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Analysis Of Number And Mass Concentration Of Coarse And Fine

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ANALYSIS OF NUMBER AND MASS CONCENTRATION OF COARSE AND FINE PARTICULATE MATTER MEASUREMENTS WITHIN A HEAVY-DUTY DIESEL TRUCK STOP

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By

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Abstract

There is currently much concern over particles suspended in the ambient air, their effects on people and the environment throughout the world. The suspended particles can cause adverse health effects, reduce visibility and over the course of time wear buildings. Primary air quality concerns are of particles, their effects and their key characteristics. Particle number concentration (NC) of traffic emissions is an important element of the study, specifically heavy duty diesel engine emissions. Particle number concentration is the number of particles of a specific size in a unit of air; in this study they are measured by the number of particles of a specific size range per cubic centimeter (#/cc). Particulate matter (PM) are microscopic pieces of matter that can be formed in the atmosphere or emitted by a source, and can be characterized by their diameter size range. Fine particulate matter are particles of diameters 2.5 µm or smaller and Ultra Fine (UF) PM are particles of 0.1 µm and smaller.

The current regulated $PM_{2.5}$ particles are the mass concentration (MC) of those with a fifty percent cutoff diameter at 2.5 µm. The regulation for PM does not evaluate the size range of the particles or their quantitative number count. The size of the particle is important in that it determines it's potential to travel through the respiratory system. As there are many studies that measure particulate matter and determine the important affecting characteristics, there are also concerns of the PM from diesel emissions and their impacts. Diesel fuel and gasoline are both usually created from petroleum, although gasoline is more refined (World Book Inc., 2005). Vehicular emissions have been studied for many years and it's important that distinctions are made between gasoline and

diesel emissions. This study compares the mass and number concentrations of diesel emissions to a prior study of gasoline emissions done at The University of Texas at El Paso. The purpose of the study is to characterize the particles' mass and number concentrations, as well as to distinguish diesel particulate emissions from gasoline (petrol) particulate emissions at a truck stop.

The study took place outside an IdleAire office located in a Petro truck stop parking lot. The Petro truck stop is located in El Paso, Texas along the Interstate Highway 10 corridor. Mass concentrations of $PM_{2.5}$ and PM_{10} along with particle number concentrations of over 190 particle size ranges were measured. The number concentration and mass concentration of particles from 0.3 µm to 20 µm were measured by the Aerodynamic Particle Sizer spectrometer (APS), Model 3321 of TSI. Number concentrations of diameters from 5.94 nm to 225 nm were measured by the Scanning Mobility Particle Sizer (SMPS), TSI (SMPS) Model 3936, with a 0.70 µm impactor that discards the larger particles. The mass concentrations of $PM_{2.5}$ and PM_{10} were measured by two Tapered Element Oscillating Microbalances (TEOM series 1400a, Rupprecht & Patashnick Co. Inc.). All instruments were collocated outside the IdleAire office and placed in a designated shelter to protect the instruments from excessive heat and moisture.

This study found that the plateaus and peaks in the diurnal mass concentration graphs did not adequately represent the number concentration trend unless there was an abundance of ultra-fine particles identified. Size distribution graphs show the majority of

these particles to be in the ultra-fine size range between 0.01 µm and 0.06 µm which are much finer than the $PM_{2.5}$ regulations. When graphs were compared to a UTEP study, Investigation of the Nocturnal PM Peaks for Evidence for Association with Population Health: Diurnal Variations in Ambient Fine and Ultrafine Particles Concentrations in El Paso, Texas by Jessica Gamez which was assessed in a gasoline dominant parking area, the Petro emissions showed up to ten times more particle concentration, especially in the ultra-fine range. Therefore, it is evident that mass concentrations measurements are not equivalent to number concentrations, omitting vital information as to what's in the atmosphere. This is proven by the divergent mass and number concentration graphs that are only remotely comparable during extremely large amounts of suspended particulates. The study consequently illustrated the mass concentrations to represent a different and less accurate result than number concentrations. The study shows diesel engines to emit significantly more ultra-fine particles than gasoline engines, proving their emissions to be more detrimental to our health and increasing the vulnerability to exposure.

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Chapter 1

1 Introduction

1.1 Introduction

The present study is focused on comparing diesel engine emissions, a significant source of particulate matter, with gasoline engine emissions. The study also investigates the number concentrations versus mass concentrations of these emissions for their importance and relation to health issues. Spark ignition vehicles use spark plugs and electricity to ignite the fuel and air mixture in the cylinders while the diesel's use a compression-ignition engine which compresses the air into the cylinders. Kittelson's 1997 "Engines and Nanoparticles: A Review" found that "by number," almost all the diesel particles emitted are in nanoparticle range and that spark ignition emissions are similar. PM emissions are found to be up to 100 times greater in diesel emissions than those from spark ignition engines.

There are thousands of diesel engine vehicles on the roads which are used for heavy duty loads to transport food, materials, people and many other commodities. These heavy duty vehicles affect about three quarters of the population in the U.S. and are a considerable source of air pollution. Diesel exhaust particles consist mainly of highly agglomerated solid carbonaceous material, ash, volatile organic and sulphur compounds (Kittelson, 1997). Diesel particles in the size range of 0.1 to 0.3 μm range are considered to be in the accumulation mode and consist of carbonaceous agglomerates such as elemental and organic carbon soot (Kittelson, 1997; Hill, 2005). Particles in the size

range of 0.005 to 0.05 μm are in the nuclei mode and are made of volatile organic compounds, sulphur, solid carbon and metal compounds (Kittelson, 1997).

1.2 Objective

The present study was assessed to 1) promote and support studies of PM number concentrations, 2) categorize vehicular emissions, and ultimately, 3) aid in the reduction of detrimental air pollutants. Emissions were not directly measured from the tailpipes of vehicle types under investigation but both the present study and the study used for comparison were conducted in parking lots with vehicle populations predominantly of heavy duty diesel engine vehicles or gasoline engine vehicles respectively. The substantial difference in vehicular population of the two studies allows them to demonstrate a good representation of both heavy duty diesel engine and gasoline engine emissions. The particulate matter number and mass concentrations of diesel engine parking lot emissions were measured; specifically $PM_{2.5}$ and PM_{10} mass concentrations along with over 190 size-specific bins of particulate matter number concentrations. The study was assessed from October 30, 2007 to November 9, 2007 in a Petro truck stop located in far East El Paso, Texas.

The comprehension of these particulates and their effect on the general public is important to the public and policy makers. Diesel and gasoline are both made from petroleum, although gasoline is more refined and chemically altered which makes diesel less energy intensive to create (Norbec, 2001). Diesel emissions contain much less CO_2 than spark engines, but have considerably more particulate matter (PM), carcinogenic PM and nitrogen oxides than gasoline engines which are harmful to the general public. Diesel emissions enhance and cause health effects such as difficulty in breathing, lung irritation, asthma attacks, heart attacks, strokes

and ultimately deaths (Hill, 2005). Hill found in a 2004 study that nitrogen dioxide has adverse health effects on the lung development in people between 10 and 18 year olds (Hill, 2005).

Chapter 2

2 Literature Review

2.1 Number Concentration vs. Mass Concentration

Particle number concentration is the number of particles per cubic centimeter. More particles of 2.5 µm in diameter can fit into a cubic centimeter than particles of 10 µm. Size distribution is the number quantity of particles per cubic centimeter for a specific diameter. When the size distribution of particles is graphed, it compares the quantitative magnitudes of particles for different sizes. The mass concentration of particles is the mass of particles of different and unknown sizes per cubic centimeter. PM_{10} is the particle fraction with a fifty percent cutoff diameter at 10 µm, $PM_{2.5}$ is the particle fraction with a fifty percent cutoff diameter at 2.5 µm. Particles of 10 µm can deposit in the human nasal passage; particles that are 2.5 µm or smaller can transport further through the body into the lungs. Since PM_{10} regulations are driven by larger particles and consist of particles 10 µm and smaller, these restrictions tend to hinder the purpose of such government policies. The regulations that restrict the mass of particles 2.5 µm and smaller are more controlling to the proven hazardous particles, but because different mass concentrations contain different size distributions, one sample could be more toxic than another of the same mass.

Regardless of the minor correlation between particle and mass concentration with particle number concentration, the particulate emissions from inside combustion engines

are regulated only on the particle mass (Kittelson, 1998, 2005). These regulations, as explained earlier, are limited in the amount of toxins that they control. Regardless of the decline in particle mass from traffic due to advanced technologies, the particle number concentration has actually increased (Wahlin, 2001; Vaaraslahti, 2004). This means that quantitatively, there are more pollutants now than before and regulations have focused on larger pollutants.

The mass concentrations that were decreased could possibly not be nearly as harmful as those currently allowed, given that the smaller particles travel further into the body. Traffic number concentrations consist more than eighty percent of ultrafine particles, although the bigger, heavier particles control the mass concentrations; this shows how important the number concentration and size distribution are in the research of air quality (Zhu, 2002). Zhu's study found diesel particles to vary from 20 to 130 nm; the particles from gasoline vehicles varied from 20 to 60 nm; it is important to quantify these particles that take up so little of the mass and understand their behavior as they travel into the atmosphere (Zhu, 2002). Quantifying the general traffic defines a major source of the ultrafine particulates that are detrimental to our overall health and the environment. Narrowing this diverse source to the more concentrated diesel emissions allows an opportunity for more aggressive and significant regulations.

Many studies have determined that the smaller, ultrafine particles are more detrimental than larger particles of the same mass concentration and components; their association with health effects increases as the particle diameters decline (Whalin, 2001;

Dockery et al., 1993; Pope et al., 1995; Zhu, 2002; Brown et. al, 2000; Churg et. al., 1999). It is evident that because these particles are minuscule in mass, they limit the influence of the present regulations that are intended to control air pollution for health and environmental purposes. Particles between 0.1-10 µm can stay in the atmosphere for about a week, although larger particles settle faster and have an average residence time of about 15 minutes. Particles 10 nm and smaller have a similar residence time as the larger particles due to diffusion and coagulation (Kittelson, 1997). The particle diameter size contributes to determining its potential to transport, its health effects and its ambient residence time which are all viable aspects in determining their degree of toxicity.

2.2 Traffic Emissions

Results published by many researchers (Kittelson, 2005; Wahlin, 2001; Whitby et al., 1972; Zhu, 2002) show that traffic is the prevailing contributor to fine and ultrafine particulate matter pollution in urban areas, regardless of the improvements in engines. New research in this area will perhaps help sway regulations for more stringent particulate guidelines. The concentration of particulate matter near the freeway is thirty times higher than in a rural area. This shows that communities that are within 100 meters of the freeway are more prone to this pollution (Zhu, 2002). Vehicles are a major contributor to particulate matter and are dangerous to those communities in visual range of the freeway.

Particles produced from vehicles are normally in the accumulation size mode, which are 50 nm or greater, and in the nucleation mode that ranges below 50 nm (Wahlin, 2002; Kittelson, 1997, 2005; Zhu, 2002). Both accumulation and nucleation particles are considered to be ultrafine, which make them negligible in the PM_{10} mass concentrations and occupy very little of the regulated $PM_{2.5}$ mass concentrations. Ultrafine particles are formed from high temperature in engines, exhaust pipes, gasoline and diesel emissions (Wahlin, 2001). These are particles directly produced from vehicle emissions. Fine roadway particulate matter is produced from tires, dust, brake linings, and abrasions of road material (Wahlin, 2001). Particles aren't just comprised from vehicular emissions; the wear of the roads from the vehicles use and the wear of the vehicles parts contribute to vehicles' particulate emissions. Ambient weather conditions, atmospheric dilution and coagulation have a role in moving the particle distribution mode from larger particles to

smaller particles as they disperse from the driveway (Kittelson, 2005; Zhu, 2002). This explains the morphology that particles go through when transporting from the roads and their sources as they attach and grow or change.

Wahlin's 2001 study found a relationship between CO, Nitrogen Oxides (NOx) and ultrafine (UF) particles which demonstrates traffic to be a significant source of UF particles. Zhu's study shows that particle number concentration, Carbon Monoxide (CO) and Black Carbon (BC) track similarly from the freeway, which shows their relation to vehicle emissions (Zhu, 2002). The relationships and concentrations of these pollutants allow researchers to separate particles not related to traffic, those related to gasoline traffic and those related to diesel traffic. Particle number concentrations from non-traffic sources contain small amounts of CO and NOx that contribute a minute amount to the number concentrations and consist primarily of coarse particles, which suggest that they are secondary, distantly transferred particles (Wahlin, 2001). Zhu's 2002 study states that Booker (1997) found PM_{10} MC to be uncorrelated with traffic when compared to number concentrations. He stresses the importance of quantifying particles and observing their behaviors as they transport. As air pollutants travel from their source, their chemical composition and physical characteristics change as they coagulate and agglomerate; research helps to understand such phenomenon's and their influence on the environment. Studies have found it is difficult to separate diesel and gasoline emissions in air samples, partly because they correlate so well with each other; differentiating the two is possible through knowing that gasoline traffic contains high amounts of CO and NOx, while diesel emissions alone contain nominal amounts of CO (Wahlin, 2001).

Because both gasoline and diesel contain CO and NOx, even though they have different concentrations, the ability to separate the two is limited.

The Wahlin 2001 study found that the workdays have a common and clear variation of CO, NOx and ultrafine particles that peak in the morning and afternoon rush hours, especially the CO, although the weekend's variations are different (Wahlin, 2001). Gasoline and diesel vehicles have different traffic patterns; gasoline emissions are during the workday rush hours and weekends, while diesel heavy duty trucks tend to vary, and the diesel taxis are usually at night (Wahlin, 2001). This explains the high CO peaks, which gasoline emit significantly more than diesel vehicles. Particles formed from the cooling and heating of the exhaust are normally sulfate or hydrocarbons (Kittelson, 1997). Accumulation particles are created from combustion and mainly consist of carbonaceous soot agglomerates (Kittelson, 1997).

2.3 Diesel Emissions

Diesel Emissions' are perhaps known to be a major contributor to PM emissions in urban areas (Kittelson, 2005; Wahlin, 2001). Studies have shown that traffic is a major contributor to PM emissions. Studying specific traffic emissions, such as diesel, assists in determining PM sources allowing more options for researchers in determining more significant areas to study. Studies conducted in the last 30 years that have examined the high concentrations of particles near roadways and high particle number concentrations are showing more significance and are urging that it be researched further (Whitby et al., 1972; Kittelson, 2005; Whalin, 2001). As technology advances, the restriction of studies from the lack of information are being decreased, which in turn strengthens the validation of their purpose. Past records illustrate that fine PM in urban areas are primary contributors from vehicles. Kittelson's 1997 study shows that almost the entire number concentration of diesel emissions is in the nanoparticle range. Kittelson's study narrowed the sources of more specific PM emissions to more specific fuel types and the traffic that produces more of the hazardous pollution.

Fine and ultrafine particles are detrimental to the environment and our health. The emission factors for different types of vehicles are vital for model calculations of particles emitted from traffic. Even though emissions have decreased, their ultrafine particles have increased (Wahlin, 2001). The particles can only travel as far as their size permits; the larger sized particles do not enter deep into the lungs. A particulate size that cannot travel further than the nose doesn't cause as much damage as a size that can reach to the human lung or the blood stream. Regardless of the minor correlation that mass

concentration and volume has with particle number concentration, the particulate emissions from inside combustion engines are regulated only on the particle mass for $PM_{2.5}$ and PM_{10} (Kittelson, 2005; EPA). $PM_{2.5}$ can travel into our lungs, but smaller particles can travel further, increasing their detrimental affects. The Kittelson 2005 study examined that the PM number concentrations can effect up to about 10 Km from roadways in urban conditions, but could travel up to 10 Km further in flat rural areas (Kittelson, 2005).

Zhu (2002) expresses the importance of researching diesel emissions in her 2002 study because even though there are more gasoline vehicles on freeways, diesels emissions have approximately 100 times more PM and its' exhaust is carcinogenic to animals and possibly to humans (Zhu, 2002; Kittelson, 1997, 2005; Chao, 2001; Wahlin 2001). Data obtained from the EPA in 2000 by Zhu shows that PM is emitted at 0.4 g/mi from diesel trucks and about 0.08 g/mi from gasoline cars, confirming that 62.5% of PM on highway was from diesel emissions (Zhu, 2002). It's apparent that general traffic consists primarily of gasoline traffic, but knowing that one diesel vehicle can emit the same as over ten gasoline vehicles demonstrates the need to quantify and regulate such emissions. The Chao and Wahlin studies found that diesel engines not only emit more nanoparticles than gasoline but their particles are finer with a sharper peak around 20 nm (Chao, 2001; Wahlin, 2001). Gasoline particle size distributions are broader, releasing fewer particles with various possible degrees of health effects. Diesel vehicles emit a more narrow range with higher concentrations of finer particles creating a more susceptible environment to health effects.

Diesel exhaust studies are quite difficult because of their dependence on many factors such as the engine, after-treatment, fuel, lubricating oil and driving conditions (Vaaraslahti, 2004). These factors increase the precautions and efforts that researchers have to put forth to produce accurate measures because with or without sulfur, nucleation mode particles are still created but their characteristics differ. The chemicals and characteristics in the fuels directly affect the emissions. Chao's 2001 study shows that oxygen, sulfur content, density, aromatic substances and distillation temperatures highly affect the PM emissions. Hydrocarbons and PM can contain various compounds with different toxicities. The potential variety of these chemical compositions not only modifies the toxicity of the particles but also their size and association in coagulation. When idle, long-hauled diesel engines exhaust is at low temperatures; they produce a modest amount of elemental carbon and nuclei sized particulates that are non-volatile with a few accumulation particles (Kittelson, 2005). This is an example of how driving conditions and temperature can affect the particle production in diesel vehicles. Mass measurements are usually measured after the exhaust gas is heated to 300 ºC, which removes organics and semi-volatile compounds that will travel like particles to the lung and, therefore, shows the importance of identifying the sources and exposure of these particles (Wahlin, 2001). Idle diesel emitters are not on the freeways and roads, so they affect a more restricted area such as the vicinity of the truck stops where they rest and maintain their vehicles. This doesn't suggest that studying idle emissions are not vital; it just presents another variety of a different set of particles. Vaaraslahti (2004) reported

that the sulfur in the diesel's exhaust oxidizes during combustion into SO_2 and a small amount is changed to SO_3, which leads to H_2SO_4 that can nucleate and produce particles.

Kittelson (2005) studied four heavy duty diesel trucks that produced bimodal nucleation particle sized distributions from 6 to 11 nm and accumulation mode particles from 52 to 62 nm. This is an example of how understanding the potential effect of the two size ranges could contribute to identifying the more toxic particles or their possible effects. Organic and sulfur compounds in the tailpipe are normally in the vapor phase that convert from gas-to-particle during dilution and cooling which produces accumulation particles (Kittelson, 1997,2005). The position of the samples collection is important because these compounds are vulnerable to their ambient conditions. Nucleation particles form from low volatile species that nucleate, such as water and sulfuric acid. Heavy hydrocarbons, mainly from unburned lube oil, assist in growth; the smallest particles have higher sulfur content (Vaaraslahti, 2004; Kittelson, 2005; Chao, 2001). Identifying the compound position in particle configuration and their separate influences helps identify the more significant elements. Studies have related the formation of nucleation mode particles to the dilution of fresh vehicle exhaust, and particles of this size that occur in fuels with high sulfur content are primarily composed of hydrocarbons and semi volatile organic compounds (Vaaraslahti, 2004; Kittelson, 2005). Understanding the sulfurs' part in particle formation helps identify how reduction could affect the structures of particles created from diesel engines.

Volatile precursors become supersaturated as the exhaust dilutes and cools and begin to nucleate and grow; they may also endure gas-to-particle conversion by adsorption through the accumulation mode. This reduces their driving force for nucleation and growth of concentration. Regardless of the precursor concentration, the accumulation mode particles will suppress the nucleation and growth, which is dependent on the surface area for adsorption and the dilution history (Kittelson, 2005, Wahlin, 2001). Essentially, the sulfur in the fuel assists in the growth of the nuclei particles that are primarily hydrocarbons; the nucleation particles are almost always volatile except when the diesel vehicles are idle (Kittelson, 2005). This shows how driving conditions of the same vehicle can produce particles of different size and chemical composition and how different compounds assist in particle construction.

2.4 Health Effects

Particle number concentrations and mass concentrations are areas of high health concerns. Observing certain sources and the possible solutions available to reduce these detrimental air pollutants is extremely beneficial for society, the environment and is worth the investment. Many studies correlate particulate matter influence on health effects and mortality. Some argue that it is the surface toxins that are important while others say the characteristics and sizes are most important because they control the deposition of particles in the body (Zhu, 2002; Hinds, 1999; Berube et al., 1999).

Some argue that toxicity is important because if the particle is not toxic, it shouldn't harm the body, regardless of size. These particles can be non-toxic in μm size but are capable of being toxic in the nm range, even if they are of the same composition (Zhu, 2002; Kittelson, 1997, 2005; ICRP, 1984). Their deposition is also important and dependent upon size; the smaller the particle, the further it can travel, which can alter the health effect from just irritation to diseases (ICRP, 1984; Kittelson, 1997). Hence, size is important over toxicity because the toxicity doesn't harm the body if it doesn't even penetrate beyond the head airway region.

The characteristics of these particles are extremely important in evaluating their adverse health effects and deposition in the lungs; some of these properties are: size, chemical composition, state, morphology, volatility, density and hygroscopicity (Wahlin, 2001). The morphology and volatility are important because of the possible effects of these particles if altered from their original form and their degree of damage. The

number concentration and size distribution are extremely important when examining these particles. Fine along with even smaller particles can travel deep into the lungs and reside there up to several months (Who, 1997; Wahlin 2001; Kittelson, 1997). Traveling into the lungs modifies the health effects from irritation to diseases. These small particles (Nanoparticles) raise concerns not only for their morbid effects, but also on the environment, soiling of buildings and visibility (Kittelson, 1997). When airborne, particles contribute to the wearing of the buildings and hinder visibility. Some of these health effects are cardiovascular disease, cancer, irritation of nose, throat, eyes and allergies (Wahlin, 2001). Cardiovascular effects occur when particles, travel to the lungs, enter the bloodstream and then the heart.

