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# CROSS-VALIDATION OF MODAL VEHICLE ACTIVITY DATA USING REMOTE AND ON-BOARD INSTRUMENTATION

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Better estimates of emissions can be made by modeling the distribution of operating modes by reflecting emissions as a function of operation rather than an "average" variable. Remote sensing and instrumented vehicle studies have demonstrated that certain vehicle operating modes (high power demand) lead to significantly elevated emission rates. These enrichment activities are not currently modeled in the emission inventory process, but are being incorporated into new modal emissions models. Modeling vehicle fleet composition and the distribution of operating modes (cruise, acceleration, deceleration, idle) is critical, as new modal emissions models will employ speed-acceleration mode distribution rather than averaged speed.

Sampling speeds and accelerations under real world conditions is necessary to capture the behavior of the drivers operating on the network. Several new technologies allow for remote sensing of modal activity of vehicles operating on the transportation network. Laser rangefinders (LRF), or "laser-radar guns," can collect positional data from a vehicle with frequencies in excess of 200 Hertz. Autoscope is a remote video based detection system which can count, classify, and record speeds of vehicles at various positions along the roadway. In-vehicle instrumentation systems can also record speed. A scanner unit manufactured by Snap-On attaches to a vehicle's computer systemand downloads over 30 different engine parameters every second, including vehicle speed. Global Positioning Systems (GPS) can also be employed as onboard vehicle instrumentation, utilizing timed signals from satellites to calculate vehicle positions on a second-by-second basis.

A controlled experiment simultaneusly employs two laser rangefinders (LRF), two video cameras (for Autoscope analysis), an onboard Snap-On scanner, and an onboard GPS to collect second-by-second vehicle speeds under a variety of operating mode profiles. This paper addresses a number of technical issues associated with measurement of modal vehicle activity using these four technologies: sampling issues for each technology; sample variance within each technology; accuracy and precision of the data across the four different collection techniques; impacts of time averaging; and the general utility of collection techniques for recording speed acceleration, and deceleration over a variety of operating ranges.

Keywords: Emissions, Operating Mode Profiles, GPS, Laser Rangefinder, Instrumentation

# Cross-Validation of Modal Vehicle Activity Data Using Remote and On-Board Instrumentation

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## Representative On-Road Speed-Acceleration Profiles Needed for Modal Emissions Models

Challenge: When do methods provide representative speed/acceleration distributions?

Collection of comprehensive spatial data from a sample of vehicles (i.e. instrumented vehicle / car following)

vs.

Collection of comprehensive vehicle fleet activity data from a sample of spatial locations (i.e. laser gun studies)

# Representative On-Road Speed-Acceleration Profiles Needed for Modal Emissions Models

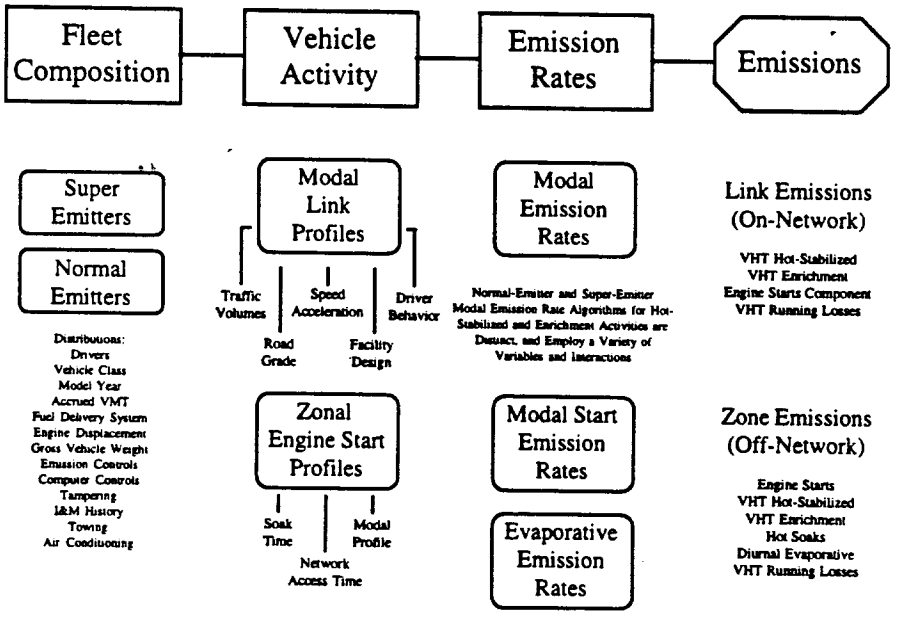
Needed:

A compact instrumentation package to collect vehicle activity (speeds / accelerations), GPS spatial location, driver trip log, etc...

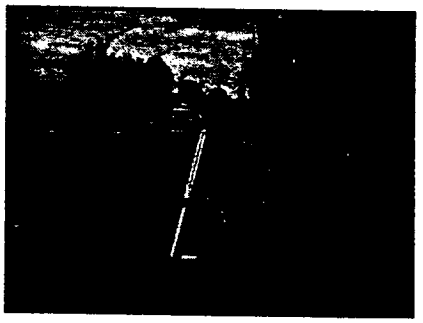
Accuracy, precision, and limitations of GPS, laser gun, and on-board instruments

Applicability of technologies for estimating mobile emissions in a modal model

# GIS-Based Modal Model



# ProSurvey Laser Rangefinder



238 readings per second
Precision/Accuracy: 1/2 foot
Data storage via laptop computer
Time stamp from computer clock

# ProSurvey Laser Rangefinder

Typical site location of laser gun for
collection of vehicle activity at an on-ramp

# ProSurvey Laser Rangefinder

Site location (day 3) of laser gun for recording vehicle activity from instrumented vehicle

# Trimble Pathfinder GPS

One reading every 3/4 to 2 seconds
Accuracy: 2 to 5 meters, kinematic
Self contained data storage
Time stamp from satellite signals

# Snap-On Diagnostic Scanner

Stores vehicle parameters once a second
Precise to 1 mph
Data storage via laptop computer
Time stamp from computer clock

# Simultaneous Data Collected

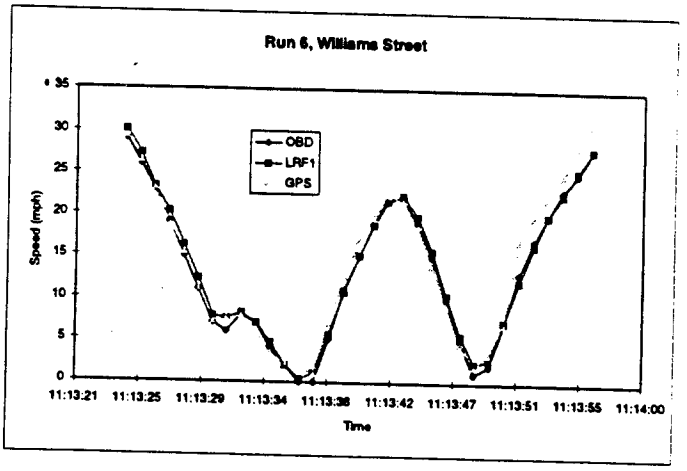
| Day | Location | Number of Runs | Amount of Data |
|---|---|---|---|
| 1 | Interstate 75/85 | 8 | 77 seconds |
| 2 | West Peachtree Street | 9 | 97 seconds |
| 2 | Williams Street | 17 | 301 seconds |
| 3 | Williams Street | 24 | 424 seconds |
| Total | | 58 | 899 seconds |

