Valley motor vehicle emissions

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Abstract

Editor’s note, none provided by author

Introduction

The resort in the town of Steamboat Springs possesses an ideal source to investigate air pollutants. Due to the large amount of tourism and a large coal-fired power plant to the west of the town it is a good location to conduct studies of transportation and dispersion of pollutants.

From January 14 to 22 of 2005, students from CCNY and BCC collected meteorological and aerosol particle measurements at the valley floor (SPLB) and at the mountain top Storm Peak Laboratory (SPL). Measurements of NOx and SO2 were made at SPL and SPLB.

For this project I will refer to the data collected at SPLB during January 15th when snow removal was in progress by a wheel loader in the parking lot of SPLB, and compare the data with data collected on January 16th. The instruments that measure NOx (NO and NO2) and SO2 at SPLB were situated in a trailer located on the parking lot of Celebrity Resorts (SPLB).

Objectives

The objective of the project is to compare two days, January 15th at the time that a wheel loader was operated and regular traffic was flowing, a period of around two hours (12:04:00 to 14:07:00 MST), and compared at the same time during the 16th when there was no wheel loader working, just regular traffic to identify the diesel “signature”. First, I will introduce the starting place of Nitrogen Oxides, its compounds and Sulfur Dioxide (SO2) related to motor vehicles. Then, I will present the procedures and locations to obtain the gas measurements and the description of the video, the experiment for establishing the gas “signature” from the diesel-fueled wheel loader. Finally, I will present the correlation of vehicle movements with gas measurements.

Nitrogen Oxide NOx (NO & NO2)

The following four paragraphs were excerpted from www.caw.ca.

Gasoline and diesel fuels are mixtures of hydrocarbons, compounds that contain hydrogen and carbon atoms. In a "perfect" engine, oxygen in the air would convert all the hydrogen in the fuel to water and all the carbon in the fuel to carbon dioxide. Nitrogen in the air would remain unaffected. In reality, the combustion process cannot be "perfect," and automotive engines emit several types of pollutants.
One of the major sources of hazardous air pollutants is transportation. The combustion of an engine produces a large percentage of pollutants. For instance, the diesel engine produces hazardous waste such as Carbon Monoxide, Nitric Oxide, Nitrogen Dioxide, Sulfur dioxides and others. In addition gasoline and diesel in the liquid form contribute to chemical pollution when it is release in the form of vaporization when the gas tank heats and cools.

Diesel exhaust can produce a variety of ill-health effects to humans. Nitrogen dioxide (NO₂) and Nitric oxide (NO) affect the body if it’s inhaled or in contact with the eyes or skin. It also causes breathing difficulties, Pneumonia, irritation of the eye, nose. It has also short-term, high-exposure effects that may also occur as throat and wet skin. Long-term effects may occur below the legal limit that causes severe effects such as long-term lung damage. The U.S. National Institute for Occupational Safety and Health (NIOSH) recommends the TLV (threshold limit value) of 1 ppm (parts per million) of Nitrogen dioxide.

Nitrogen Oxides (NOₓ) and its compounds not only affect humans directly but also indirectly. They play an important role in the atmospheric reactions that create ozone (O₃) and acid rain. Individually, they may affect ecosystems, both on land and in water. NOₓ forms when fuels are burned at high temperatures.

**Sulfur Dioxide (SO₂)**

The following three paragraphs were excerpted from www.caw.ca.

The primary source of SO₂ is from burning fuel containing sulfur, like coal, oil and diesel fuel. Some of the largest releasers of SO₂ are coal- and oil-fired power plants, steel mills, refineries, and others.

Exposure to SO₂ affects breathing and may aggravate existing respiratory and cardiovascular disease. In addition, short-term exposures can lead to lung resistance. Long-term exposure can lead to chronic bronchitis. The ACGIH (American Conference of Governmental Industrial Hygienists) TLV is 2ppm. The U.S. NIOSH recommendation is ten times lower, 0.5 ppm.

Equally to NOₓ, SO₂ affects the habitat. It causes acid rain, which causes acidification of lakes and streams and can damage trees and crops.

Information on the components of diesel exhaust can be found at www.osha-slc.gov/SLTC/dieselexhaust/index.html
Procedures

Storm Peak Lab Base is located at the Celebrity Resort. It is located at 6,700 ft MSL. The instruments are located in a parked car-trailer in the parking lot close to Pine Grove Road (See Fig. 1). The trailer is a dry and well-equipped environment for the instruments.