Chapter 3

Methodology & Materials

2.5 Site Description

El Paso is located in the western tip of Texas and borders New Mexico and Cuidad Juarez, Mexico alongside the Rio Grande River. The Petro truck stop is located off the Interstate 10 at 1295 Horizon Blvd. El Paso is surrounded by desert landscape. Figure 3.1 shows the geographical location of El Paso while Figure 2.2 shows the exact location of the Petro site in relation to the City of El Paso and the Interstate Highway 10. The geospatial coordinates of Petro are: Latitude 31.659225, and Longitude 106.240226.

Petro is the top rated chain truck stop in the United States of America and has many locations throughout the nation. This travel plaza contains services for the traveling population primarily consisting of diesel truck drivers. These plazas also consist of businesses such as shopping stores, diners, laundry facilities, fueling services, automobile services, etc. with plenty of parking spaces available. Commercial Motor Vehicle (CMV) drivers are regulated by the Federal Motor Carrier Safety Administration which requires all truck drivers to rest ten hours for every eleven hours of driving time (FMCSA, 2008). Areas like Petro serve this purpose.

This ideal location was chosen because it is quite far from daily spark engine traffic. Also, its close proximity to the Interstate 10 was a reason for choosing this site. Approximately 35 miles west is another Petro stop, but it contains fewer services, which makes it less appealing to diesel truck drivers. This makes the chosen Petro a more

appropriate location for the study, and with Petro being the top rated truck stop in the nation, this represents a concentrated area of diesel trucks.

IdleAire provides Long Haul Truck drivers with an IdleAire Service Module which is connected to the window of their consumer's truck. This device provides a heater and air conditioner, along with different options of entertainment and communication. This facility allows the driver to turn off his/her vehicle when not in transit and also allows him/her to sleep comfortably with various amenities as mentioned above. This helps in reducing emissions and cuts the driver's costs for maintenance. This study was accomplished in front of the IdleAire office situated inside the Petro Truck Stop parking lot. Figure 2.3 is an aerial view of the IdleAire facility located in the Petro truck stop; this view also shows the parking lot occupied with diesel trucks. For the purpose of this study, the trucks located in the IdleAire parking spaces are assumed to be turned off. Figure 2.1 shows the geographical location of El Paso while Figure 2.2 shows the exact location of the Petro site in relation to the City of El Paso and the Interstate Highway 10.

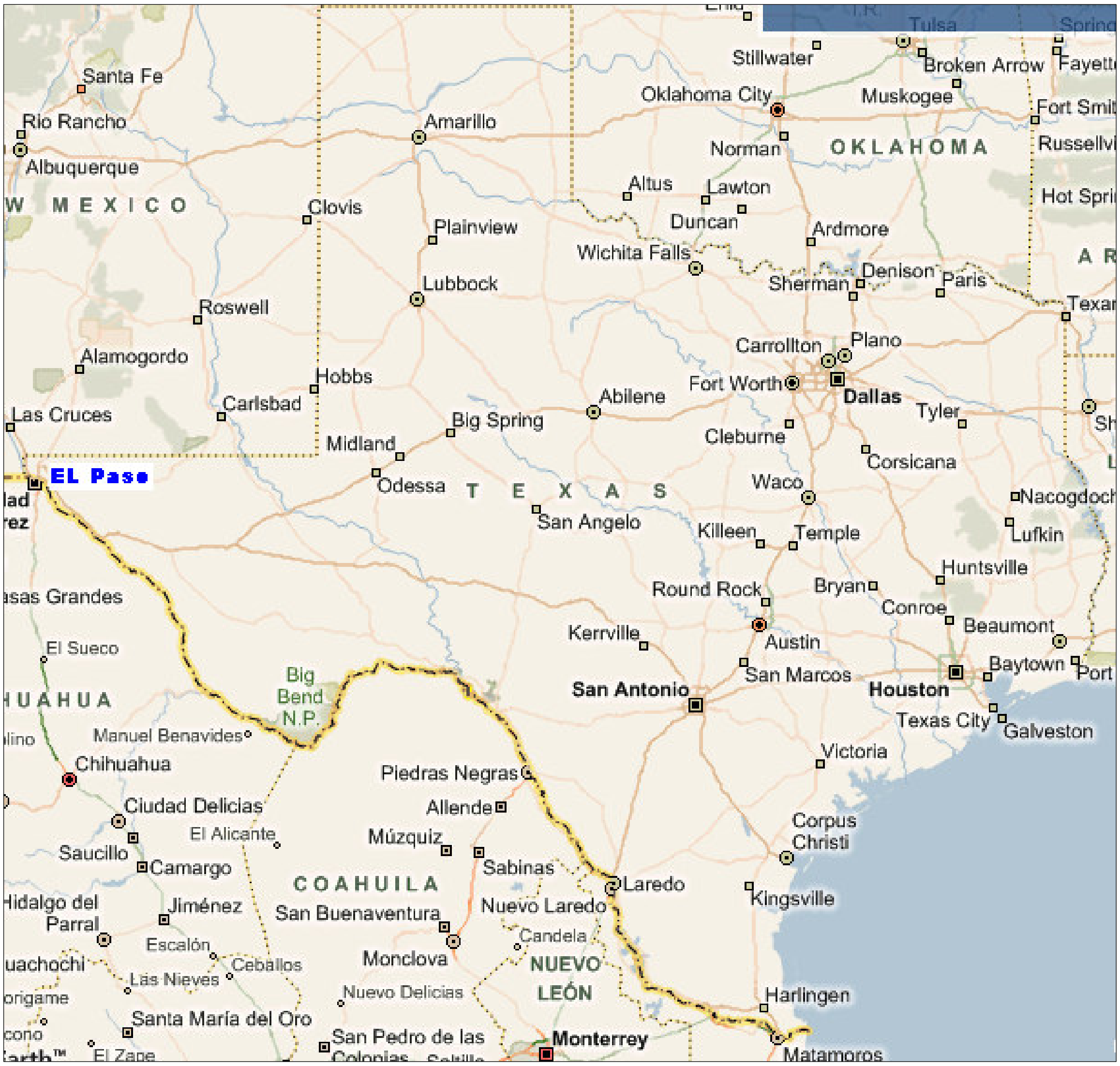


Figure 2.1 El Paso, Texas

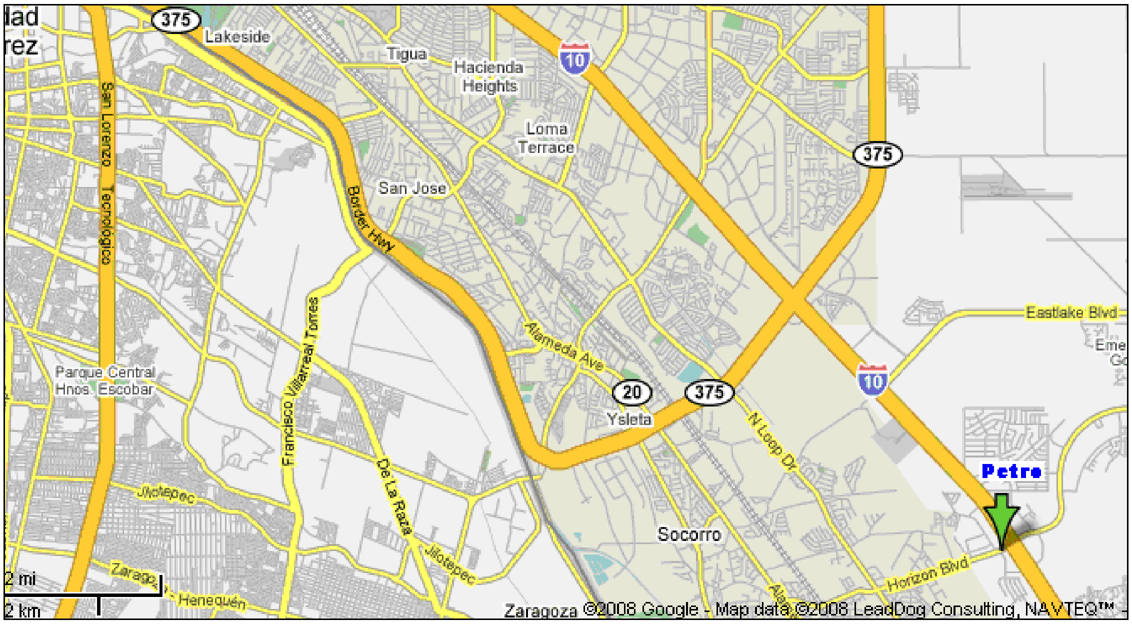


Figure 2.2 Petro located in East El Paso

Figure 2.3 IdleAire located inside Petro Parking Lot

2.6 Experiment Description

This study was conducted in the El Paso Petro Stopping Center located at the outskirts of El Paso (Figure 2.2). Particulate Matter Number Concentrations and Mass Concentrations were measured between October 26, 2007 and November 9, 2007. These measurements were conducted in front of the IdleAire office, which is located inside the parking lot of the Petro Stopping Center. During this study; ultrafine, accumulation, and fine number concentrations were determined.

The monitoring instruments were set up inside enclosures adjacent to the IdleAire office and its parking spaces for diesel trucks. The instruments used are designed for indoor monitoring; the enclosures were used to protect the instruments from the outdoor conditions. The APS, SMPS and their entirety were assembled inside a wooden cabinet which contained holes for the inlets and cords of the instruments. The instruments were tied together and secured with a rope as shown in Figure 2.4. A blue tarp, which is shown being secured in Figure 2.4, was wrapped and tied around the cabinet to keep water or any other unwanted materials from entering. The two TEOMs were set up contiguously and directly in front of the cabinet so all measurements would be obtained concurrently. The cabinet of TEOM $PM_{2.5}$ contained four wheels for mobility but it was tied to a yellow pole for stability.

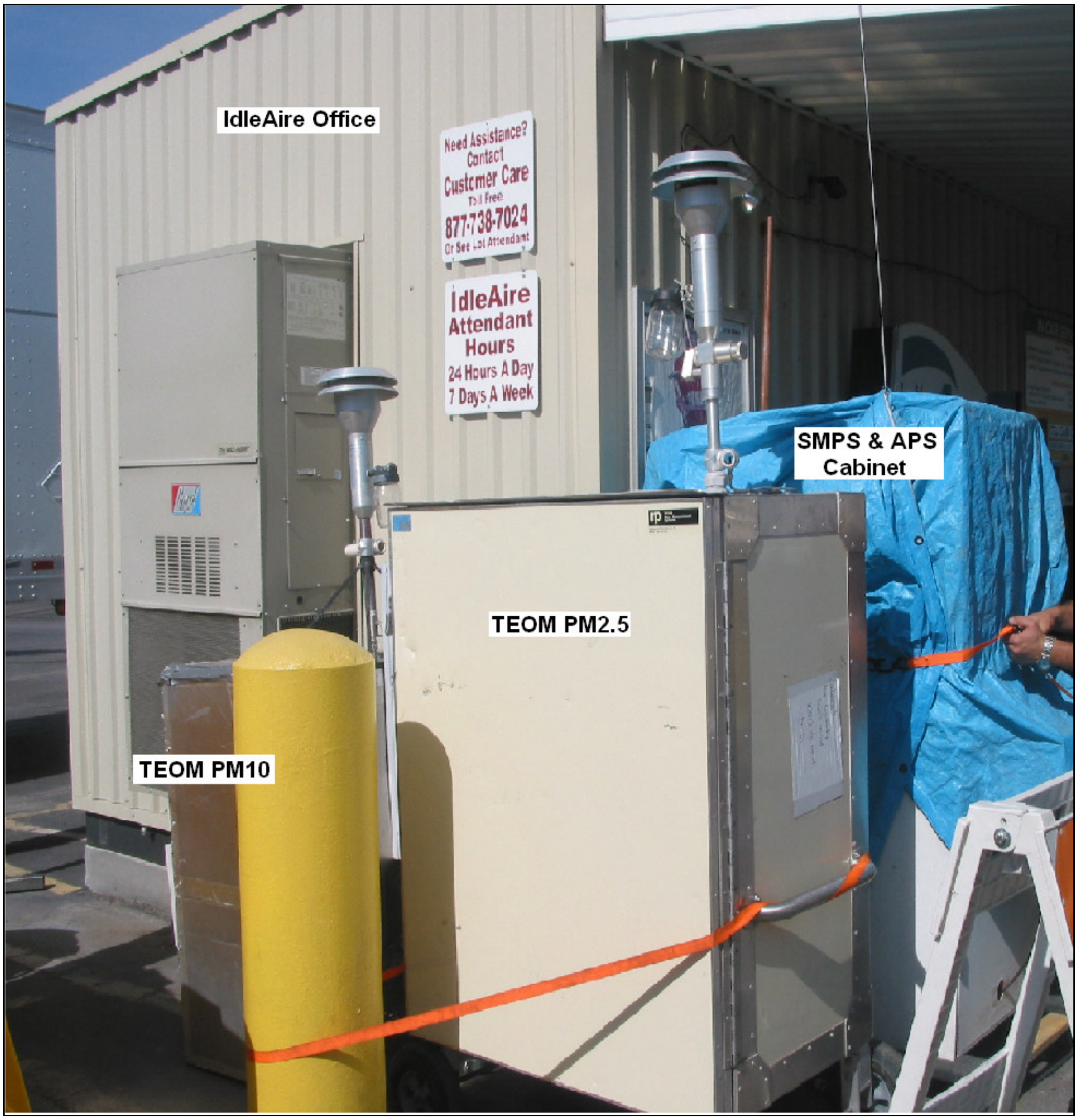


Figure 2.4 Instrument set up south of IdleAire office

The APS was set up on the second shelf from the top left of the cabinet; six feet of copper was connected to the inlet with a small vinyl tube to obtain measurements from outside the cabinet and near the inlet of the TEOMS. Kelly Erikson from the technical support of TSI Inc., the manufacturer of the APS and SMPS, suggested using either copper tubing or stainless steel tubing for the best connection in order to decrease

the loss of particles. Proper tubing is essential in avoiding particle loss due to static electricity or particles attaching to the tube. A hole was situated in the shelf above the APS to allow the copper tube through. A tripod was then placed on the shelf to support the copper tubing and keep it from touching the wooden cabinet to decrease the generation of static electricity; this is shown in Figure 2.6. The copper tubing would generate static electricity when in contact with the wooden cabinet; the tripod that supported the copper tubing was grounded to avoid any other access to static electricity.

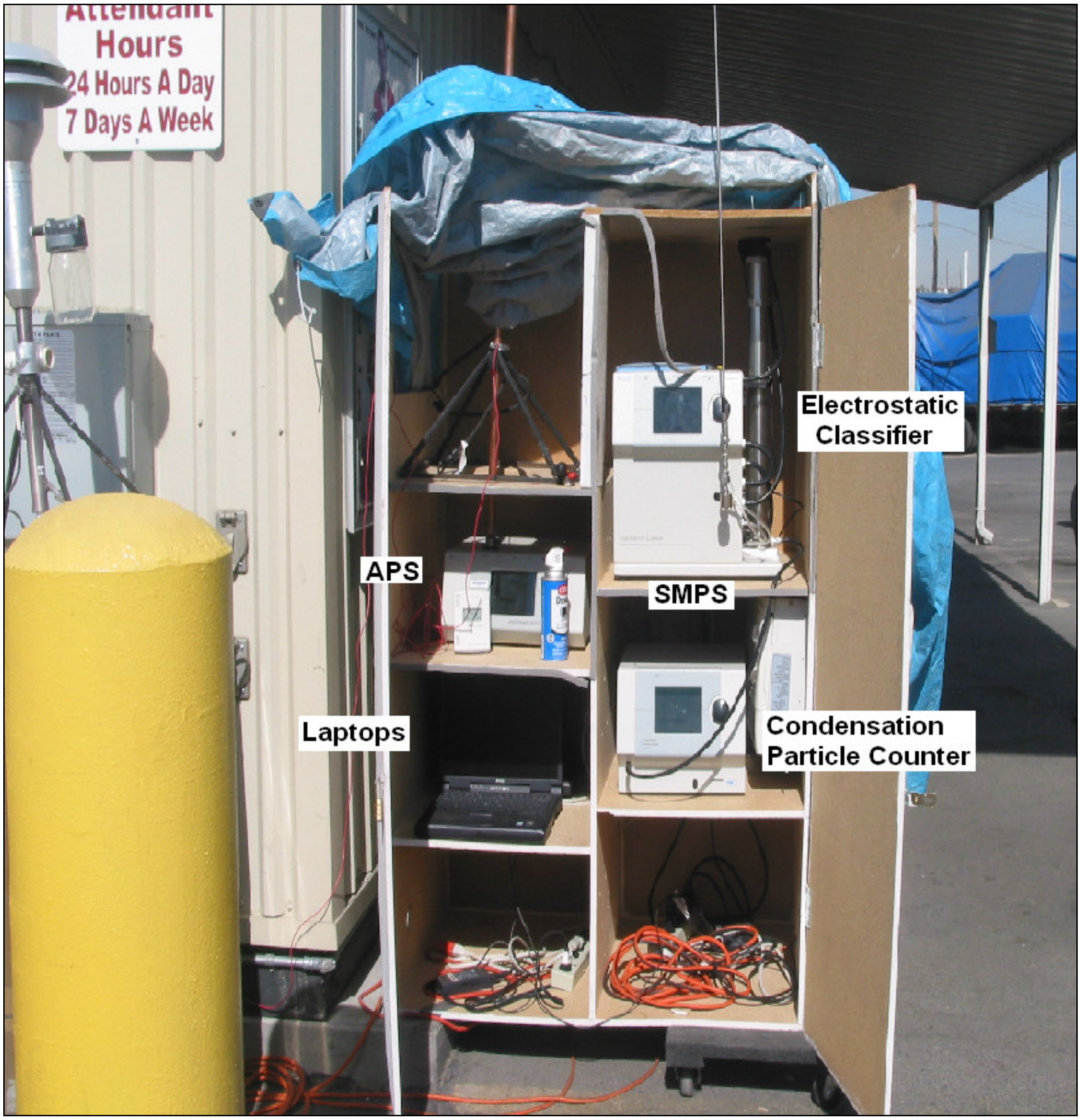


Figure 2.5 APS and SMPS Wooden Cabinet

Figure 2.5 shows the cabinet with the APS, CPC, EC and their laptops set up inside for the study. The shelf at the top right of the cabinet held the Electrostatic Classifier, which contained a six foot stainless steel tube that was connected to the impactor of the EC, also suggested by Kelly Erickson. As shown in Figure 2.6, this tube was employed to avoid as much particle loss as possible; it was positioned to obtain

measurements above the cabinet, with the top of the tube bent 135 degrees so that it faced down to prevent rain from entering. The inlet was placed higher than the APS inlet to compensate for its smaller diameter. The shelf below the EC held the Condensation Particle Counter which was adjacent to the air conditioner that was attached to the cabinet to avoid over heating of the instruments during the study. The power cords and surge protectors were placed on the shelf below the CPC. The adjacent shelf contained other power chords and surge protectors. Each unit bore a designated laptop to electronically set up the instruments parameters, view measurements and identify any errors. The instruments were inspected every morning for performance or errors, and inconsistencies found were serviced right away.

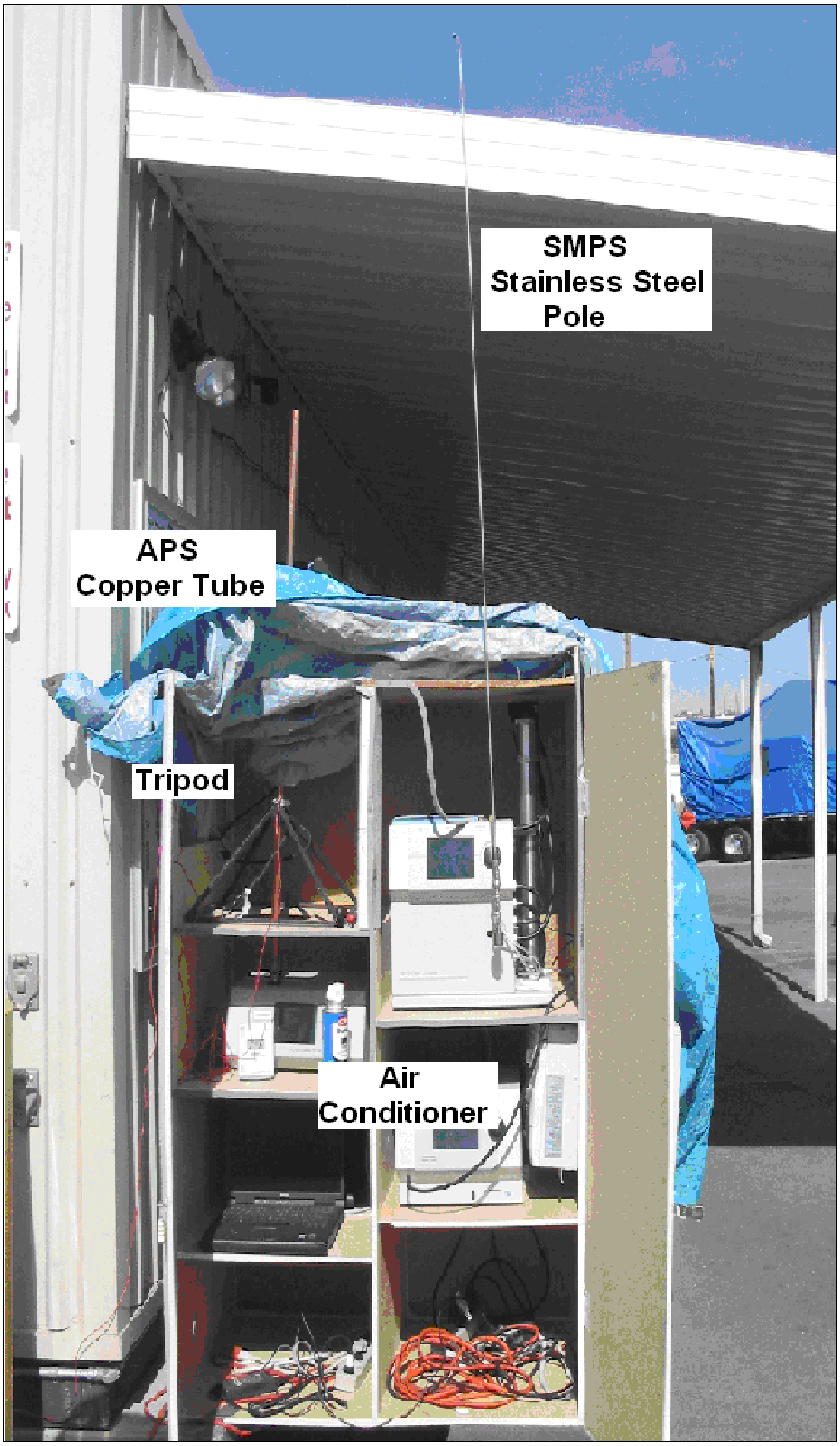


Figure 2.6 APS and SMPS Wooden Cabinet

The TEOMS were collocated in front of the wooden cabinet; TEOM $PM_{2.5}$ was moved when necessary to download data from the cabinet. Both TEOM cabinets contained their own air conditioner to keep the instruments from overheating. Both TEOMs had pumps at the bottom left of their cabinet. The Sensor Unit, which contains the microbalance, was beside the pump and obtruded through the top of the instrument to the outside where it was connected to the inlet. The top left shelf of each cabinet held the control unit which displays the status of the instruments and shows error messages if there are any present. TEOM PM_{10} allows the thoracic particles that are below 10 µm to be measured; TEOM $PM_{2.5}$ contains a Sharp Cut Cyclone (SCC) in between its inlet and sensor unit which only allows particles 2.5 µm in diameter and smaller to be weighed. Figure 2.7 shows the TEOM PM_{10} situated caddy corner to the cabinet. The mobile TEOM $PM_{2.5}$ is shown in Figure 2.8, where it's separated from the cabinet and TEOM PM_{10}.