# Example Speed-Time Data

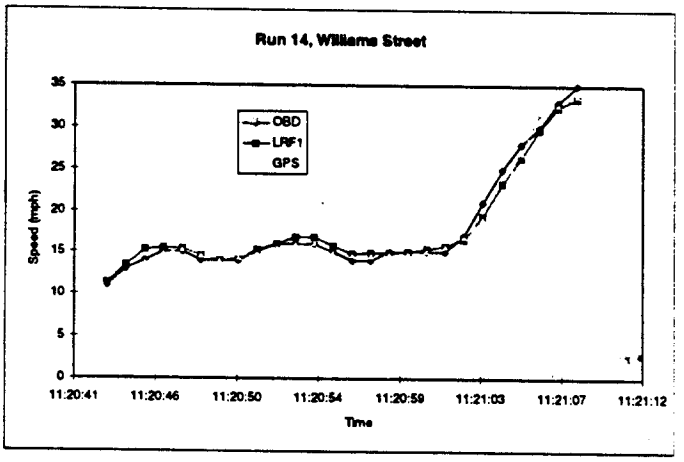
| LRF | | Scanner | | GPS | |
|---|---|---|---|---|---|
| Time | Speed | Time | Speed | Time | Speed |
| 11:13:23.29 | 32.03 | 11:13:24 | 29 | 11:13:24.29 | 28.48 |
| 11:13:24.29 | 29.20 | 11:13:25 | 26 | 11:13:25.95 | 23.40 |
| 11:13:25.30 | 26.48 | 11:13:26 | 23 | 11:13:27.20 | 18.06 |
| 11:13:26.30 | 21.82 | 11:13:27 | 19 | 11:13:28.48 | 13.72 |
| 11:13:27.30 | 19.61 | 11:13:28 | 15 | 11:13:29.79 | 7.13 |
| 11:13:28.30 | 14.94 | 11:13:29 | 11 | 11:13:31.04 | 7.52 |
| 11:13:29.30 | 11.30 | 11:13:30 | 7 | 11:13:32.29 | 8.13 |
| 11:13:30.31 | 6.37 | 11:13:31 | 6 | 11:13:33.48 | 4.35 |
| 11:13:31.32 | 8.08 | 11:13:32 | 8 | 11:13:35.20 | 1.90 |
| 11:13:32.40 | 8.24 | 11:13:33 | 7 | 11:13:37.01 | 1.10 |
| 11:13:33.36 | 6.38 | 11:13:34 | 4 | 11:13:38.29 | 8.68 |
| 11:13:34.34 | 3.80 | 11:13:35 | 2 | 11:13:39.60 | 15.96 |