Instruments

SO₂

The API Model 100A SO₂ Analyzer was used to measure continuous SO₂ concentrations between 0-ppb and 500-ppb. It works by converting SO₂ to excited-state SO₂ and detecting the fluorescence photon-emission when SO₂ drops back down to the ground state. Ambient air containing SO₂ is continuously flushed through the kicker into the reaction cell. While in the reaction cell, the SO₂ is exposed to UV light and a PMT measurement of fluorescence is made. Every 30-minutes, a ‘Dark PMT’ measurement is made by closing off the UV light source with a shutter. This reference measurement is intended to account for any external light leaks into the reaction cell. A rolling 1-hour average Dark PMT is calculated and used to offset the continuous PMT measurements. The SO₂ concentration measurement is calculated as the difference between the current PMT measurement and the current 1-hour average Dark PMT measurement.

The instrument was programmed to store several parameters automatically on a 1-min time basis; the data includes the internal time stamp from the instrument and measurement and diagnostic parameters from the SO₂ instrument (see Lab 6c in Hindman (2005) and more details at www.teledyne-api.com)

NO / NO₂ / NOₓ

Also we used a Chemiluminescence’s NO/NO₂/NOₓ Analyzer Model 200E which could record independent reading every 1-minute for NO, NO₂ and NOₓ. It uses multitasking software that allows complete control of all functions while providing online indication of important operating parameters. The measurements are automatically compensated for temperature and pressure changes (see Lab 6d in Hindman (2005) and more details at www.teledyne-api.com)

Condensation nuclei

The condensation nucleus (CN) concentration was measured with a TSI PortaCount Plus (PCP, TSI model 8020) and the concentrations were recorded on a computer at 1-second intervals to be analyzed at CCNY (see the Manuel Lopez paper in this volume for more information).

Video camera

A video camera was located in 309A room where the camera was aligned so that it could continuously record Pine Grove Road, the parking lot, the trailer and the
mountain. Every day from January 14 to 22 at 0800 MST the tape was changed. The tape was used to determine the hourly vehicle movements to correlate with the gas and CN measurements.

On 15 January between 12:04:00 to 14:07:00 MST, a wheel loader was observed from the video to be working in the parking lot cleaning the snow and, of course, in front of our trailer with all the instruments. The loader was working as close as 6” to the trailer.

From the videos, I could record with precision the movements of the wheel loader and, as a result, have 1-second position data to compare with the 1-second CN measurements. I selected three types of positions for the wheel loader: red, orange and green colors to describe the position of the front loader when it was, respectively, close, in the middle and far from the trailer (Figure 1).

Results

I compared the 1-second CN measurements of the two days and found many more peaks of much greater magnitude on the 15th (see Graph 1) than on the 16th (see Graph 2). This means that on the 15th there is another source of CN that gives those high peaks. Most likely it is the wheel loader working in the parking lot. When I plotted the Jan 15 CN data and I compared the wheel loader positions (Fig. 2), the data is inconclusive, as follows. The positions and the CN peaks do not relate, as they should; that is when the wheel loader is close to the trailer one would expect large CN peaks and when the loader is far from the trailer one would expect small CN peaks. At exactly 12:36:04 MST the 1-s CN data shows the first big peak of 163215.4 cm$^3$ but it does not correspond to the wheel loader near or close to the trailer instead, the wheel loader does not come near the trailer until around 12:41:00 MST.

The biggest peak of CN (208504.5 cm$^3$) is from 13:01:00 to 13:07:00 MST but the wheel loader position shows a “gap” (the loader was not on the video screen but it was not close to the trailer either). This shows that there is no relation between the CN data and the position of the wheel loader. The high peaks should relate with the front loader close to the trailer, but nothing coincides.

Then, I took into account that wind could be the one of the reasons why the CN and the wheel loader movements do not coincide. I compared the CN peaks and the wheel loader positions (Fig. 2) and the wind direction (Graph 2.5) as follows. The direction of the wind for the first peak at 12:36:02 MST was from 319º with speeds (not shown) of 0.828 knots and for the big second peak, at 13:05:21 MST, the direction was from 290º with wind speed 0.751 knots and for the third highest peak at 13:20:08, the direction was from 308.5º and wind speed 0.721 knots. This analysis shows that the wind was blowing almost directly toward the direction of the trailer from the wheel loader. Hence, the peaks were caused by the loader.
In another position at 12:48:00 MST where the wheel loader was in an “orange” area (near the trailer) the CN values are amazingly low 31205.3 cm$^3$. This result could be due to the fact that the wind direction was 80.9º with speed 0.527 knots. In this case, wind direction shows that the wind was blowing the exhaust plume away (toward the southwest) from the wheel loader and the trailer.

At 13:00:00 MST we have another low value 24134.04 cm$^3$. Instead, it should be one of the greatest CN values, because the wheel loader is oscillating between the orange and red areas, the closest to the trailer. At this time wind direction is 130.9º with speed 0.979 knots. The low value could be due to the wind blowing opposite (toward the northwest) the direction of the wheel loader from the trailer.

I have shown that wind direction and wind speed play a big part to determine which peaks in the CN data were due to the diesel signature.