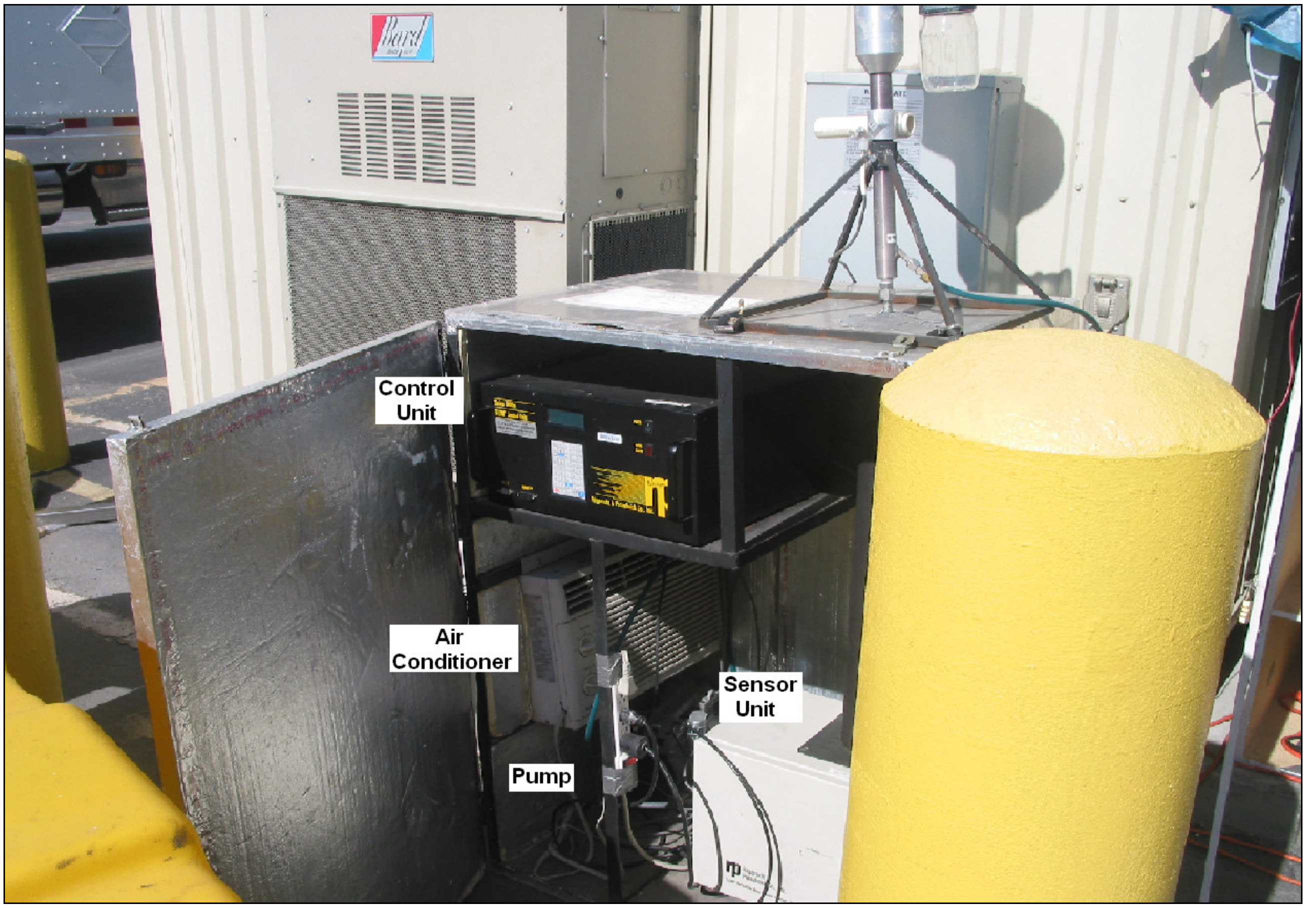


Figure 2.7 TEOM PM_{10} instrumentation set up located south of IdleAire office

Figure 2.8 TEOM $PM_{2.5}$ cabinet is located on rollers east of TEOM PM_{10}

The Texas Commission on Environmental Quality (TCEQ) has Continuous Air Monitoring Stations (CAMS) distributed around El Paso. Data was collected at one of the sites to be used in the study to verify and compare measurements of the instruments. These monitoring stations measure various pollutants and weather conditions such as $PM_{2.5}$, PM_{10}, wind speed and wind direction. Wind Data from two nearby stations were initially chosen to be analyzed individually, averaged, then evaluated and used to compare with that measured by the instruments at the Petro site. The sites are TCEQ's Moon City CAMS 415 and Socorro CAMS 49 located at 201 South Nevarez Rd and 10039 North Loop Dr El Paso, TX, respectively. CAMS 49 was determined to be the best associated, although neither station was located near a freeway or high volume traffic, as is shown in Figure 2.9. CAMS 49 is located in a residential

area with desert surrounding (Figure 2.10) similar to Petro; a picture of the site is shown in Figure 2.11. The variation in measurements between the stations and the monitoring site of the study are possible results of the different ambient environments and locations.

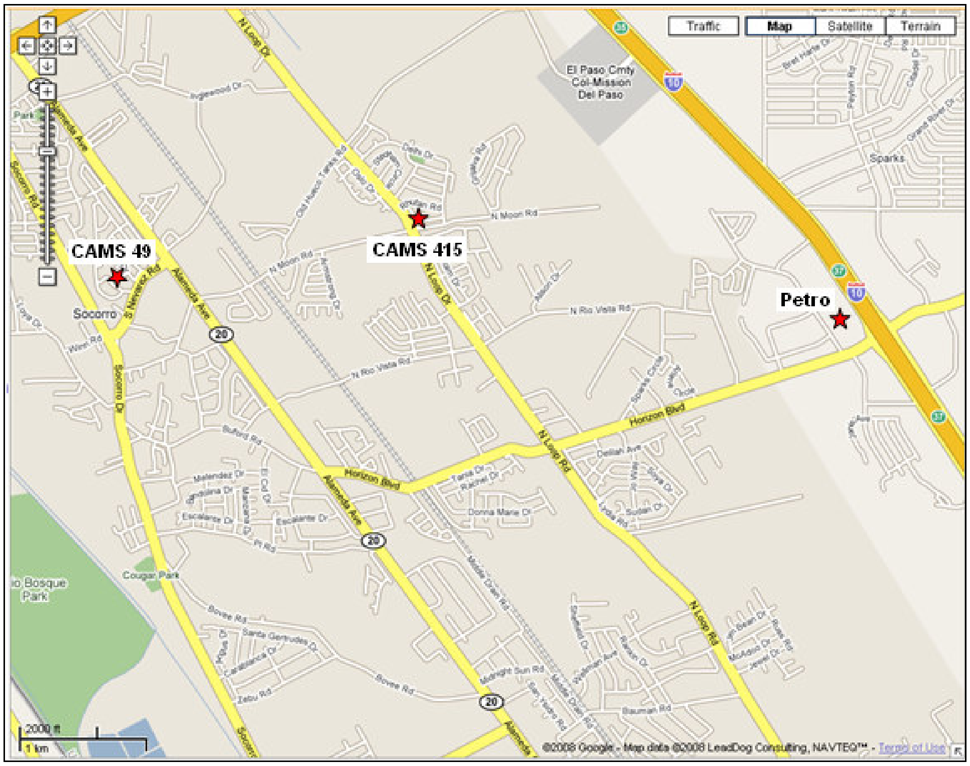


Figure 2.9 TCEQ CAMS sites used in study

Figure 2.10 CAMS 49 desert surrounding

2.7 Instrument Description

2.7.1 APS

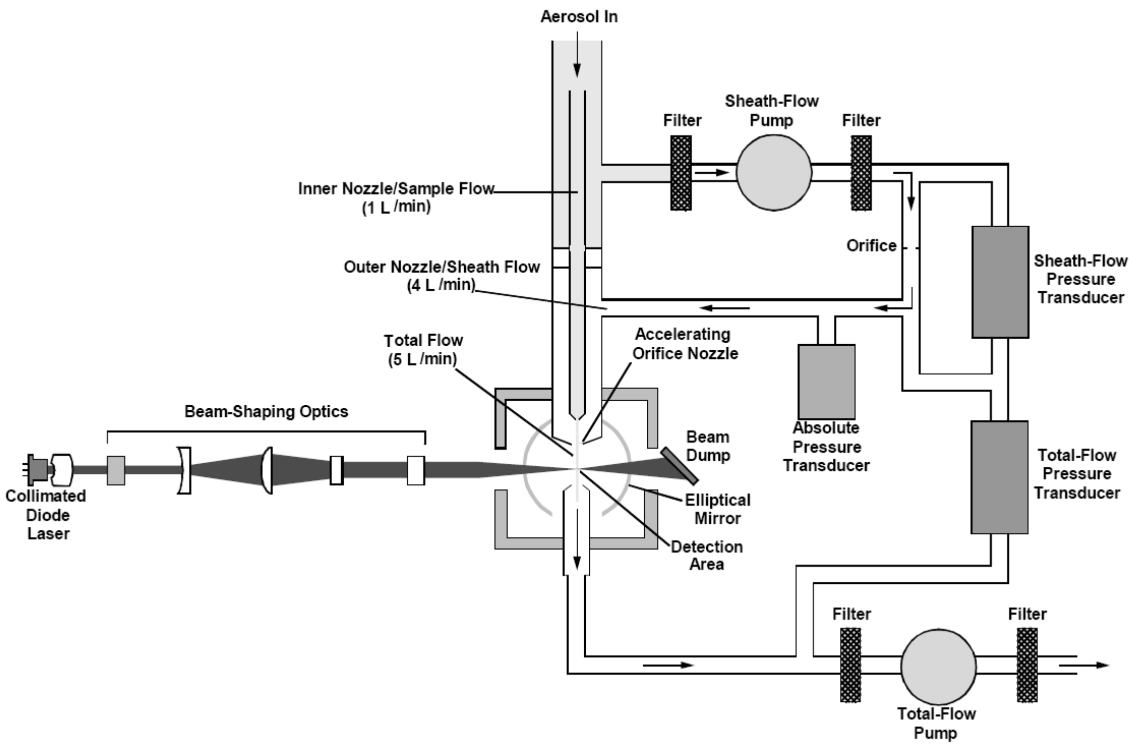


Figure 2.11 Schematic Flow Diagram of the APS Model 3321 (TSI, 2004)

The Aerodynamic Particle Sizer spectrometer (APS) model 3321 was used in the study to measure the real time number and mass concentrations of the fine particles ranging from 0.3 µm to 20 µm. The APS measures particles of diameters from 0.5 to 20 µm which it separates into 52 bins or channels. The particles from 0.3 to 0.5 µm are detectable and placed together in the 0.523 µm bin. The APS uses the reflected light of two laser beams (Figure 2.12) to create electrical pulses which are used to calculate the velocity of each particle; this velocity is then used to determine the aerodynamic particle

diameter of the particles. A schematic flow diagram of the APS and its process is shown in Figure 2.11.

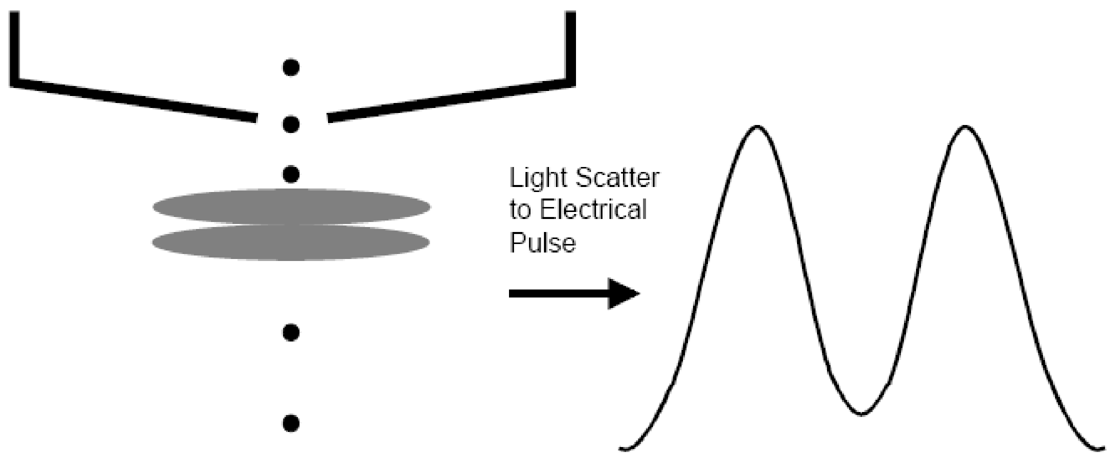


Figure 2.12 Double-Crested Signal from particles passing overlapping beams (TSI, 2004)

2.7.2 TEOM

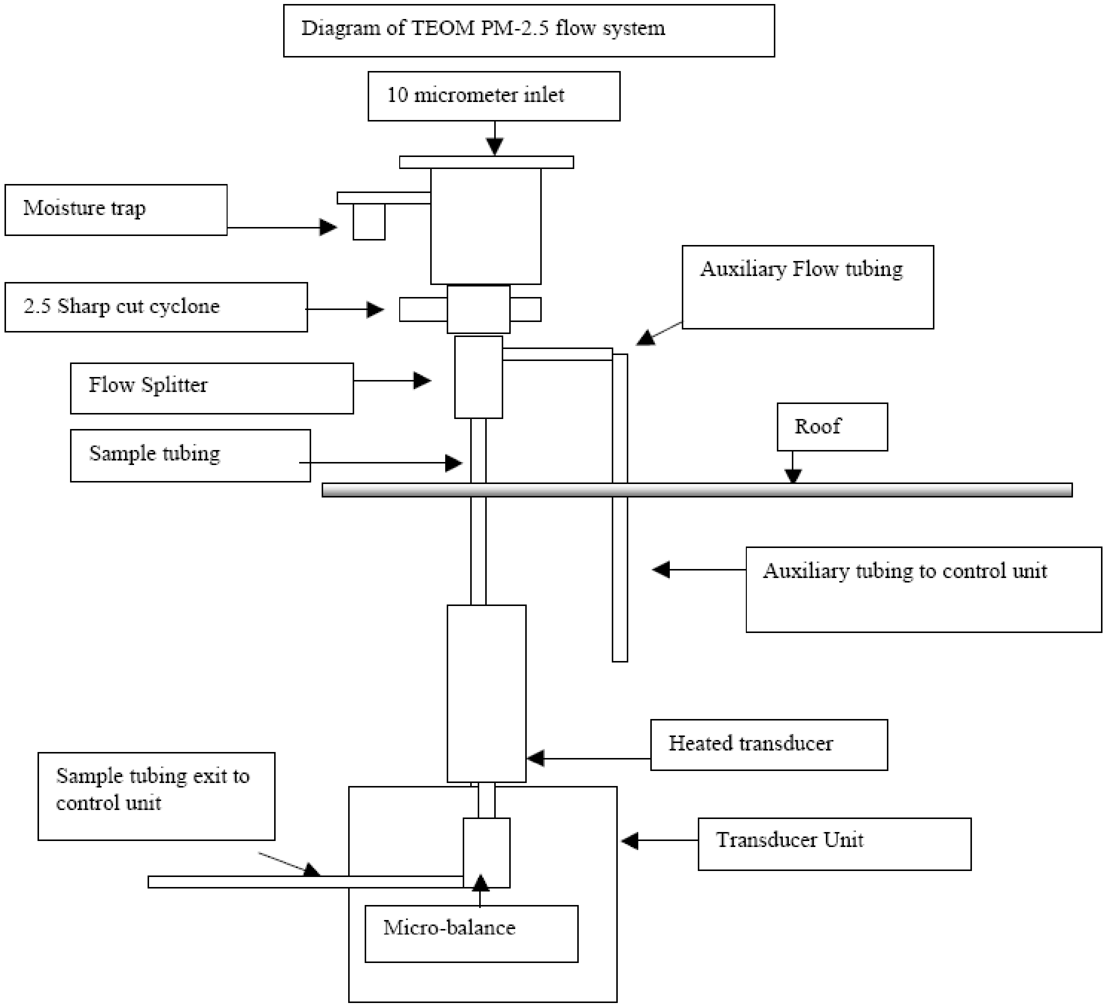


Figure 2.13 Schematic Flow Diagram of TEOM series 1400a (Rupprecht, 2007)

Two Tapered Element Oscillating Microbalances (TEOM series 1400a, Rupprecht & Patashnick Co., Inc.) were used in the study to measure the $PM_{2.5}$ and PM_{10} mass concentrations. These instruments were placed side by side in front of the cabinet that contained the other air monitoring instruments. The TEOMs gravimetrically measure the mass concentrations of PM every ten minutes. These weights, along with the mass flow rates, are used by the TEOMs in calculating the mass concentrations collected.

The customary adult breathing rate used in studies is 16.7 liters per minute, which is the flow rate the TEOMs used to measure the particulate matter and is utilized in calculating the mass, 13.67 liters per minute being auxiliary flow and 3 liters per minute belonging to main flow. A schematic flow diagram of the TEOMs is shown in Figure 2.13. Each TEOM contained its own modified inlet to only allow its designated size of PM to be measured.

2.7.3 SMPS

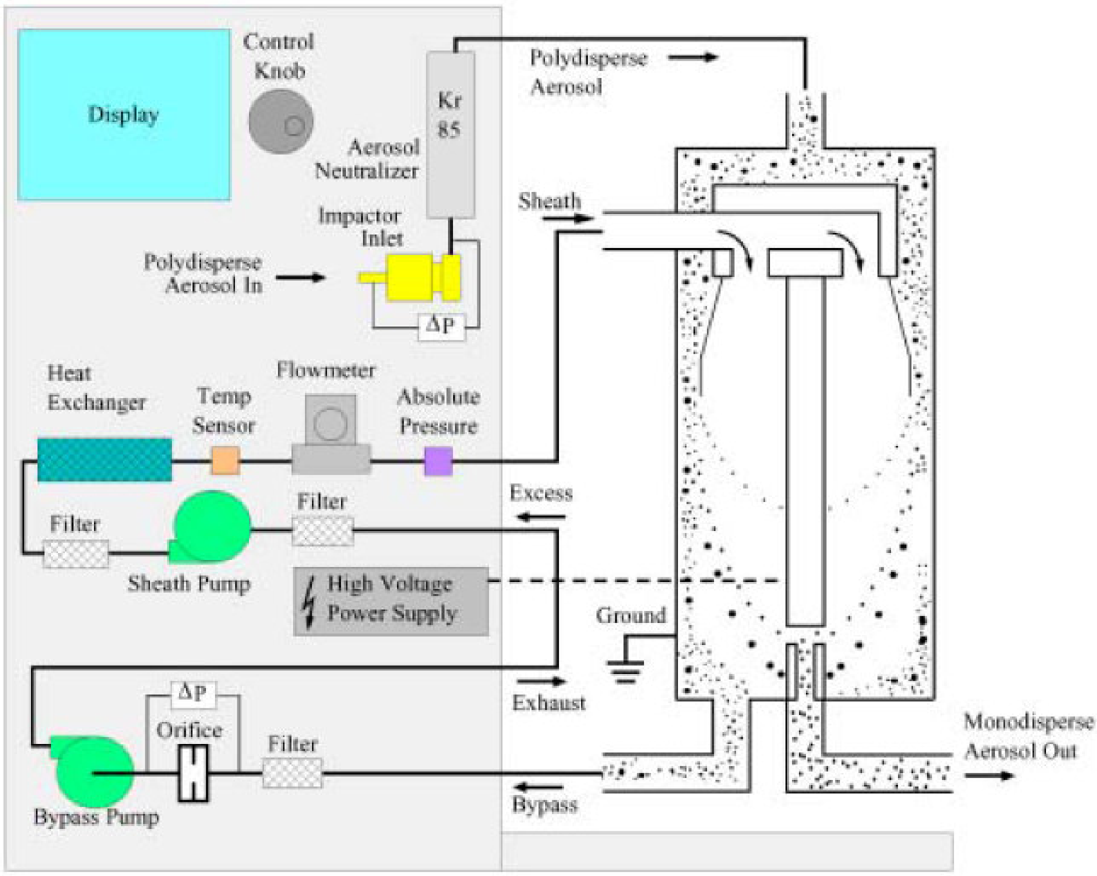


Figure 2.14 Schematic Flow Diagram of Classifier with LDMA (TSI, 2003)

Number Concentrations between 5.94 nm and 225 nm were continuously measured by the Scanning Mobility Particle Sizer (SMPS) model 3936 with a 0.701 impactor that only allows particles that are 0.701 µm and smaller, discarding the larger particles through inertial impaction. The model 3080 Electrostatic Classifier and the 3081 Long Differential Mobility Analyzer (DMA) (Figure 2.14) were used to allocate particles and then the model 3075 Condensation Particle Counter (CPC) measures the particle concentration.