Note: Time offsets in computer clocks may require matching efforts

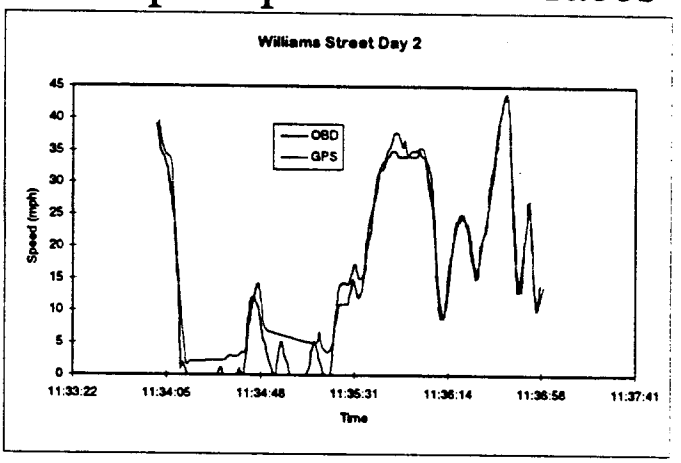
# Example Speed-Time Traces



# Example Speed-Time Traces

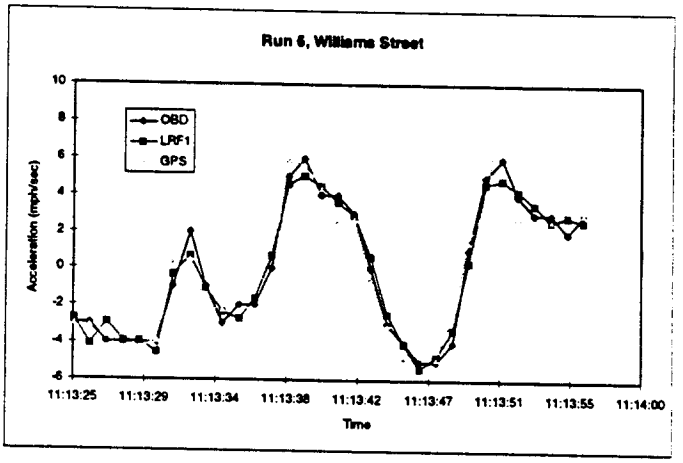



# Example Speed-Time Traces

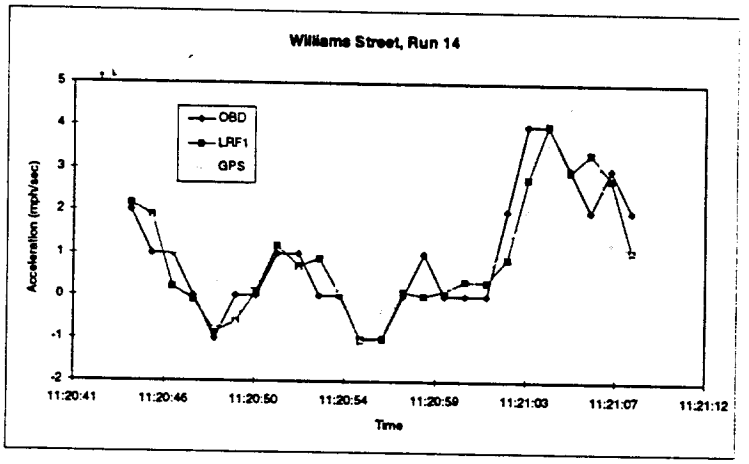



Note: GPS proprietary speed algorithm creates bias at low speeds and at the end of accelerations

# Example Acceleration-Time Traces




# Example Acceleration-Time Traces



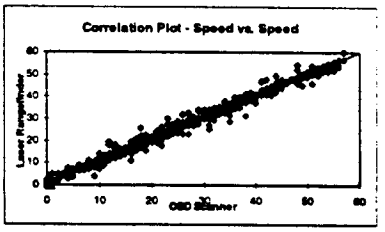
## Speed Correlation Matrix

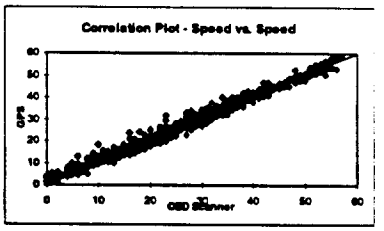
| | Scanner | LRF | GPS |
|---|---|---|---|
| Scanner | 1 | | |
| LRF | 0.99314 | 1 | |
| GPS | 0.99221 | 0.98777 | 1 |

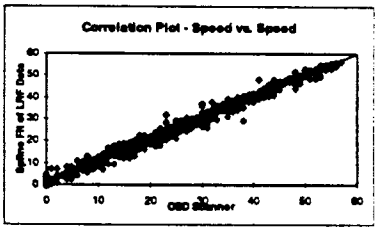
## Acceleration Correlation Matrix

| | Scanner | LRF | GPS |
|---|---|---|---|
| Scanner | 1 | | |
| LRF | 0.89603 | 1 | |
| GPS | 0.90489 | 0.85889 | 1 |