Also, I correlated hourly vehicle movement (5–min data) on Pine Grove Road with the corresponding CN data concentrations. The regression analysis on the 15th (Graph 3) shows a negative correlation ($R = -.14$) and a positive correlation ($R = .36$) on the 16th (Graph 4). Scantelbury (2000) found a positive correlation ($R = .53$) between vehicle movements and CN concentrations at SPLB. Wee (2004) found a positive correlation ($R = .59$) between vehicle movements and CN concentrations at SPLB. Thus, the negative correlation on the 15th may be due to the emissions from the wheel loader which was not included in the vehicle movement data.

Graphs 5 and 6 show the SO$_2$ concentrations and vehicular traffic versus time at SPLB. Graph 6 is incomplete due to the camera was moved and it was not viewing either the parking lot or Pine Grove Road. The graphs show a related increase from 06:00 to around 10:00 MST and in Graph 5 the SO$_2$ concentration continues in the same track as the number of cars with a little oscillation. Graphs 5 and 6 indicate the vehicle movements appear to be correlated to sulfur dioxide concentrations. That is, the vehicles appear to be a source of sulfur dioxide.

I also correlated NO, NO$_2$ and NO$_x$, versus vehicle movement in scatter diagram and calculated a correlation coefficient. For the 15th the results are NO $R^2 = -0.0154$, NO$_2$ $R^2 = 0.0071$ and NO$_x$ $R^2 = -0.0002$ (Graphs 7, 8 and 9, respectively) and for the 16th NO $R^2 = -0.0377$, NO$_2$ $R^2 = 0.001$ and NO$_x$ $R^2 = -0.029$ (Graphs 10, 11 and 12, respectively).

Editors note, this is a surprising result. Cars are prolific sources of CN and the CN correlated with vehicle movements (Graph 4). Likewise, cars are known to be prolific sources of nitrogen oxides, so we would expect a strong, positive correlation with vehicle movements. The wheel loader emissions could have confounded the gas measurements as they did with the CN measurements (Graph 3). But, a strong, positive correlation would be expected on the 16th as was found with the CN analysis.
Conclusions

I can conclude that due to wind direction and wind speed variations, the diesel plume affected the measurements when it was close and upwind of the trailer. Even if the wheel loader was close to the trailer the plume could not be detected if it was a downwind of the trailer.

Also, the cars and in particular the wheel loader were a surprising source of sulfur dioxide but not nitrogen dioxides as expected. Editor’s note, this puzzling result needs additional investigation beyond the time available for this study.

References

Hindman, E. E., 2005: *Handbook for the CUNY Environmental Field Project Course at SPL*. On file with Prof. Hindman, EAS Department, CCNY, NYC, NY 10031


Recommendations

Editor’s note, none provided.

Acknowledgements

Editor’s note, none received.
Figure 1. Location of the instrumented trailer and weather station at the Celebrity Resorts. The parking lot scene from the video camera location is shown in the BCC paper in this volume.
Figure 2. CN concentrations vs. wheel-loader position. Color representation of the wheel loader position from the trailer: far (green), middle (orange) and close (red). No color means the wheel loader was not visible in the video.
Graph 1: 15 Jan 05. CN data vs. time (MST)
Graph 2. 16 Jan 05. CN data vs. time (MST)
Graph 2.5 Wind direction as a function of time for 15 Jan 2005. The location of the Campbell weather station with respect to the trailer is given in Figure 1. Editor’s note, disregard the large direction letters, N, W, etc. and replace the word “trajectory” with “direction”.
Graph 3: Regression analysis of vehicle movements and CN concentrations on 15 Jan 05.

Graph 4: Regression analysis of vehicle movements and CN concentrations on 16 Jan 05.
Graph 5: 15 Jan 05. SO₂ concentrations and vehicle movement versus time.
Graph 6: 16 Jan 05. SO₂ concentrations and vehicle movements versus time.
Graph 7: 15 Jan 05. Regression analysis of NO. Editor’s note, the horizontal axis is vehicle movements (number per minute) and the vertical axis is nitrogen oxide concentration in ppm.
Graph 8: 15 Jan 05. Regression analysis of NO₂. Editor’s note, the horizontal axis is vehicle movements (number per minute) and the vertical axis is the gas concentration in ppm.
Graph 9: 15 Jan 05. Regression analysis of NOx. Editor’s note, the horizontal axis is vehicle movements (number per minute) and the vertical axis is the gas concentration in ppm.
Graph 10: 16 Jan 05. Regression analysis of NO. Editor’s note, the horizontal axis is vehicle movements (number per minute) and the vertical axis is the gas concentration in ppm.
Graph 11: 16 Jan 05. Regression analysis of NO₂. Editor’s note, the horizontal axis is vehicle movements (number per minute) and the vertical axis is the gas concentration in ppm.
Graph 12: 16 Jan 05. Regression analysis of NOx. Editor’s note, the horizontal axis is vehicle movements (number per minute) and the vertical axis is the gas concentration in ppm.