB = 0.9868
New EPA_NB = 0.9868 * EPA_SB = 92303.71

A: Adjust NBL1 to average of NBL2, 3 & 4
New Hourly AADT = 993.2885
New Daily AADT = 23839.93
New EPA_NB = 95359.72

D: Avg. ratio of Sahara & B.D.
mean(0.9646,0.9868) = 0.9757
New EPA_NB = 0.9757 * EPA_SB = 91264.13

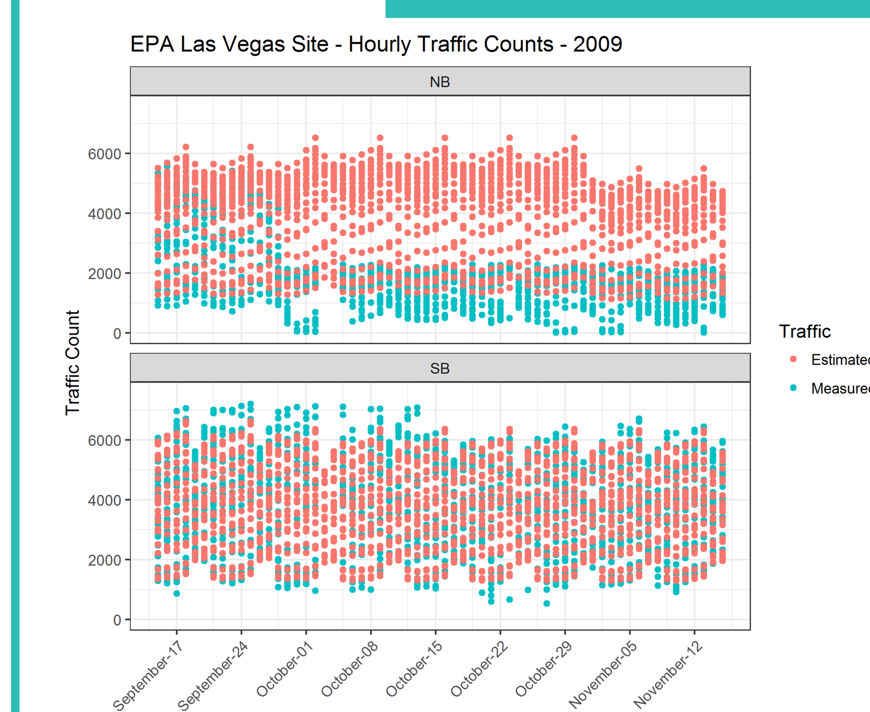
NOTE: AADT's were found by calculating an average hourly measurement for each lane and the total independently. Due to data availability, the AADT for the sum of the 4 lanes and for the total is different.

The difference between min and max estimated AADT is 3846.06 or ~4.1%

AADT Recommendations:

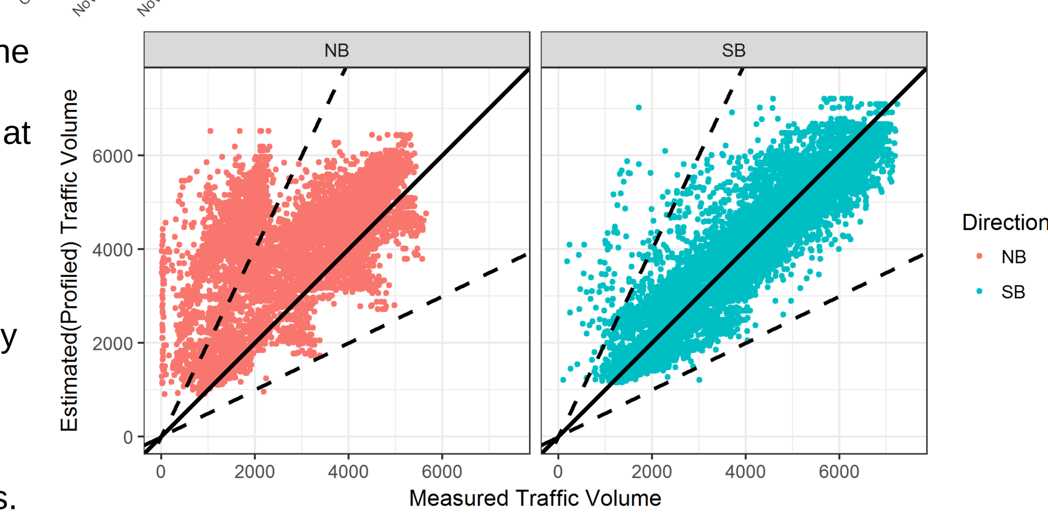
- **Given the small difference between the four options, we recommend use OPTION D for AADT of EPA_NB (modeling as 1 source), because that uses the supplemental measurements at both Sahara and Blue Diamond, which are to the north and south of the EPA site.**
- **Use EPA_SB AADT (no adjustment!).**

CONCLUSIONS



As shown in the Figure (to left) during the period on mid-September through mid-November there is a drop off in the measured Northbound hourly traffic volumes. This drop off was corrected by using the profiled traffic techniques to "fill the gaps" in traffic measurements. The estimated traffic volumes for the Southbound traffic match up very nicely with the measured traffic volumes during this time. The method of profiled traffic estimates also preserves the temporal patterns of traffic as seen in the measurements.

The method of determining the profiled traffic and an AADT, then an hourly traffic volume at the I-15 study site yields reasonable results as compared to the measured hourly traffic volumes (see Figure to right). The unusually low traffic volumes from the Northbound traffic measurements are replaced by reasonable traffic volumes.



Methods similar to this could be used to adjust traffic volumes when there are incomplete or suspicious traffic volume measurements to allow comparisons of modeled air quality to measured air quality to increase accuracy and performance of both air quality and emissions models.

The authors would like to thank Sue Kimbrough (U.S. EPA) for her thoughtful insights into this dataset and analysis effort.