# Speed Correlation Plots

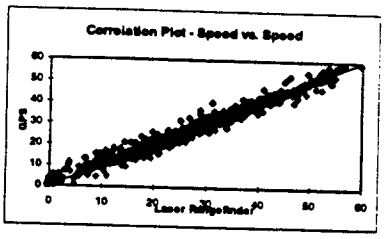


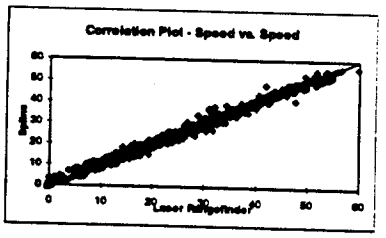



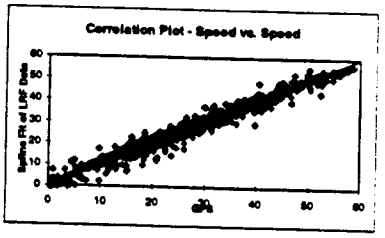




Note: Potential biases at low and high end speeds

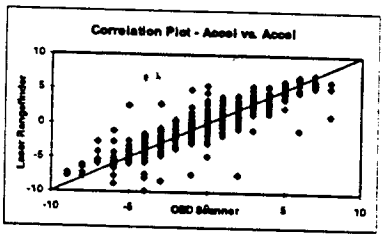
# Speed Correlation Plots

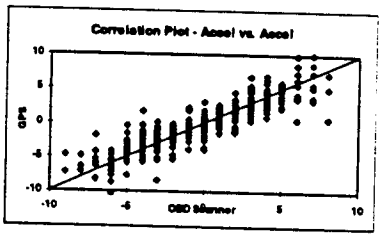


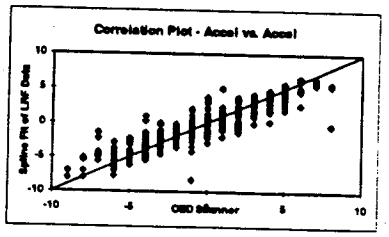