2.7.4 **TCEQ**

Parameters obtained from the CAMS 49 (Figure 3.15) for weather were: wind direction, wind speed, temperature and humidity. The TCEQ sites measure various pollutants including PM_{10} and $PM_{2.5}$, which are this study's pollutants of interest. The sites chosen for the study measured and reported PM_{10} NC but not $PM_{2.5}$ MC. TCEQ contains these hourly averages of their measurements online; thus, the study's data was averaged hourly in order to properly compare.

Figure 2.15 TCEQ's CAMS 49

Chapter 4

3 Results

3.1 Quality Assurance

A week prior to the study, the instruments were set up in the basement of The University of Texas in El Paso's Engineering Building. This was done to examine the proper functioning of the instruments, determine their arrangement for the study and their necessary accommodations. The instruments are not designed for extreme weather conditions; therefore, the TEOMs had a cabinet designed to protect the instruments from such surroundings. The APS and SMPS were placed in a wooden enclosure built by the staff of the Air Quality Research Lab to protect them from the inclement weather. The inlets of the instruments limited their sample intake to the inside of the enclosure; therefore, copper tubing and steel tubing were purchased to extend the inlets to outside and above the casing. These tubes allowed the instruments to intake measurements from a similar height as the TEOMs. The next concern was with static electricity being conducted through the copper tubing; this was resolved by placing the copper tube through a tripod that kept it from touching the wooden cabinet. Although static electricity was reduced, the APS still accumulated enough static electricity to restrict the instrument from working properly; hence, a grounding wire was wrapped around the area of the copper tube preventing direct contact with the tripod and the cabinet.

This study used the same instruments as the study entitled "Investigation of the Nocturnal PM Peaks for Evidence of Association with Population Health: Diurnal

Variations in Ambient Fine and Ultrafine Particles Concentrations in El Paso, Texas," a 2007 study done at UTEP by Jessica Gamez. Measurements from TCEQ Continuous Air Monitoring Stations (CAMS) were used in both studies for meteorological data and quality assurance. An important difference between the studies is that the UTEP study was assessed inside a CAMS site with instruments set up directly next to the TCEQ measuring monitors. The present study is a remote study located near two CAMS locations, CAMS 415 and CAMS 49. The averages of measurements from the two locations were considered, but the results correlated more efficiently with the CAMS 49 site alone. Another distinction from the two studies is that the other UTEP study was further from the freeway and not inside a parking lot, as the present study was done. The location for this study was concentrated specifically where there are more heavy duty diesel trucks.

Data was downloaded from the instruments daily for quality assurance. The frequency of data collected lead to the loss of a couple of data points, but had no crucial effect on the analysis. The APS and SMPS sampling was stopped when measurements were being downloaded, which caused the loss of one to two data points, equivalent to ten minutes worth of sampling. Small amounts of data points were also lost from the PM_{10} TEOM when the TEOM was moved from the front of the shelter with the SMPS and APS for access. A few other data points were lost due to the instruments reaction to various weather conditions, such as freezing in the night.

On October 31st, the inlet to the SMPS was changed to an inlet that allowed a finer range of particle sampling; thus, the prior sampling data was not used in the study. The study's TEOMs were not close enough to the TCEQ TEOMs to validate the comparison through correlation graphs; therefore, the time series graphs were used to qualitatively validate the information. The November 3, 2007 data were observed to be an adequate day to represent the study's quality assurance observations. Figure 3.1 shows the mass concentration comparisons throughout the day for TCEQ, the PM_{10} TEOM and the APS PM_{10}. Figures Figure 3.2, Figure 3.3 and Figure 3.4 show the correlation graphs for PM_{10} between the instruments; TEOM vs TCEQ, APS vs TCEQ and APS vs TEOM, with the correlation values of 0.0225, 0.0018 and 0.5409, respectively. The TEOM and the APS display similar peaks at different magnitudes; the difference in magnitude could explain the 0.5409 correlation shown in Figure 3.4. The difference between the operation of theory for the APS and TEOM could also clarify their correlation, which from the concentration graphs shows a strong relationship. The TCEQ CAMS 49 is 4.2 miles from the study location. Although it is not the closest location, it is the location that could be best correlated to measurements at the Petro study. From the evaluated TCEQ sites, CAMS 49 was determined to have the closest relationship with Petro's data. Furthermore, UTEP's study was best associated with its TCEQ data, which could be a result of many factors, such as the difference in distance. The constant activities of the heavy duty vehicles in the parking lot have a greater influence on the ambient conditions of the instruments than the regional meteorological conditions. The instrument's performance was determined to be functioning properly in

a recent previous study, which contributes to the verification implemented in the present study.

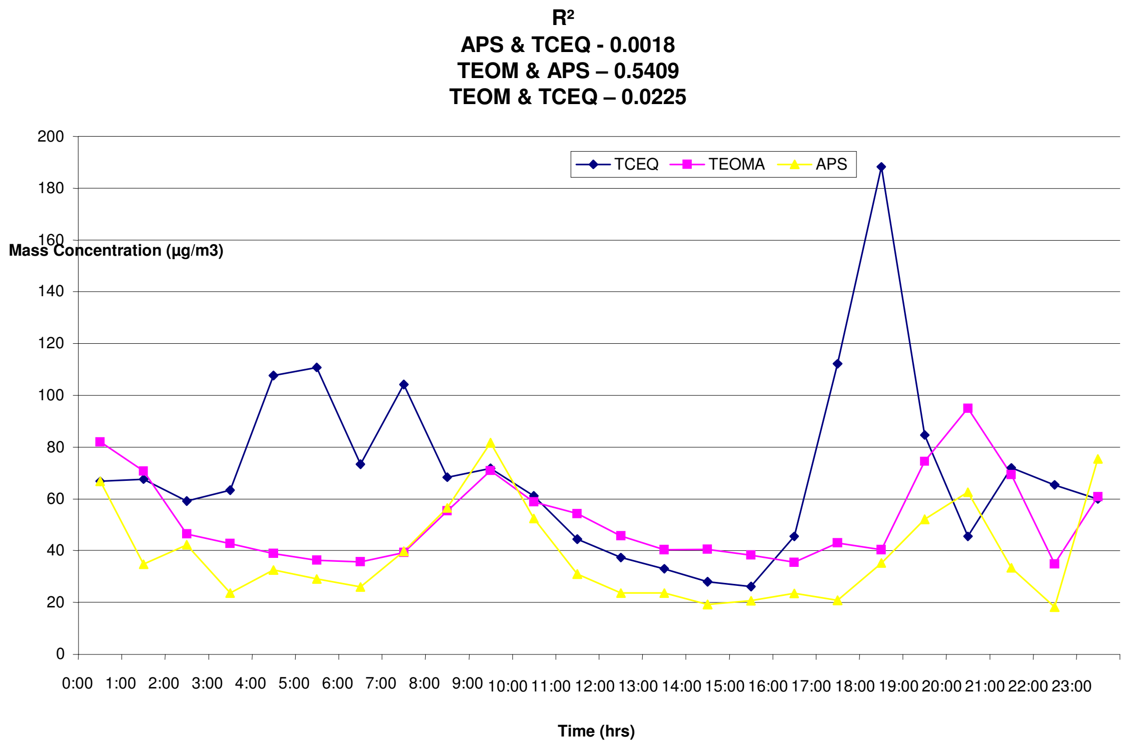


Figure 3.1 TEOM, APS & TCEQ PM_{10} Mass Concentration November 3, 2007

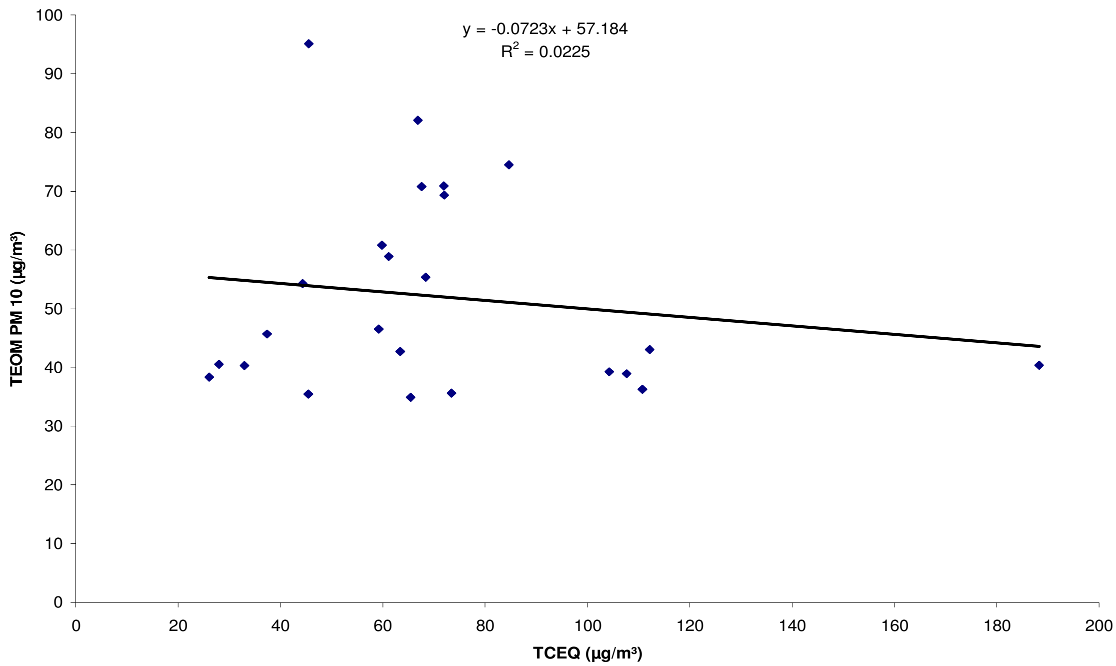


Figure 3.2 TEOM & TCEQ PM_{10} Mass Correlation November 3, 2007

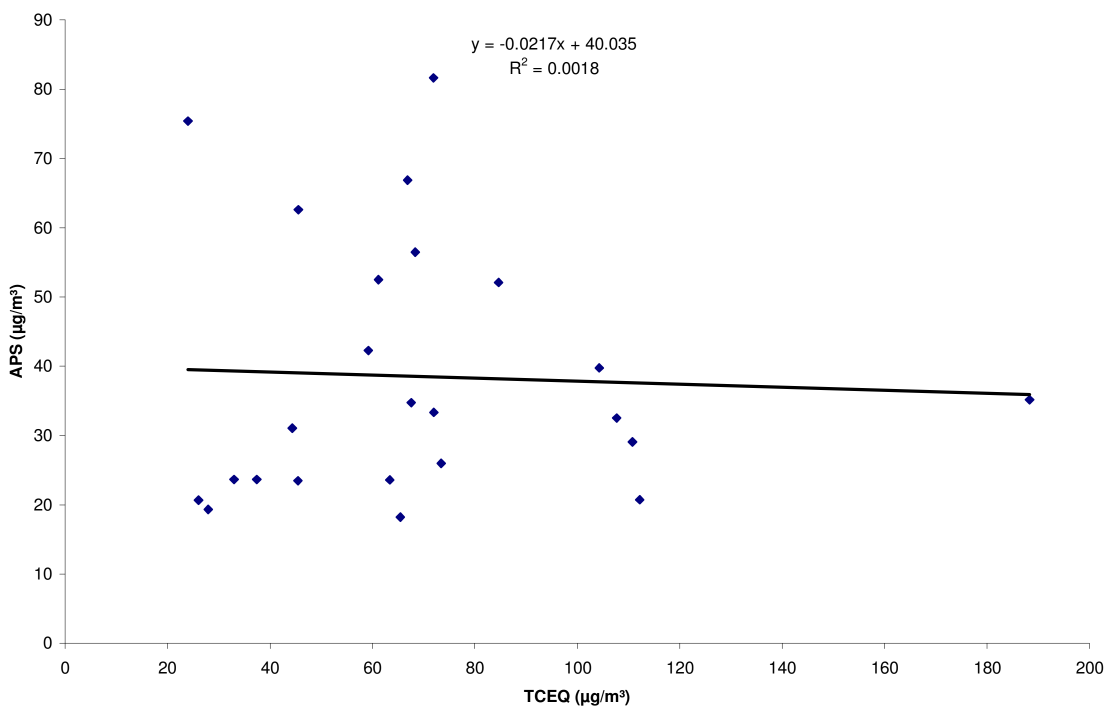


Figure 3.3 APS & TCEQ PM_{10} Mass Correlation November 3, 2007

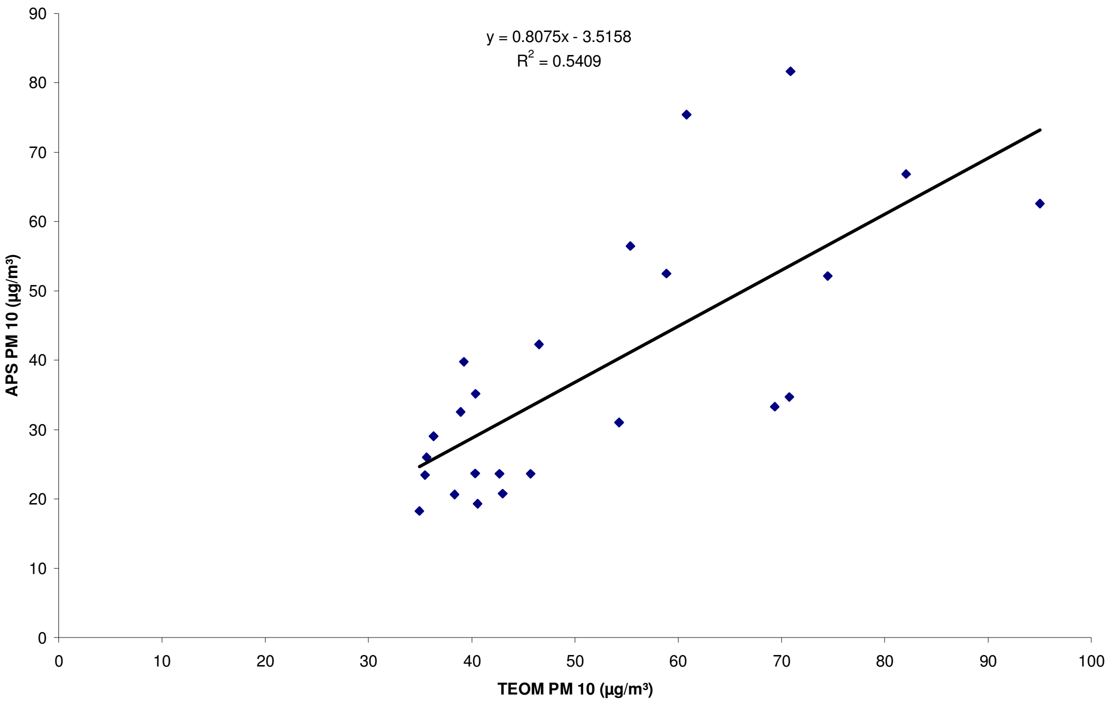


Figure 3.4 APS & TEOM PM_{10} Mass Correlation November 3, 2007

CAMS 49 does not measure $PM_{2.5}$; therefore, the TEOM and the APS' $PM_{2.5}$ mass concentrations could only be quality assured by comparing the results against one another. Figure 3.5 shows their simultaneous peak measurements with a reasonably good 0.566 correlation coefficient (Figure 3.6). The consistence in adequate correlation between the two instruments is shown in Appendix A and Appendix B for both PM_{10} and $PM_{2.5}$ mass measurements, which further confirms their reliability. Figure 4.7 shows the averaged PM_{10} concentrations of the APS, TEOM and TCEQ data throughout the study. Figures Figure 3.8,Figure 3.9 and Figure 3.10 show the 0.4272, 0.6882 and 0.4114 correlations of the instruments, respectively.

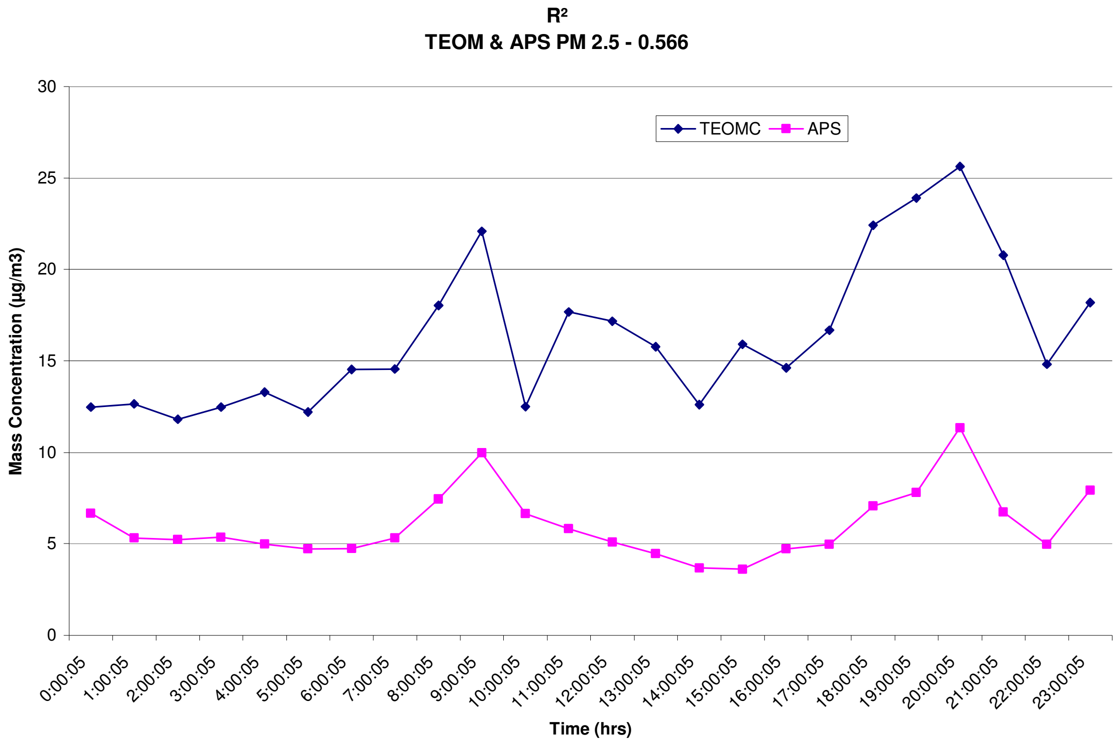


Figure 3.5 TEOM & APS $PM_{2.5}$ Mass Concentration on November 3, 2007

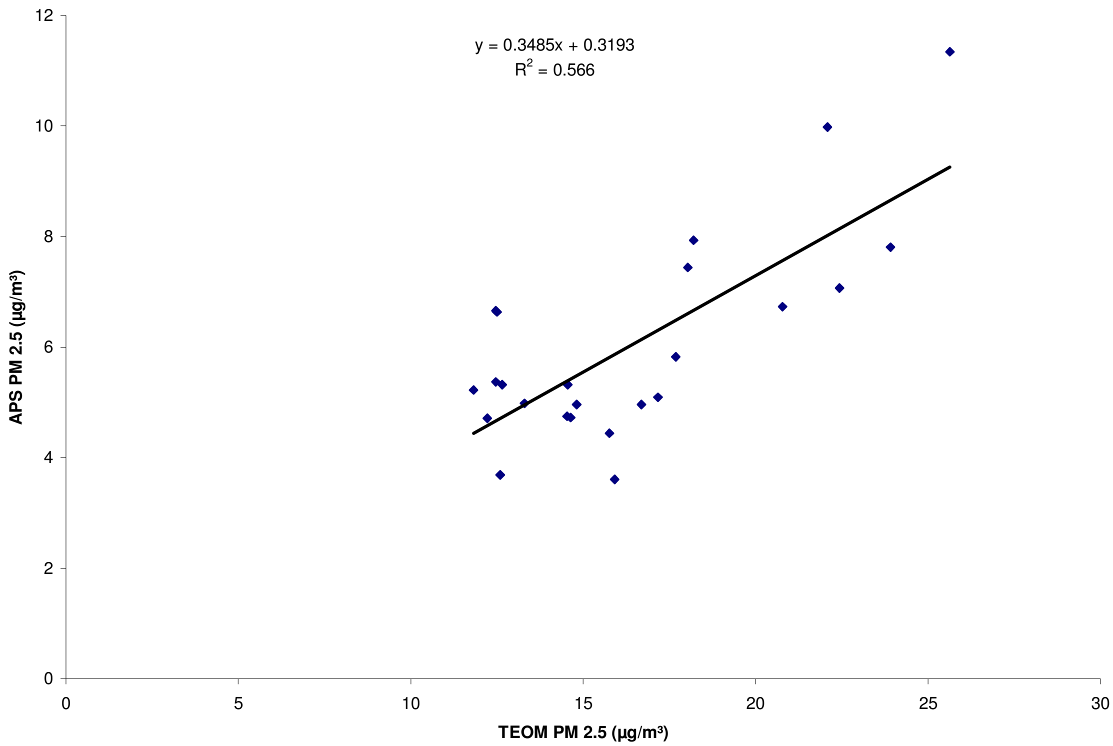
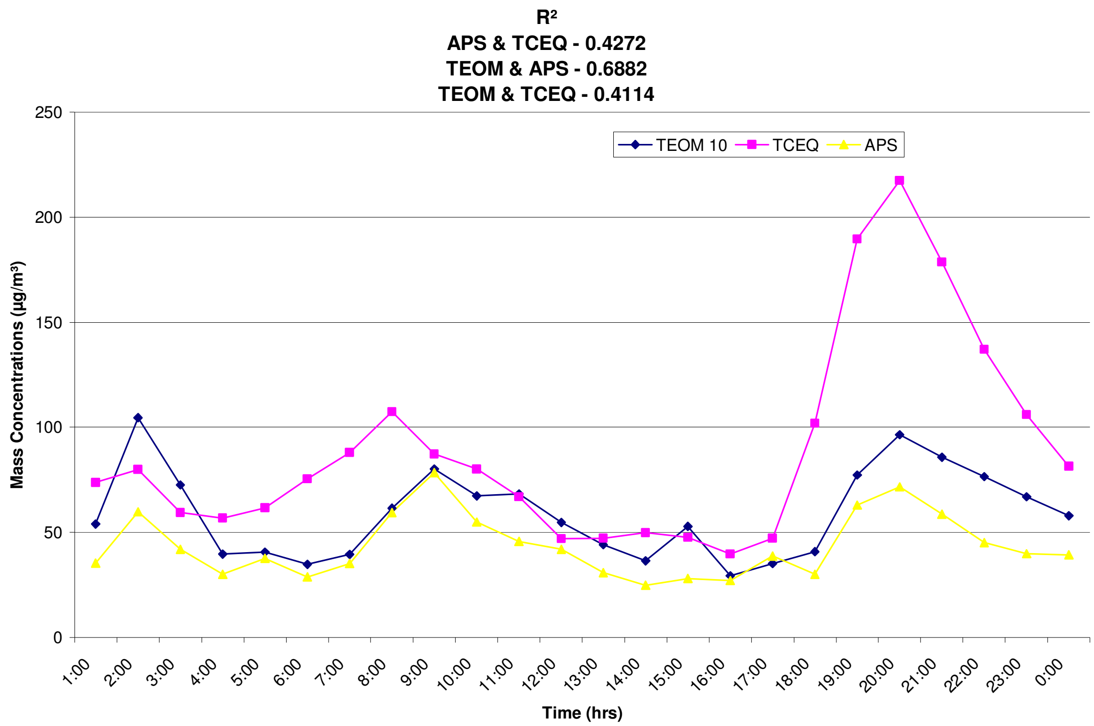