# Acceleration Correlation Plots

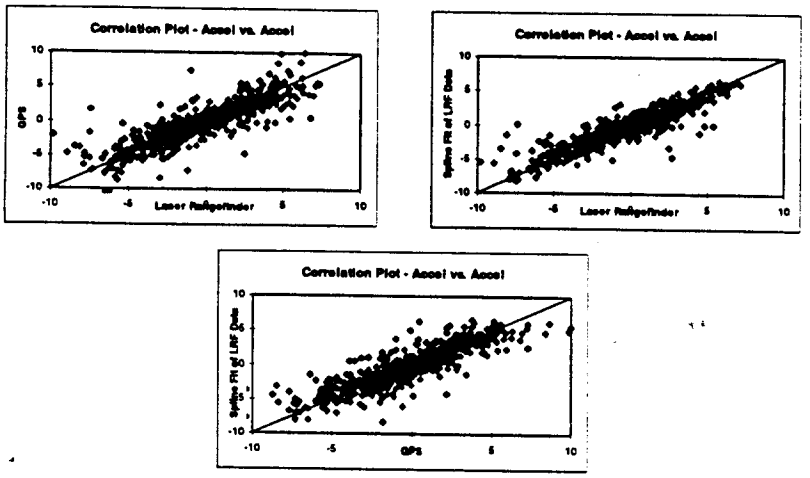


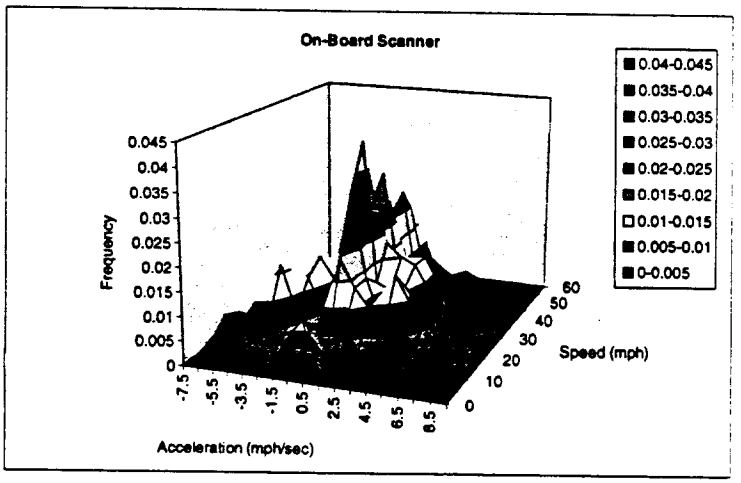




Note: One-second bins due to 1 Hz rate of scanner

# Acceleration Correlation Plots




# Speed/Acceleration Frequency Plots



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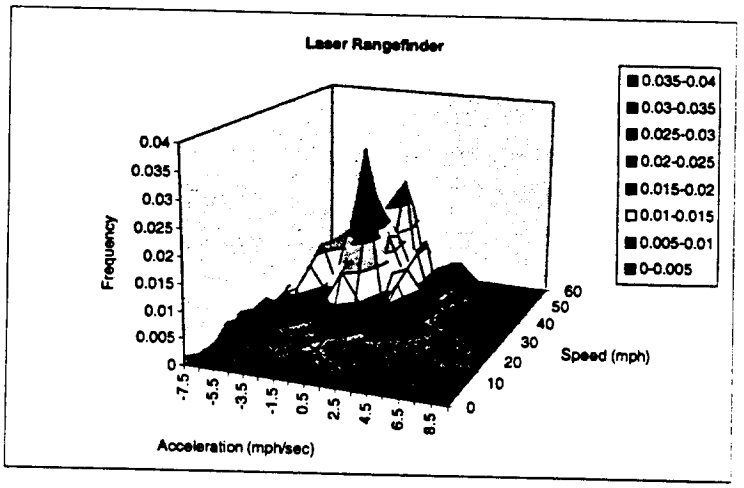


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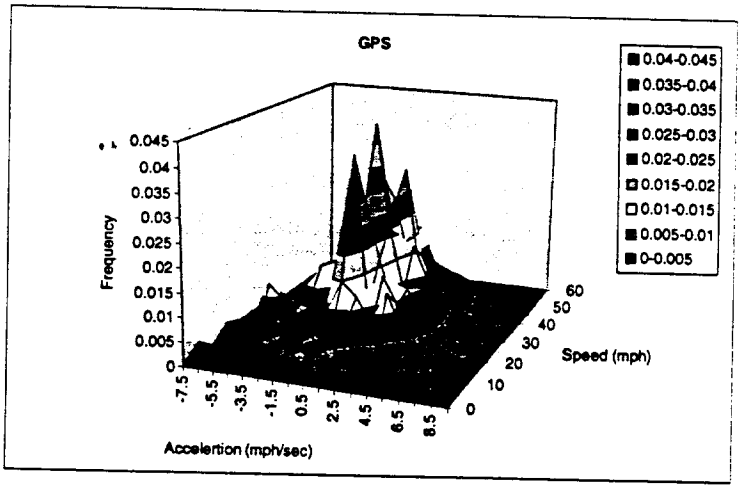

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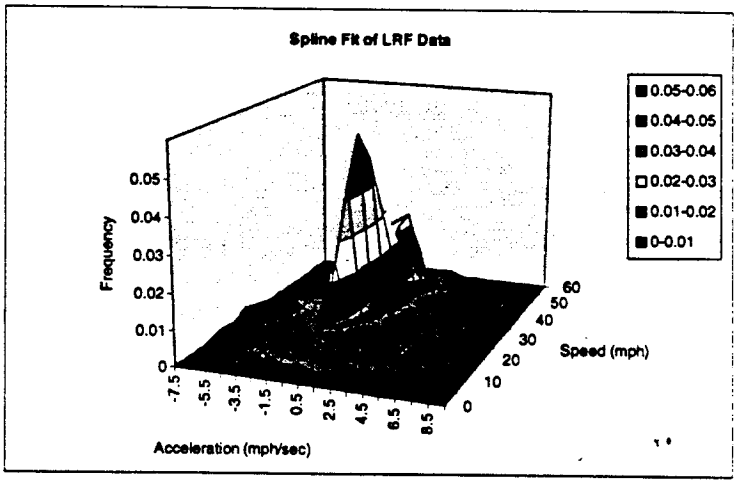
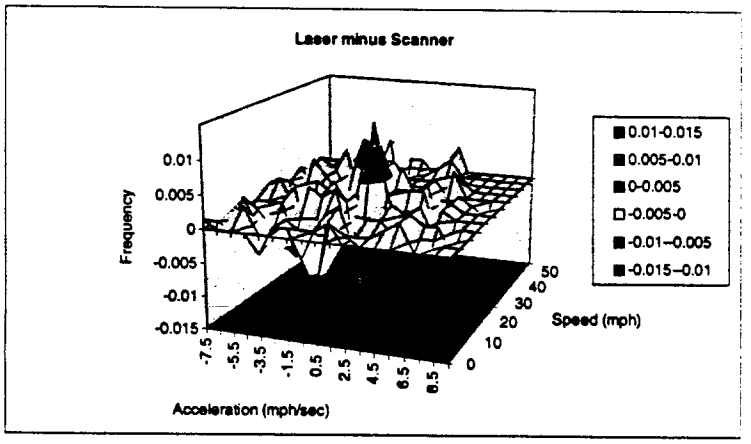



# Difference in Frequencies



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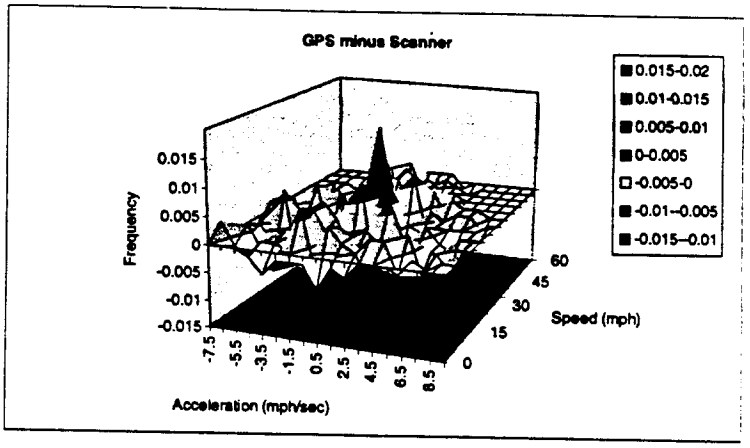


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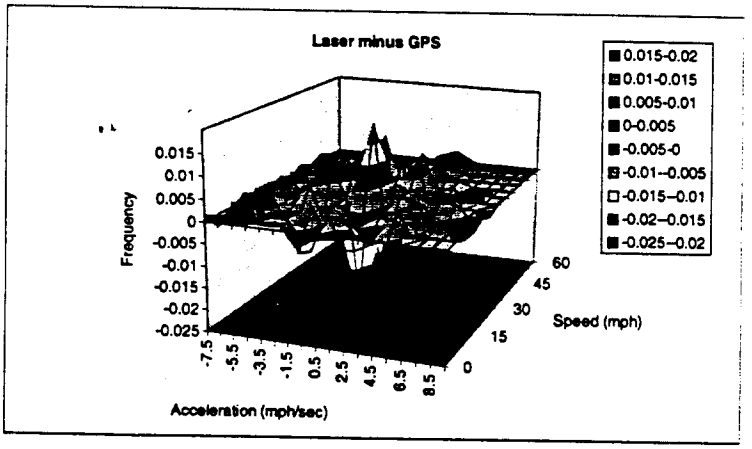

## Conclusions

- Good correlation between scanner data and laser rangefinder
- Must improve data capture rate to 2 Hz (minimum) for scanner
- GPS does not appear accurate enough for speed/acceleration activity development under stop and go situations

## Conclusions

- Potential biases in instruments require additional study, and the potential impact on emission estimation
- Good correlation of data indicates random error may be acceptable
- Challenge to gather representative speed/acceleration data: Comprehensive activity data from a sample versus sample data at a point in space from mulitple vehicles