Figure 3.6 APS & TEOM $PM_{2.5}$ Mass Correlation on November 3, 2007

All of the instruments functioned effectively throughout the study, from October 31 to November 9. All measurements during this time period were averaged. The only significant amount of data lost was that from TCEQ on November 7th and most of the 8th. This was due to "No Valid Measurements," which means there wasn't an adequate amount of suitable data to record for an hour or more. According to the TCEQ web site, this error could occur for various reasons, but only two affected the data for the present study. There was no data on November 7 because the data exceeded the criteria for rejection (LIM), and the November 8 lost data were attributable to Preventative Maintenance (PMA).

Regardless of TCEQ's loss of data and separate location, the correlation between this study's instruments and TCEQ's is still acceptable to suggest the proper functioning of the instruments, in addition to the validation from the UTEP study.



3.7 APS, TEOM PM10, TCEQ Mass Concentration Average (Oct 31-Nov 9 2007)

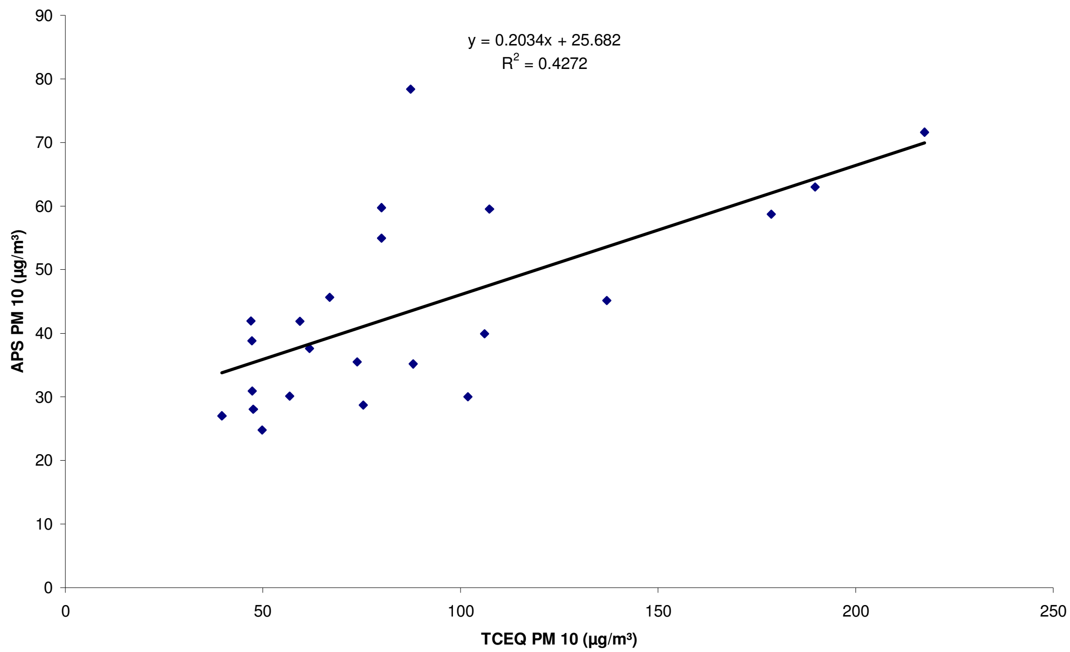


Figure 3.8 APS & TCEQ PM_{10} Mass Correlation Average (Oct 31-Nov 9 2007)

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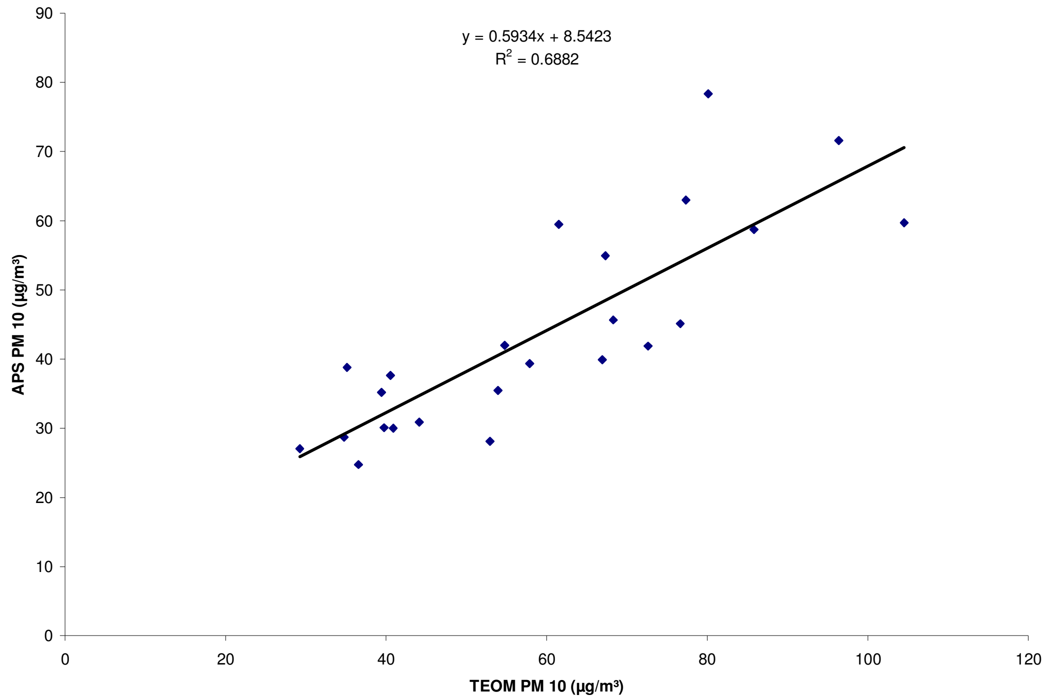

Figure 3.9 APS & TEOM PM_{10} Mass Correlation Average (Oct 31-Nov 9 2007)

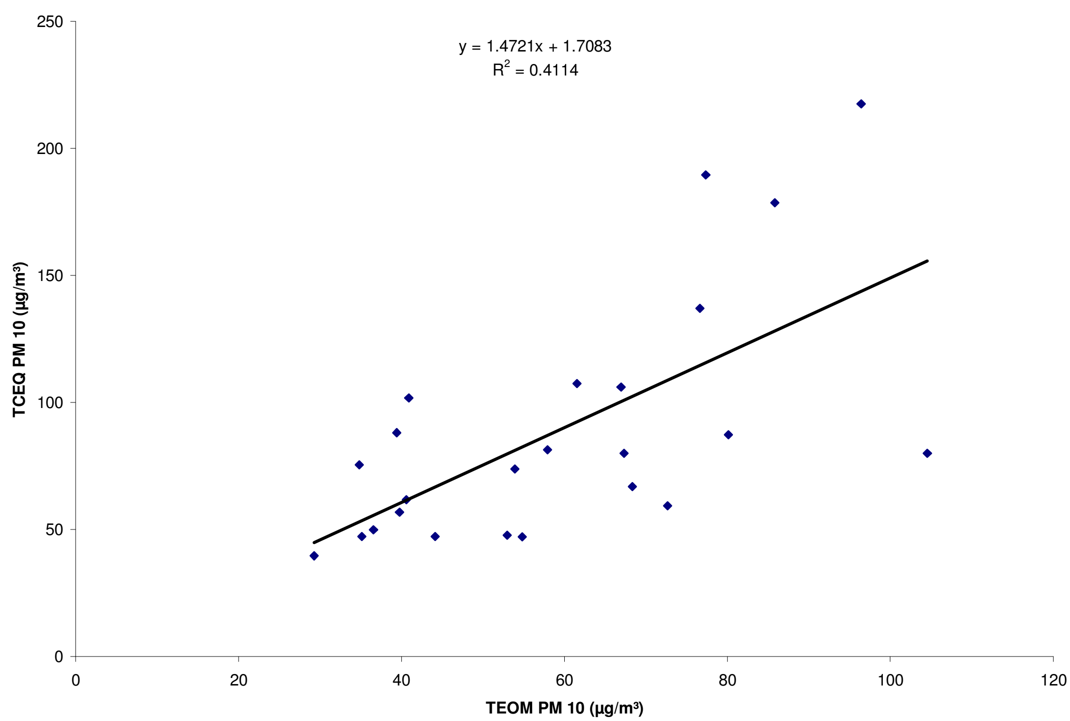

Figure 3.10 TCEQ & TEOM PM_{10} Mass Correlation Average (Oct 31- Nov9 2007)

After establishing the performance of the TEOM and APS to be functioning properly, the APS was used to verify the performance of the SMPS. Both instruments measure the number concentration of particles for different sizes; the SMPS records particles smaller than the APS. The SMPS samples particles up to 0.224 µm while the APS samples particles from 0.542 µm to 19.81 µm and has a channel labeled 0.523 µm that samples particles from 0.523 µm and below. Because the particles measured by the SMPS are the same as part of the particles measured in the <0.523 µm channel of the APS, when graphed together in diameter and number concentration, the two instruments should transition smoothly from one to the other.

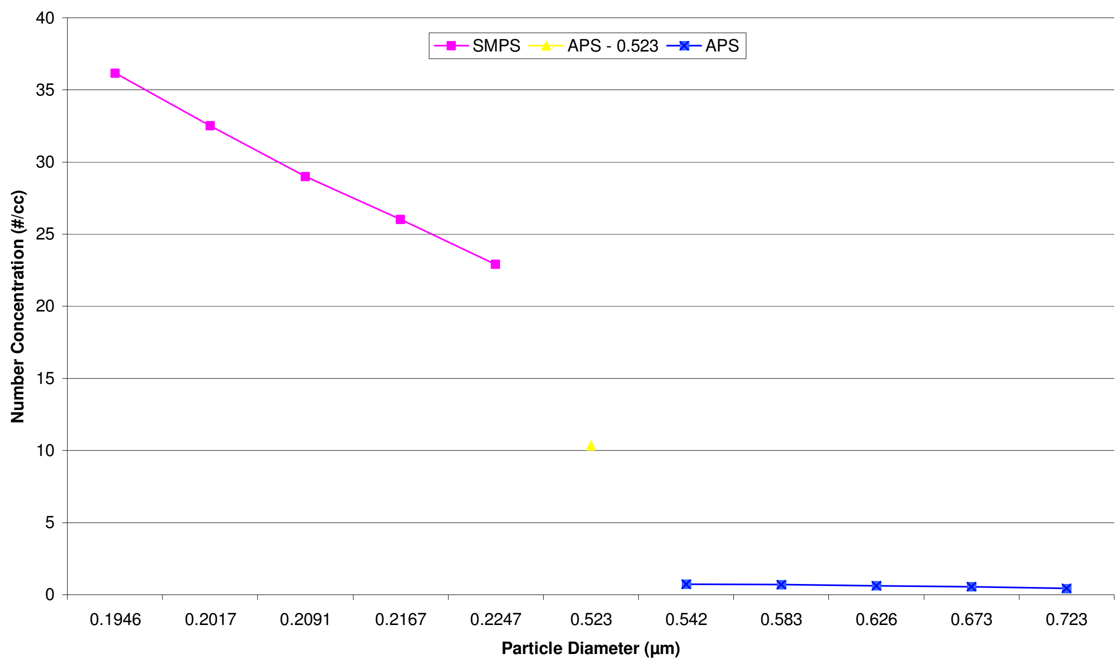

Figure 3.11 Study SMPS & APS transition diameters

Figure 3.11 demonstrates the averaged number concentrations throughout the study of the 5 largest diameters measured by the SMPS and the 6 smallest diameters

measured by the APS along with its 0.523 µm channel. It is evident that the 0.523 µm bin is almost exactly in between the measurements of the two instruments which implies proper operation.

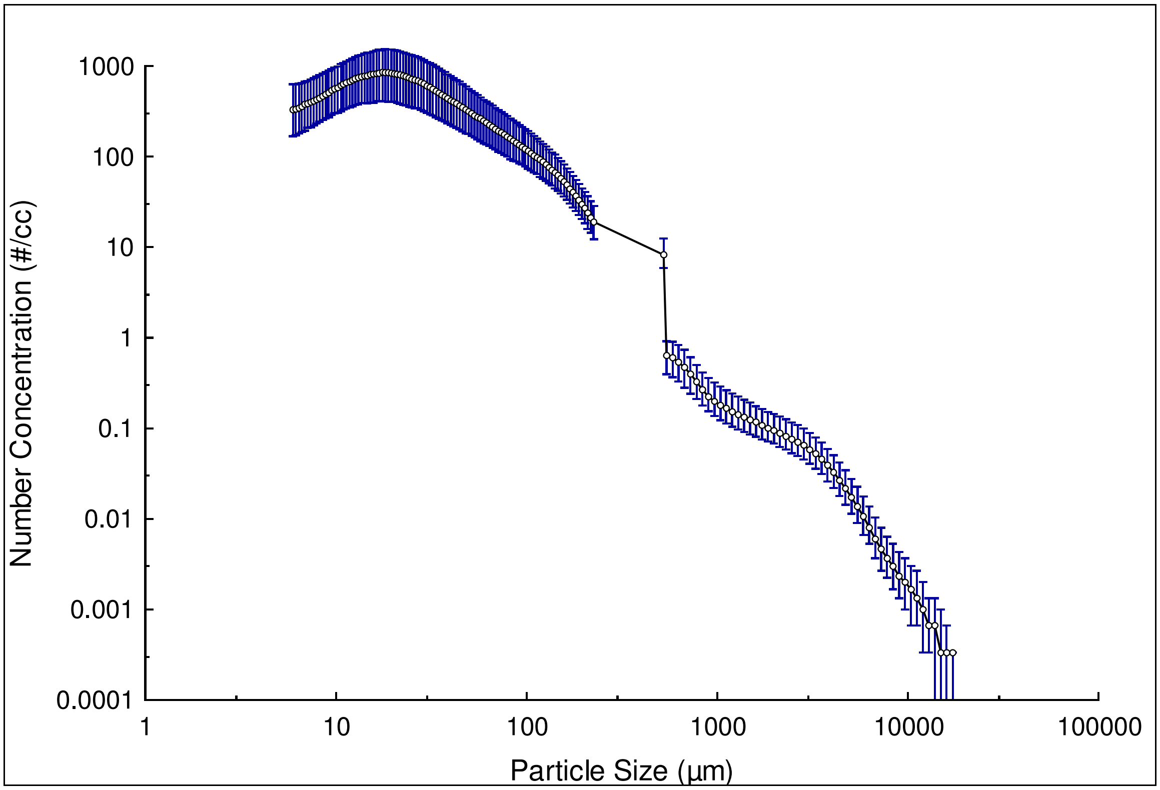

Figure 3.12 Study Average SMPS & APS merged Number Concentration

Figure 3.12 shows the entire size distribution of the study average from October 31st to November 9th 2007 with the 25 and 75 percentiles for both instruments. The first range of particles, as shown in the previous figure, belong to the SMPS; the single data point is the 0.523 µm bin of the APS and the data points following also belong to the APS. Figure 3.11 represents the middle section of the graph in Figure 3.12 to show the smooth transition between instruments. This is a broader graph of the complete size distribution of both graphs, showing the transition between the two instruments in their entirety. The smooth transition in both Figure 3.11 and Figure 3.12 shows the smooth

conversion from the SMPS to the APS, which shows the SMPS to be functioning properly.

3.2 Mass Concentrations

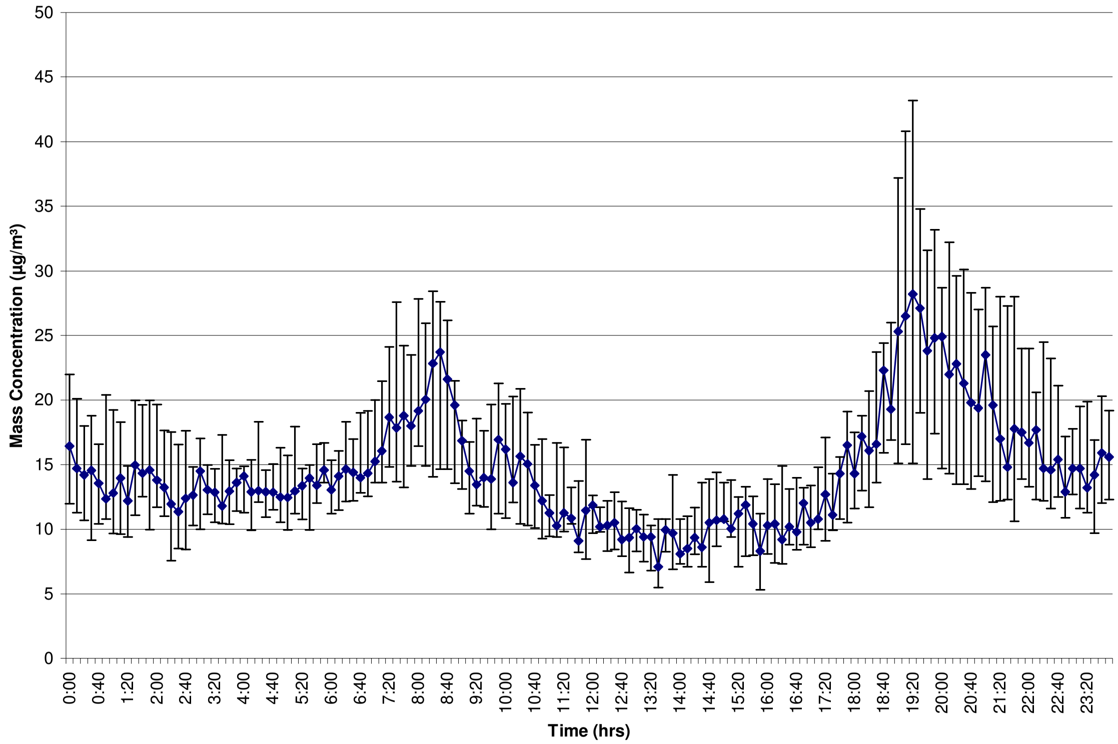

Figure 3.13 Diurnal mass concentrations for TEOM $PM_{2.5}$ from Oct 31 - Nov 9

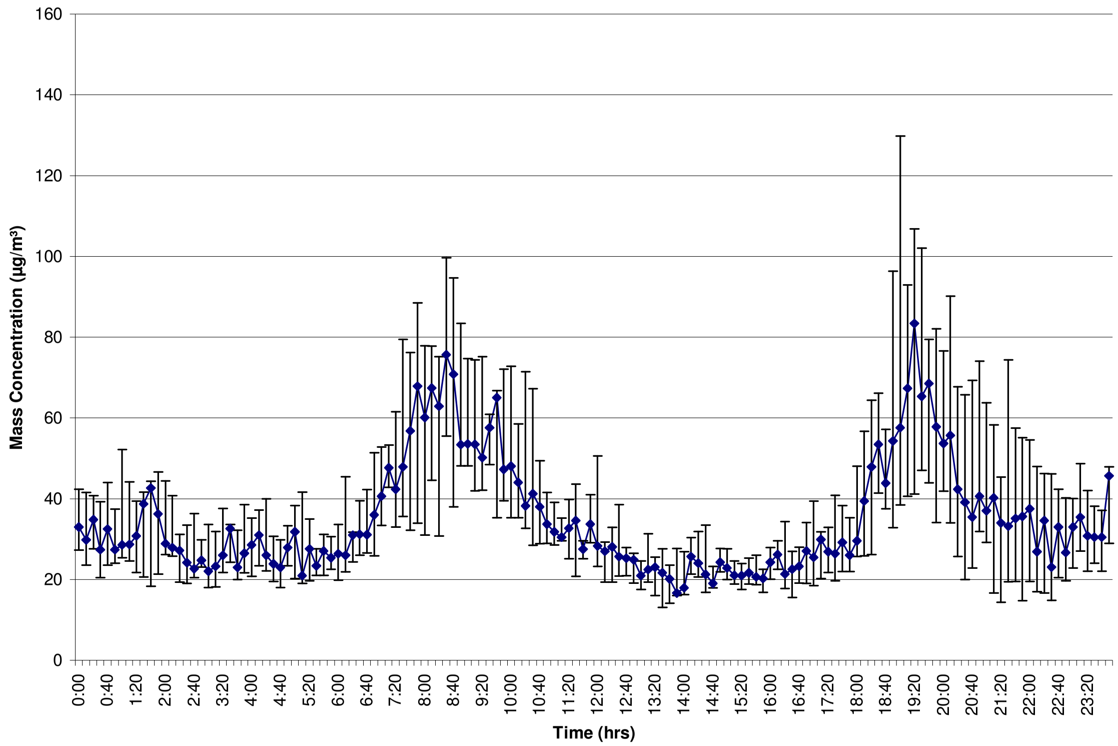

Figure 3.14 Diurnal mass concentrations for TEOM PM_{10} from Oct 31 - Nov 9

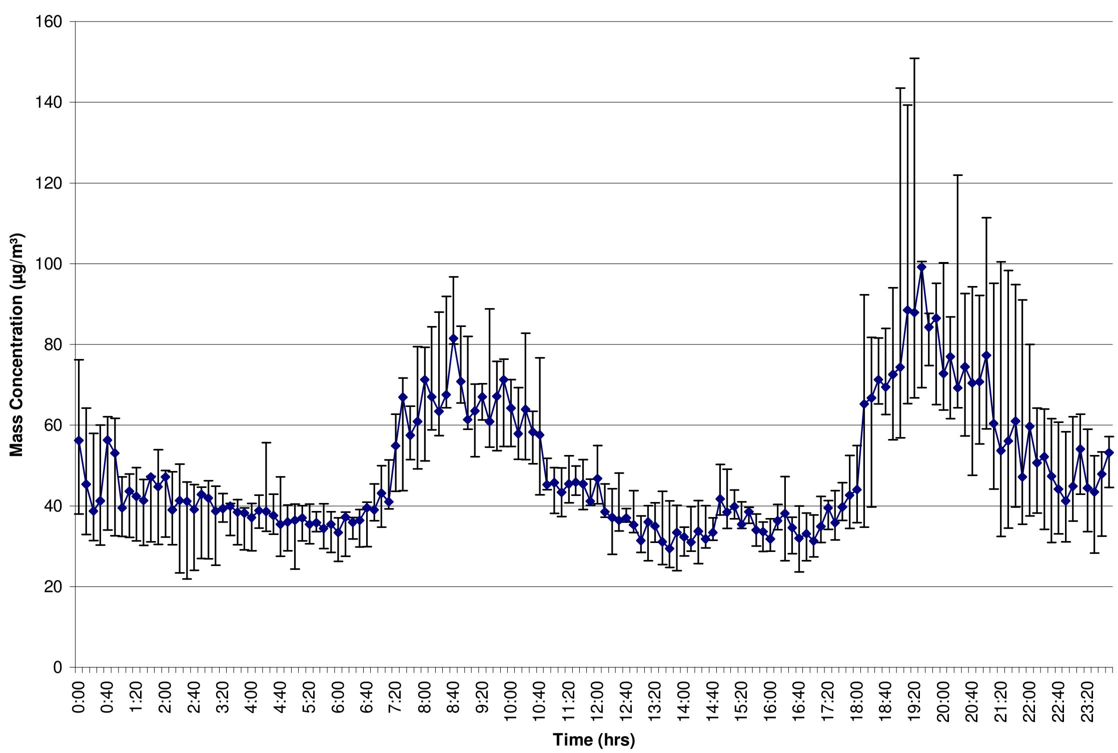

Figure 3.15 Diurnal PM_{10} mass concentrations for APS from Oct 31 - Nov 9

Figure 3.13, Figure 3.14 and Figure 3.15 are the averaged mass concentrations from the study: $PM_{2.5}$ obtained from its TEOM, PM_{10} from its TEOM and the APS, with their twenty-five and seventy-five percentile values. The morning valleys in the 3 graphs are slightly higher than the afternoon plateau but almost negligible in the PM_{10} graphs, Figure 3.14 and Figure 3.15. The morning peaks are much larger in the PM_{10} graphs and are also broader; this contradicts the number concentration averaged graphs which have higher and more concentrated peaks. As explained before, this could imply the irrelevance between mass and number concentrations (Figure 3.16). The evening peaks in the three graphs display the most variation between quartiles in all three graphs.

The mass concentrations from the APS were obtained for quality assurance and verification of the two instruments, particularly the APS. As shown in the two graphs with the PM_{10} concentrations, they both operate uniformly with insignificantly minor differences; this signifies that they are both functioning properly.

3.3 Number Concentrations

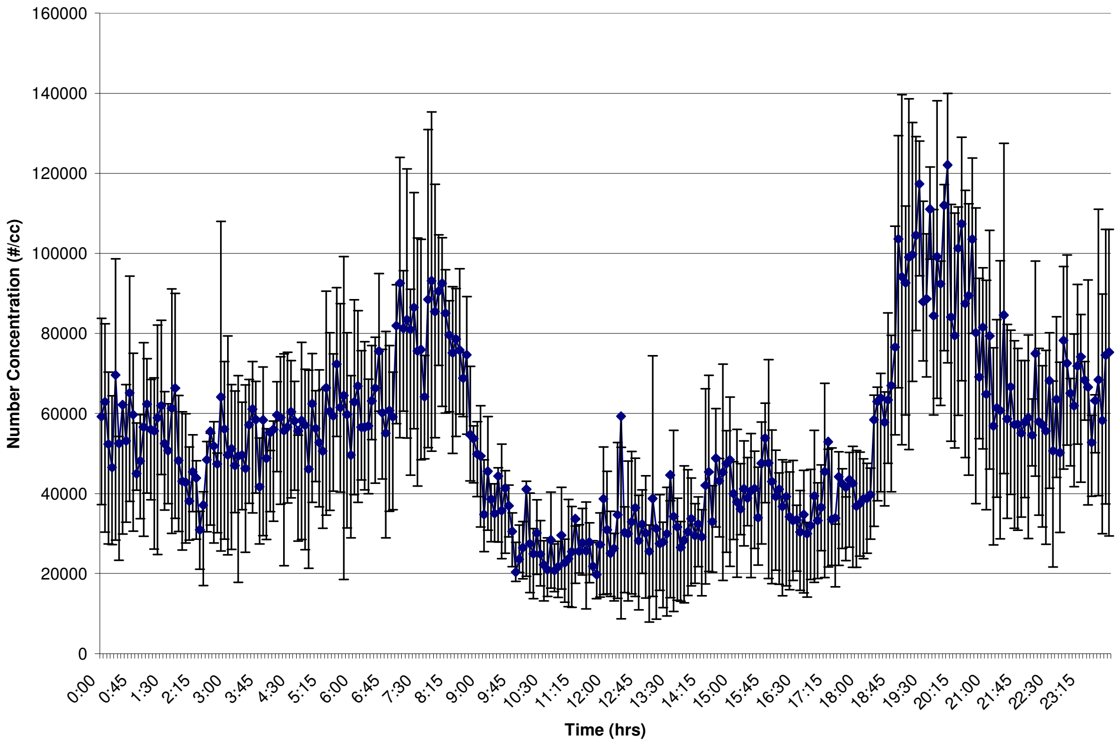

Figure 3.16 Diurnal total number concentrations for APS & SMPS from Oct 31-Nov 9

The percentile graph in Figure 3.16 shows the average percentile variations of the number concentrations for the twenty four hour days studied. Each series contains lower and upper bars that represent their respective quartiles. The lower bars represent the first quartile. This is the 25 percentile, which is the average of the number concentrations below the mean. The bars above the averaged data points signify the third quartile, which is the 75 percentile, and this is the average of the number concentrations that are greater than the mean. The inter quartile range is the range between the first quartile and the third quartile shown between the bars, which essentially displays the number concentrations that occur fifty percent of the time.

The graph in Figure 3.16 shows two peaks, one that occurs in the morning between the hours of 7 am and 9 am, and the other that occurs in the evening from 7 pm to 9 pm. This graph shows the absence of the five o'clock rush hour peak (Wahlin, 2001), which is normally displayed on graphs in studies that represent the number concentrations of daily traffic.

The evening number concentration peak is much higher than the morning peak even though the total number of vehicles in the parking lot is relatively equal in both time periods (Figure 3.21). The concentration differences could be due to the truck stop's rush hour of anticipating trucks looking for parking to rest for the night. Mr. Joe Paniagua, IdleAire site supervisor stated that the highway exit and frontage road backs up regularly and have been known to be backed up as much as two miles with idling trucks waiting to enter the Petro site around 8 pm for overnight rest. Mr. Paniagua also stated that in the morning, drivers turn on their vehicles, leave their truck running to warm up their engine and inspect their vehicle for leaks before continuing their travel. This morning activity could explain the difference in the morning concentrations and could possibly demonstrate the difference between cold start and hot running engine emissions. The trucks leaving shortly after they are turned on limits the running time of the truck inside the truck stop and the absence of the queue of trucks waiting to enter the truck stop could explain the morning peak being lower than the evening peak.

The graph also shows two plateaus between these peaks, one in the mid afternoon and the other between the evening and morning peaks. The afternoon plateau occurs in the time that the least amount of trucks is in the parking lot, the afternoon being the most likely time that the vehicles are traveling rather than resting.

Some diesel truck owners keep their engines running until before they fall asleep; others leave their engines running all night. The study was conducted in the fall during cold weather which would mean that it's likely that some truck drivers left their trucks on all night for heat. The plateau that occurs in the middle of the night displays higher concentrations than the afternoon, which is possibly due to the idle, running trucks that stay for the night in the parking lot.

3.3.1 Particulate Size Distribution

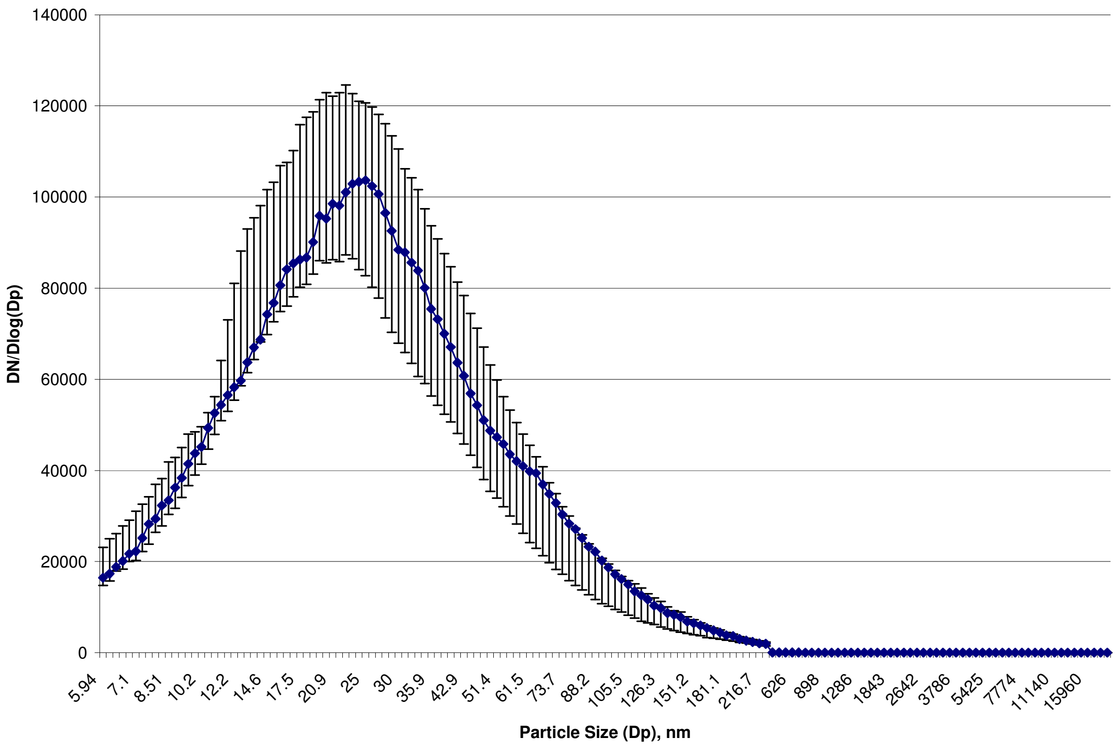

Figure 3.17 Morning particle size distribution from Oct 31 - Nov 9

Figure 3.17 represents the average number concentration for each particle diameter channel of both the APS & SMPS along with their 25 and 75 quartiles. The average highest peak of the Morning Size Distribution is 25 nm diameters and the average concentration is 103,657 #/cc. The highest number concentration for the morning size distributions that occurred in the study was on Monday November 5, 2007. The diameter was around 25 nm with a concentration of 195,840 #/cc. This peak is approximately the same diameter as the mean peak, but twice its concentration. As is evident in the graph, this concentration was surpassed by other diameters within its vicinity. However, smaller particles had several instances of much higher concentrations.

The unimodal distribution indicates that great amounts of particles occur between 10 and 61 nm. There are far less particle concentrations below 10 nm, and even less above 61 nm. The number concentrations for diameters above 600 nm (0.6 µm) seem negligible when compared to the smaller diameters.

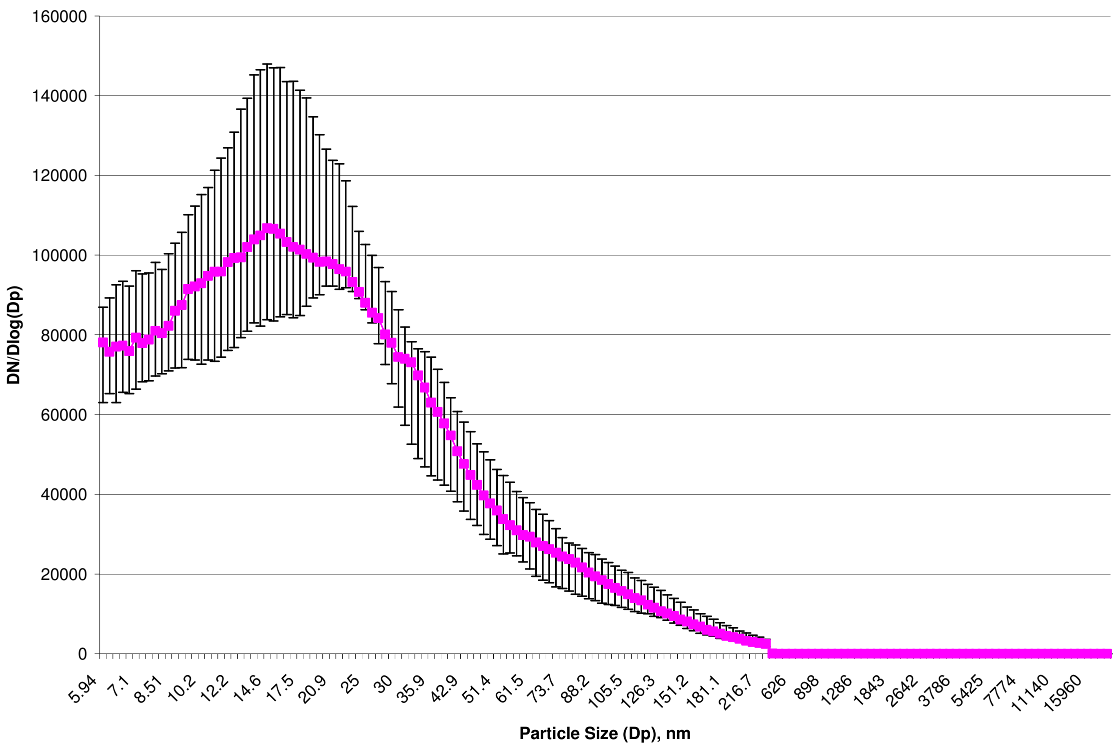

Figure 3.18 Evening particle size distributions from Oct 31 - Nov 9

The highest average concentration that occurred in the evenings (Figure 3.18) was at 15 nm with a concentration of 106,539 #/cc. The highest number concentration for evening size distribution was on Thursday November 1, 2007; the value was about 13 nm with a concentration of 211,296 #/cc. This is considerably closer to the diameter of the average highest number concentration, but is almost twice that average concentration. The inter quartile range

around the mean climax shows a vast difference. This also shows the evening variation in size distribution. The third quartile demonstrates a similar shape to the data points and shows that its peak is primarily within the same diameter of the average peak. The first quartile shape is also similar to the data points. However, it is shifted to the right displaying a peak that normally occurs at larger diameters around 22 nm.

Although the evening concentrations vary quite often, the higher concentrations occur frequently at diameters less than 30 nm, but mainly between 10 nm and 30 nm. The inter quartile range of the diameters at 25 nm and below are large and gives us an idea about concentration fluctuations in the evening. The particle concentrations decrease consistently after 25 nm and are practically negligible at 600 nm and larger.

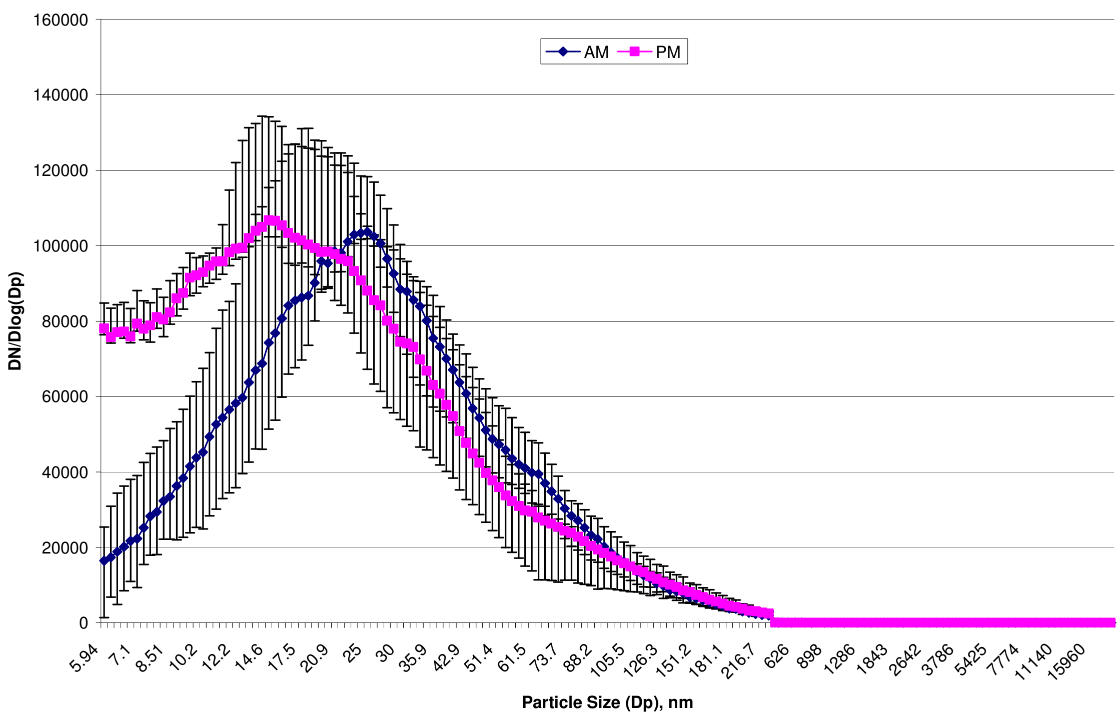

Figure 3.19 Morning & Evening Inter Quartile particle size distributions from Oct 31 - Nov 9

The bars on the graphs in Figure 3.17, Figure 3.18 and Figure 3.19 represent the lower and upper quartiles of the data for the morning and evening averages. The data points are the averaged number concentrations for 7 am – 9 am and 7 pm – 9 pm; they represent the average number concentrations of the morning and evening time intervals, which contain the highest number concentrations. The time averages were calculated with the five min data points collected from the APS and SMPS.

When viewing the first quartile of both graphs in Figure 3.17 and Figure 3.18, it is evident that the averages of the number concentrations below the medium are much more consistent and closer to their averaged data points in morning than evening. The peak of the first quartile in the morning is quite close to the peak of its mean. The peak of the first quartile in the evening is not only different from its averaged peak, but its peak is closer to that of the morning. This could be due to more variations in traffic activities in the evening than morning. The inter quartile range for diameters less than 10 nm of the evening is broader than that of the morning.

Of the two series shown, the third quartiles fluctuate similarly in relation to their second quartiles. The third quartiles are close to their relative mean for smaller particles, then increase in difference within their peaks and then that difference descends into the larger diameters. This means that the particles in this range vary more than those smaller and larger. These graphs show that the amounts of the smaller particles, namely those below 61 nm, are consistently higher than the larger particles. During both peak hours, the larger particles are almost negligible when compared to those smaller. Although the smallest particles measured are still

not as concentrated as those between 10 and 61 nm, they are more concentrated than the larger particles.

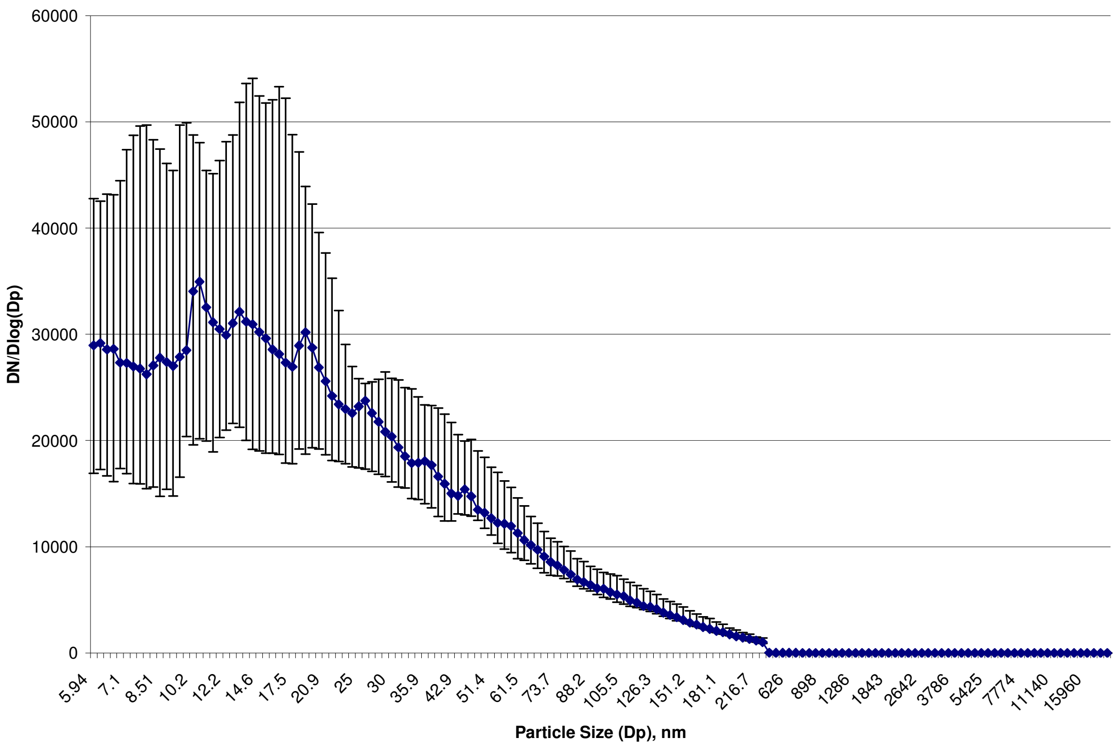

Figure 3.20 Afternoon particle size distributions from Oct 31 - Nov 9

Figure 3.20 shows the number concentration in the afternoon, which has the lowest number concentrations. Other graphs of number concentrations inside the cities near traffic would normally display a lunch hour peak at this time. The size distribution of the number concentrations between 11 am and 1 pm were taken to see if there is a difference between the size distribution of this valley and the peaks. As shown in Figure 3.17 and Figure 3.18, the size distributions at each time period are significantly different in shape, but like the evening peak in Figure 3.18, there are significantly more small particles while the afternoon distribution has less of a proportional peak in the smaller diameters. When compared to the evening graph, the

afternoon is more consistent in the large amount of small particle concentration. This graph peaks on different occasions but in the same size range as the evening and morning peaks in the graphs, with about a third of their concentrations. As the two other graphs show, the afternoon number concentrations show negligible variation in the larger particles, and they decrease in the same manner in all three graphs. The afternoon graph varies much more than the others, which implies a large variation in vehicle population during this time of day. The afternoon size distribution also shows a small peak between the size range of 42.9 nm and 51.4 nm, which is not detected in the morning and afternoon size distribution graphs.

3.4 Diesel Truck Concentrations

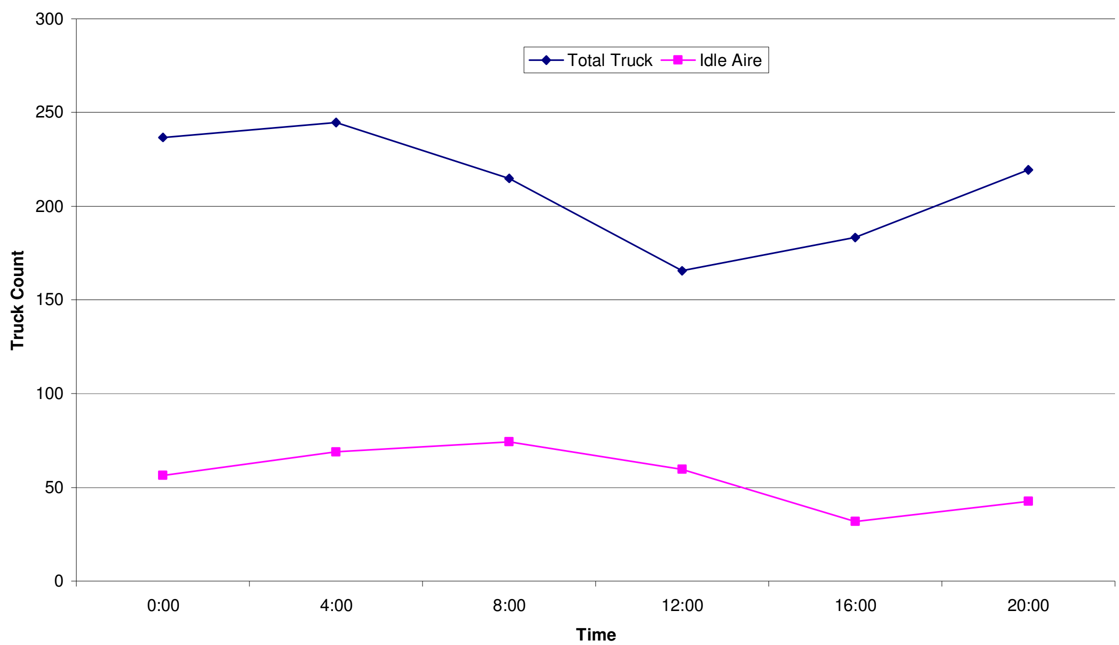

Figure 3.21 Petro & IdleAire diesel truck counts

Figure 3.21 shows the Petro and IdleAire parking spaces that were occupied with diesel trucks. The truck counts at the Petro parking lot were taken every four hours by the IdleAire employees. The entire Petro parking lot contains a total of 260 parking spaces for the heavy duty diesel trucks; out of these, two are for the IdleAire office and eighty-seven are for IdleAire customers. The typical IdleAire customers are diesel truck drivers who use their facilities for rest and recreation. The products or services offered by IdleAire includes: television, air conditioning, heating and internet access.

Figure 3.16 shows no increase in NC when the total truck count is at its highest at 4 am (Figure 3.21). However, as the IdleAire spaces are approaching their maximum

occupancy and total truck counts decrease at 8 am, the NC starts to decrease as well. This demonstrates how vehicles that have left the Petro Stop or are not running affect the number concentration, which in this case, sharply decreases it. Truck concentration's lower peak is at the NC highest peak in the evening, showing a difference in cold start engines and hot running engines. The level afternoon NC's in Figure 3.16 occurs when the total truck count is at its lowest, but vehicles are still occupying the IdleAire spaces. Assuming these vehicles are off, the NC is evidently affected by the running diesel vehicles, seeing as how their absence decreases the number concentrations.

The difference in size distribution between the morning and evening particles (Figure 3.19) indicates that the engine temperatures emit different particle ranges, with evenings having higher number concentrations and smaller particles. The scattered afternoon size distribution in Figure 3.20 occurs during the time when there is the least amount of vehicles in the parking lot. The absence of vehicles at this time illustrates that the particles in the vicinity are either the background particles in the area or a product of a mixed vehicle population. Regardless, even in the absence of heavy duty diesel trucks, the finer particles influence the number concentration graphs.

Figure 3.22 shows a different concentration pattern between the number and mass concentrations in the morning, during the decrease in total truck occupancy. The evening peaks of both NC and MC in Figure 3.22 that occur during the evening truck concentration peak further confirms the difference in the diesel emissions between the initial ignition and running engines.

3.5 Number Concentrations VS Mass Concentrations

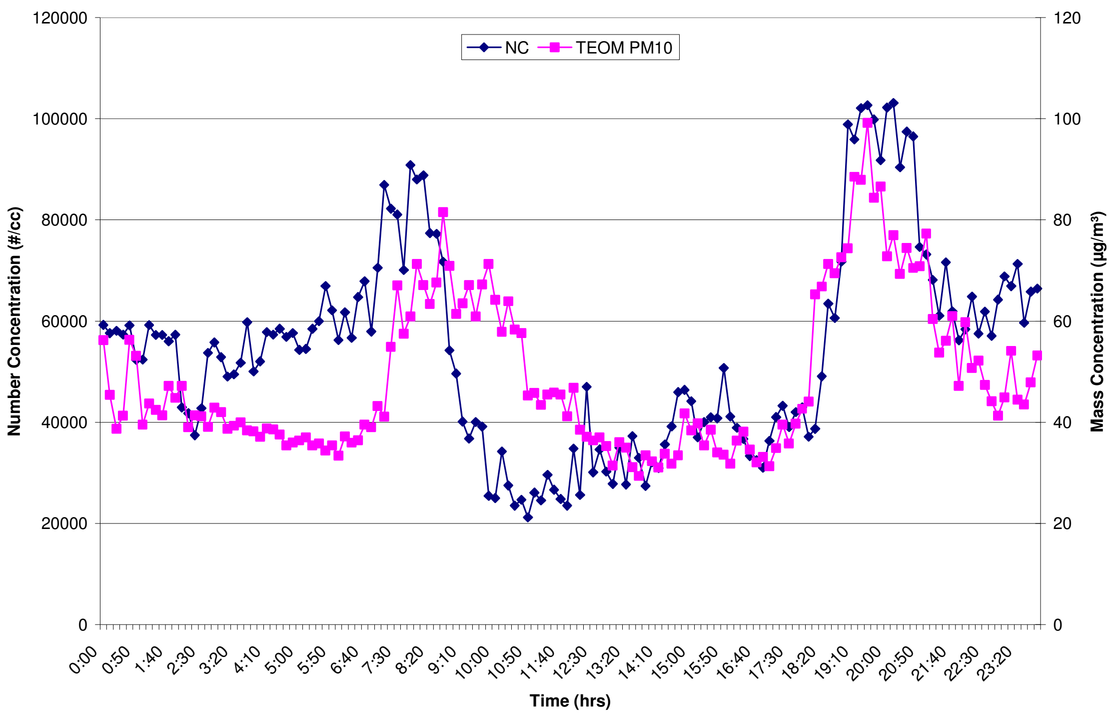

Figure 3.22 PM_{10} Number Concentration & Mass Concentration Oct 31 - Nov 9

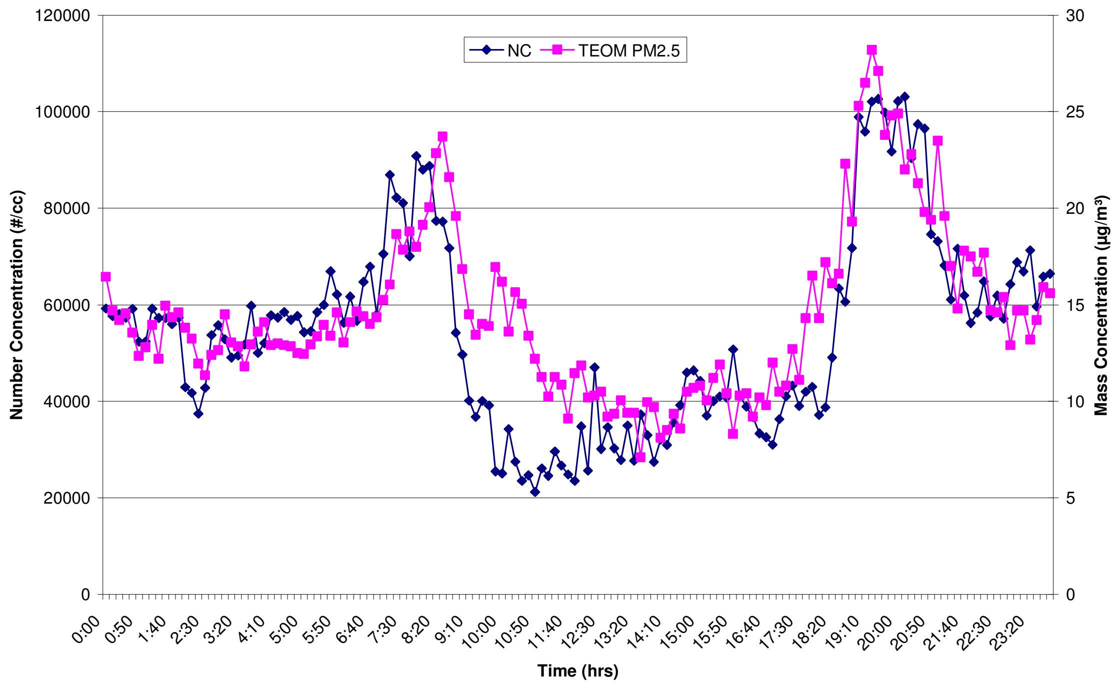

Figure 3.23 $PM_{2.5}$ Number Concentration and Mass Concentration Oct 31 - Nov 9

The top concentrations in Figure 3.22 show the averaged Number Concentrations of the study compared to the average PM_{10} Mass Concentrations from TEOM PM_{10} of the study. The bottom graph of Figure 3.23 shows the comparison of the averaged number concentrations to the averaged $PM_{2.5}$ concentrations from TEOM $PM_{2.5}$. The peaks of both TEOMs occur at similar times when compared to the Number Concentrations, although the morning peaks of the mass concentrations are slightly shifted to a latter time. This shows that the mass concentrations could be correlated with number concentrations, but not completely, or that number concentrations and mass increase when there is an abundant amount of particulate matter. The morning peak of the PM_{10} mass concentrations is not as correlated with the number concentrations as the $PM_{2.5}$ mass concentrations. TEOM PM_{10}'s peak not only occurs later in time, but lasts about twice as

long as the number concentration's morning peak. The PM_{10} is also substantially different from the number concentration from 10 pm until 6:30 am, while the $PM_{2.5}$ mass concentration is more correlated with the number concentration. The size distribution graph in Figure 3.17 shows that the average size distribution of the particles in the morning peak contains many more fine particles than the evening peak and a negligible amount of coarse particles. This difference in particle distribution could explain the disassociation between the PM_{10} mass and the number concentrations.

The distinctive gap between the mass and number concentrations that occurs after 8:40 am and before noon shows the only evident corresponding difference. This means that for that time period, both TEOMs simultaneously are disagreeing with the number concentrations. The PM_{10} mass and number concentrations do not follow as well as those from the $PM_{2.5}$ concentrations. This presents a justified argument of the irrelevance of mass and number concentrations, especially seeing that neither mass concentration graph accurately captures the behavior of the number concentration graph.

3.6 UTEP vs Petro

Both studies (i.e. UTEP and Petro) concentrated on vehicle emissions, mass concentrations, and number concentrations, but the UTEP study focused on gasoline emissions while this study focused on diesel emissions. As described in Chapter 0, Petro is located in a secluded area in the eastern outskirts of El Paso, Texas with desert surroundings. UTEP's study was conducted in a TCEQ CAMS 12 site on the UTEP campus. UTEP is located in the more congested west El Paso are that is filled with homes, businesses and is surrounded by mountain terrain. The CAMS 12 is near the UTEP parking lot and an apartment complex with constant traffic passing throughout the day. Also the studies were performed in different time periods: UTEP's in the spring and Petro's in the fall.

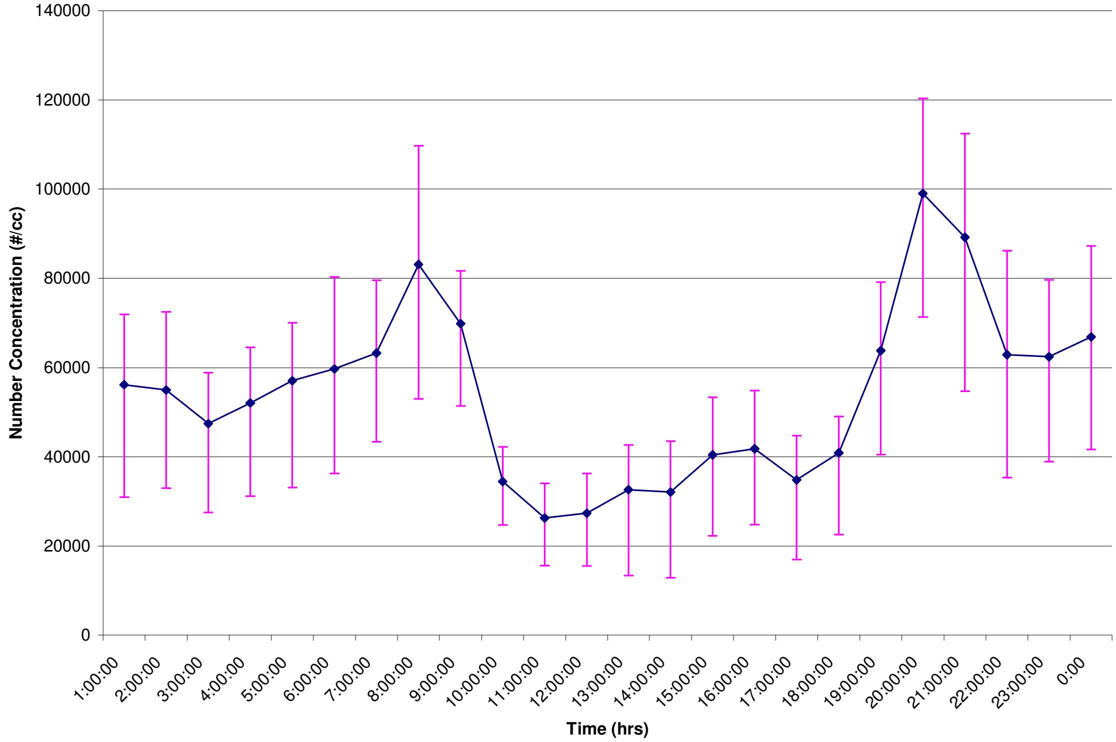

Figure 3.24 Petro Hourly Average Total Number Concentrations at Petro site for Oct 31 - Nov 9

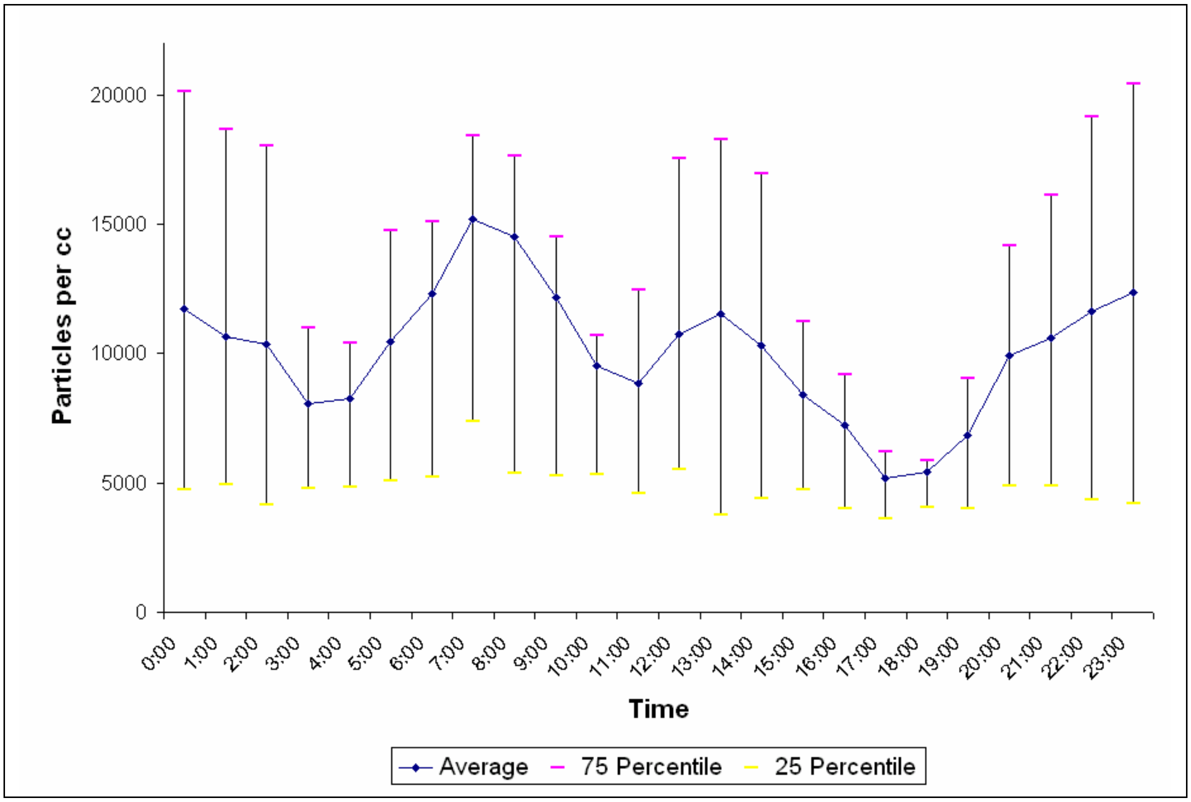

Figure 3.25 UTEP Hourly Average Total Number Concentrations at UTEP site for March 29 - April 15

Figure 3.24 and Figure 3.25 are the hourly average of total number concentrations from the APS and SMPS results in both studies. The morning rise and peak are the only obvious similar attributes of the two graphs. The Petro 81,000 #/cc morning peak occurs between 7:00 am and 10:00 am, while UTEP's 16,000 #/cc morning peak is an hour earlier, between 6:00 am and 9:00 am, implying a difference in traffic pattern. UTEP's 25 percentile is quite constant, which means those particles are probably always in the atmosphere, but Petro's concentrations moves with the average concentrations. UTEP's surroundings are everyday routine activities, like its typical traffic patterns, while Petro's surrounding's go with the typical truck driver behaviors. This could justify the background particulate difference between the studies, especially since the instruments

were set up inside the parking lot where the parking lot activities have a greater influence on the ambient surroundings.

The minimum concentration at the Petro site occurs at 26,000 #/cc at 11:00 during UTEP's lunch peak. UTEP's lowest concentration is about 5,000 #/cc at 17:00, and Petro's data shows a dip at a similar time. Petro increases in concentration from 13:00 to 16:00 while UTEP is declining with minimal variation. At 19:00 hours, Petro rises to its highest peak at 100,000 #/cc and then declines, while UTEP rises consistently to the morning. These diverse fluctuations of both studies are best explained by the different traffic populations.

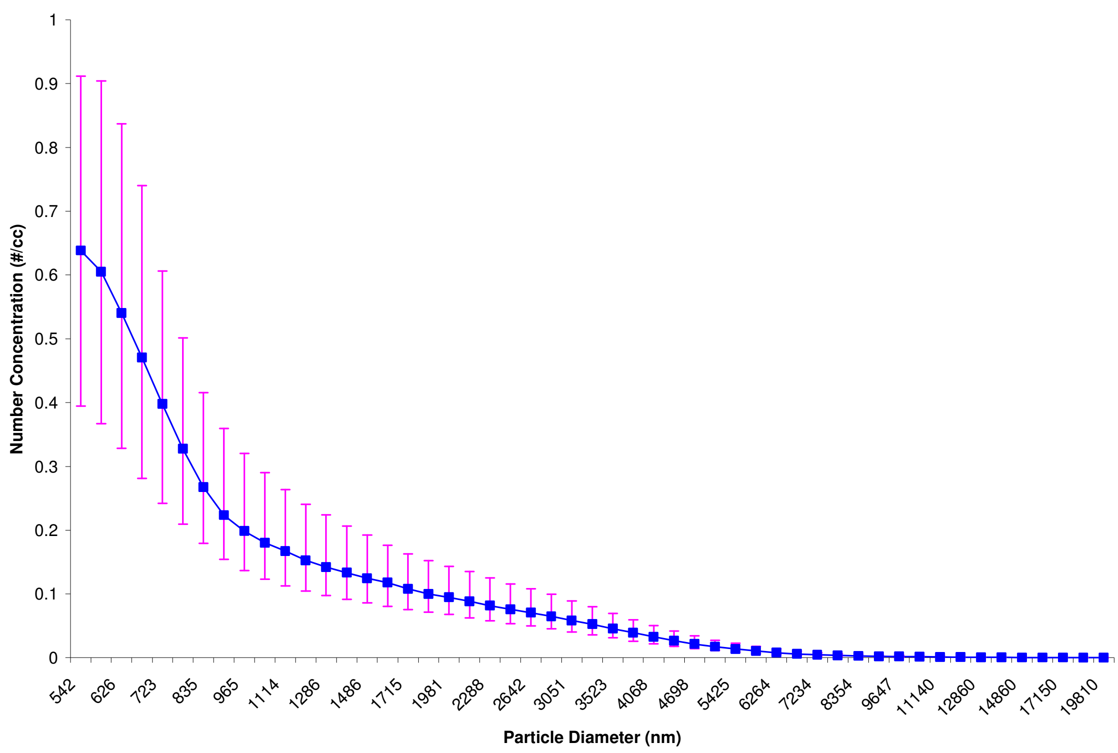

Figure 3.26 APS Daily Average Size Distribution March 29 - April 15

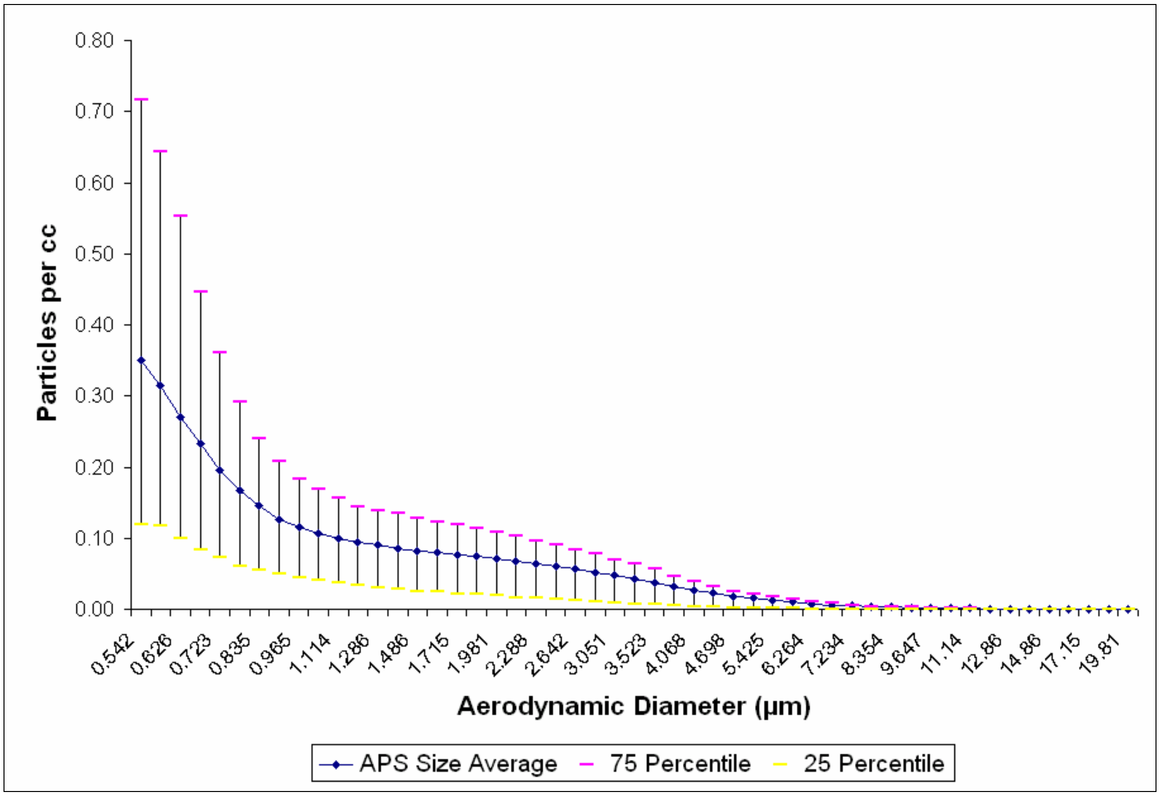

Figure 3.27 UTEP Daily Average Size Distribution March 29 - April 15

Figure 3.26 and Figure 3.27 represent the average NC received from the APS data for each study. From the two graphs, Petro has a higher average peak at 0.65µm, which is almost twice that of UTEP's 0.35 µm peak. The Petro can exceed UTEP's concentrations by up to 3 times. Both graphs are similarly shaped, decreasing with increasing particle diameter, and both graphs vary less with larger number concentrations. Petro's 25 percentile peak is higher and equivalent to UTEP's average peak. UTEP's 25 percentile number concentrations are more level, possibly representing the background number concentrations. The 75 percentile number concentrations vary quite similarly with their average number concentrations, even though Petro's

concentrations are much higher altogether. This demonstrates how many more particles diesel vehicles emit.

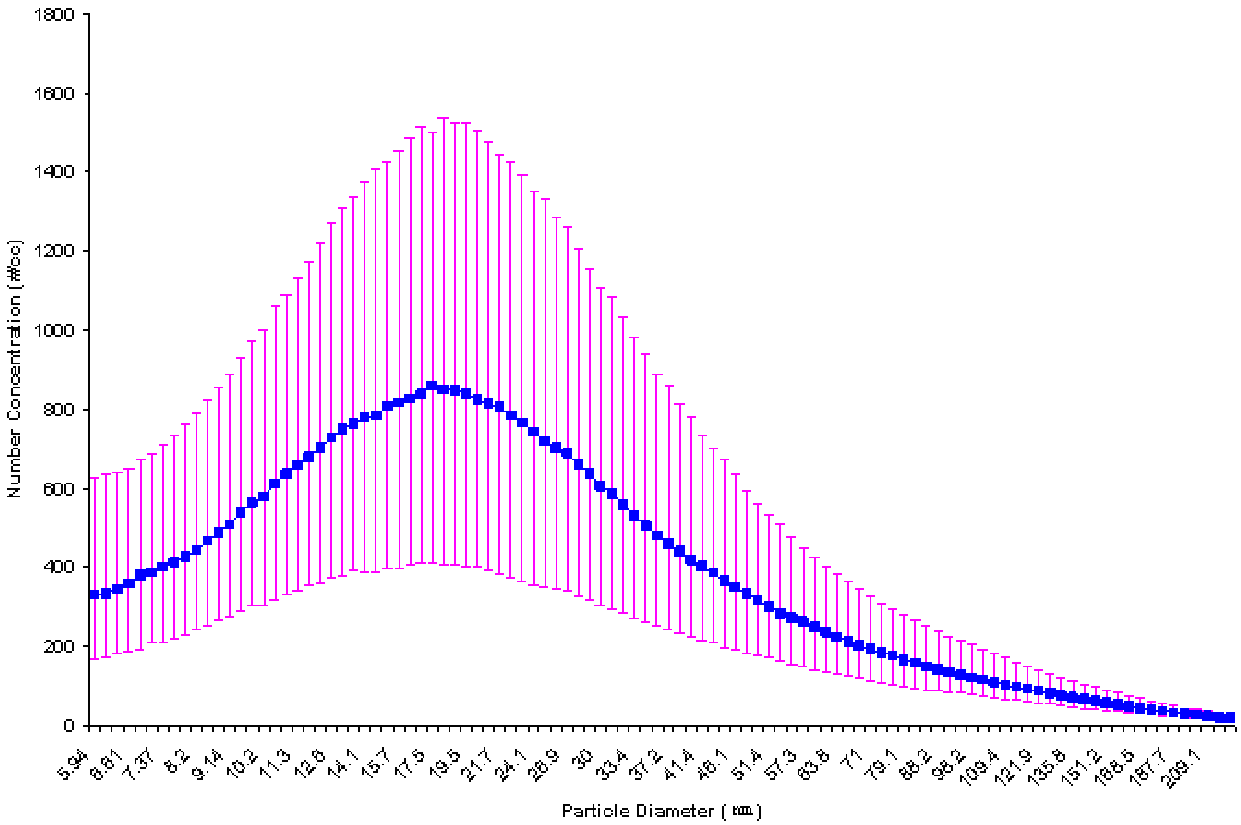

Figure 3.28 SMPS Daily Average Size Distribution Oct 31 - Nov 9

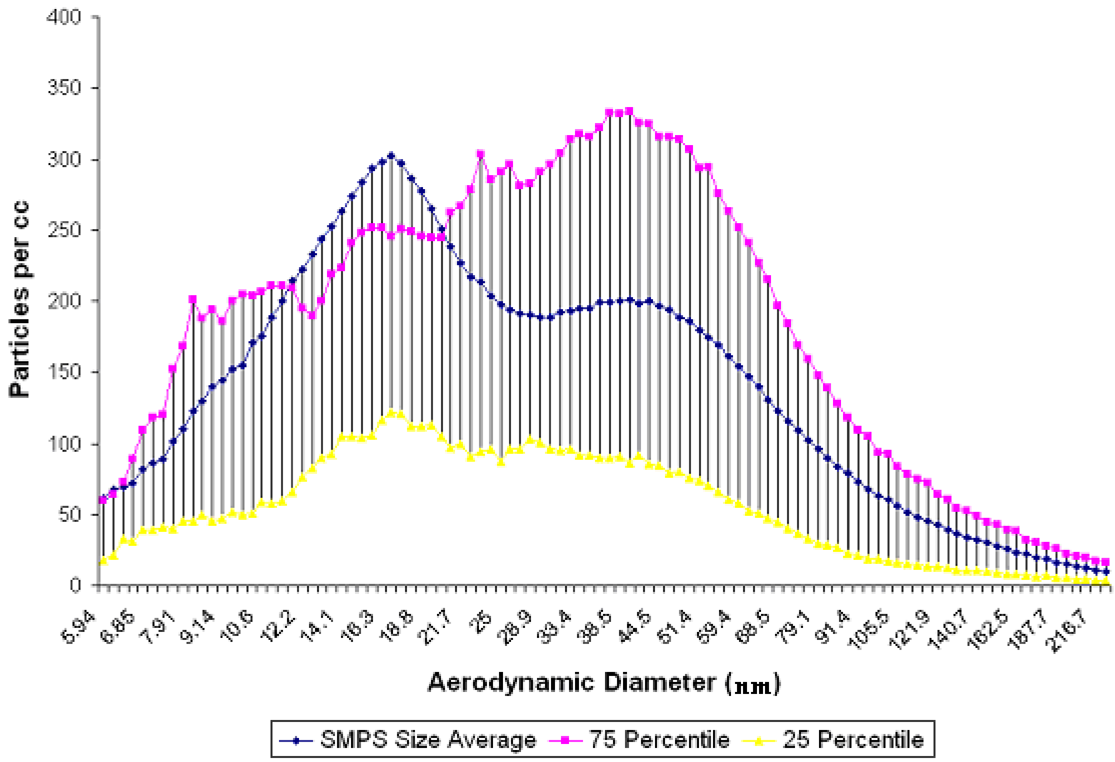

Figure 3.29 UTEP SMPS Daily Average Size Distribution for March 29 - April 15

Figure 3.28 and Figure 3.29 are size distributions with the average number concentration of the study for each diameter along with their 75 and 25 percentile concentrations. Both graphs highest peaks occur between 13 µm and 26 µm with Petros' peak being narrower. This shows that both studies are measuring predominantly vehicular emissions since they are different, but generally in the same vicinity particle distribution-wise. UTEP's bimodal distribution and considerably lower concentrations show the difference in particle size distribution, which displays the difference in production of particles between the two studies. Petro's seventy five percentile distribution is more defined and concurrent with its average while UTEP's differs from its average and is sometimes below it. UTEP's 25 percentile value rises with the bimodal peaks while Petro's peaks consistently with its average. UTEP's 25 and 75 percentile

values vary greatly from their average while Petro's are quite consistent and only vary in concentrations. This could be resulting from Petro's traffic being more consistent since it's inside a heavy duty diesel truck parking lot and UTEP's traffic varies with its proximity to the college, highway, and general traffic peak hours. The different terrain of flat land in Petro and the mountains surrounding UTEP could have a different affect on wind speed and the distribution of particles. The different conditions of the separate times of year that the studies were performed could cause the different particle distributions or number concentrations.

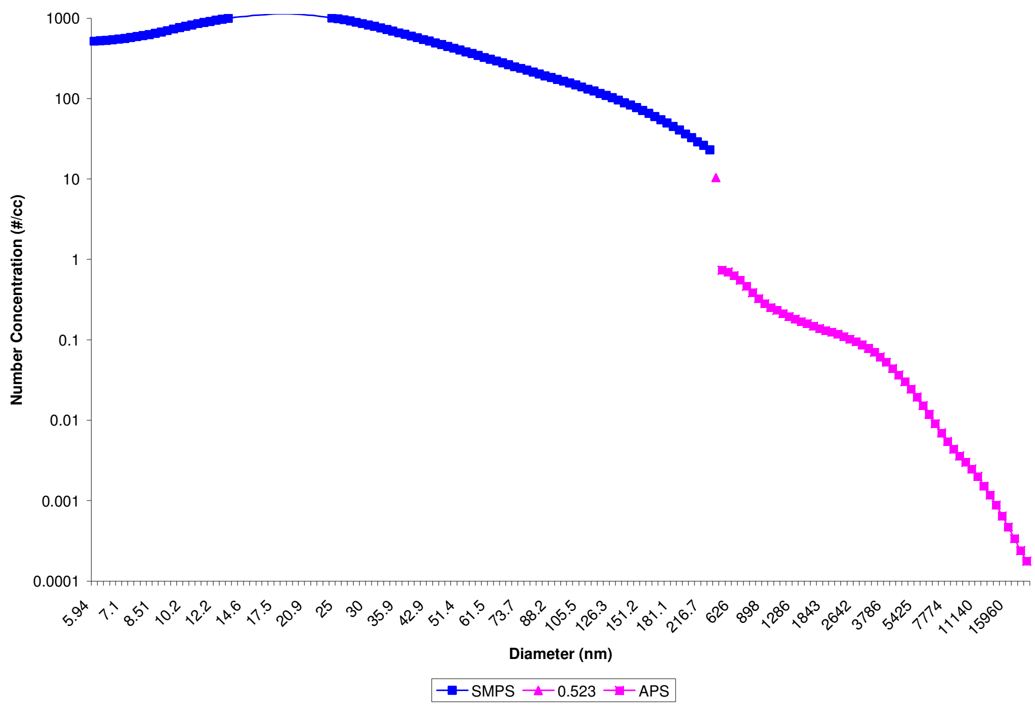

Figure 3.30 Petro SMPS & APS Size Distribution Oct 31 - Nov 9

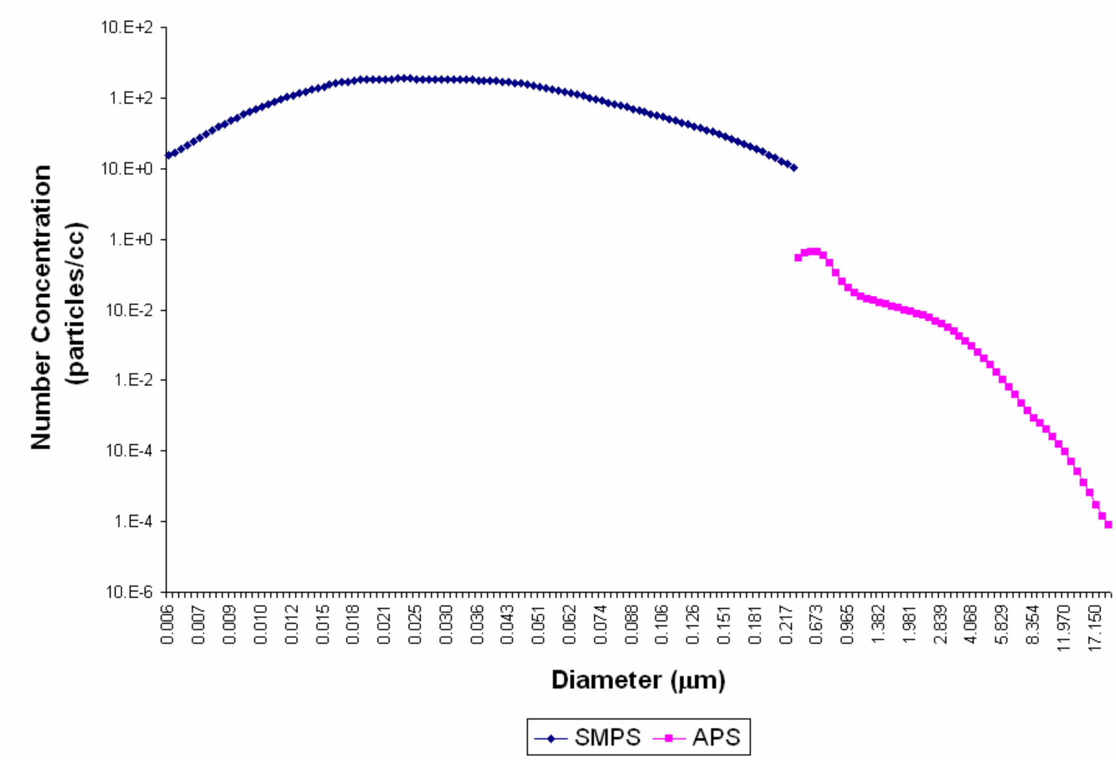

Figure 3.31 UTEP SMPS & APS Size Distribution March 29 - April 15

Figure 3.30 and Figure 3.31 contain the averaged size distribution of each study period, which is composed of results from both the APS and SMPS. The two graphs are very similar in shape, except the Petro starts more level in the beginning as compared to UTEP's which increases initially. A significant and extremely important detail is, like the other graphs, Petro emits up to ten times more particles, which is shown in Figure 3.30 and Figure 3.31. The consistency of diesel emissions being higher than gasoline emissions further confirms their higher particulate emissions.

Chapter 5

4 Conclusions

The study resulted in various findings on emissions collected at Petro and in their comparison to emissions collected at UTEP. Additional results confirmed findings of other studies on number versus mass concentrations. Number concentration is the quantitative count of particles per size and mass concentration is the mass concentration of particles.

The coarse and fine particle mass concentrations shown in various graphs represent different trends when compared, which shows their irrelevance to each other. It was found in the present study and the previous UTEP study that the mass concentrations do not adequately represent the morning particle concentrations or ultra-fine particles. It was observed in this study that an extreme amount of particles are necessary to be detected by MC and that it fails to adequately represent the finer particles. This misrepresentation of ambient particles from mass concentrations omits vital information of the air we breathe and are attempting to regulate. The size distribution graphs show the particles emitted in the morning in the Petro parking lot are between 0.01 µm and 0.06 µm while the particles emitted in the evening are between 0.01 µm and 0.03 µm. This shows the profuse amount of ultra-fine particles below 0.1 µm that are overlooked in the $PM_{2.5}$ mass concentrations.

The number concentration graphs of both studies show that the Petro detrimental emissions were multitudes higher than those from the UTEP study, especially with its lack of the customary lunch and five o'clock peak, further confirming that diesel engines emit more fine particulate matter than gasoline engines. Of the 190 particle sizes measured between 0.005 µm and 19 µm, the highest concentrations throughout the study occurred between 0.01 µm and 0.06 µm.

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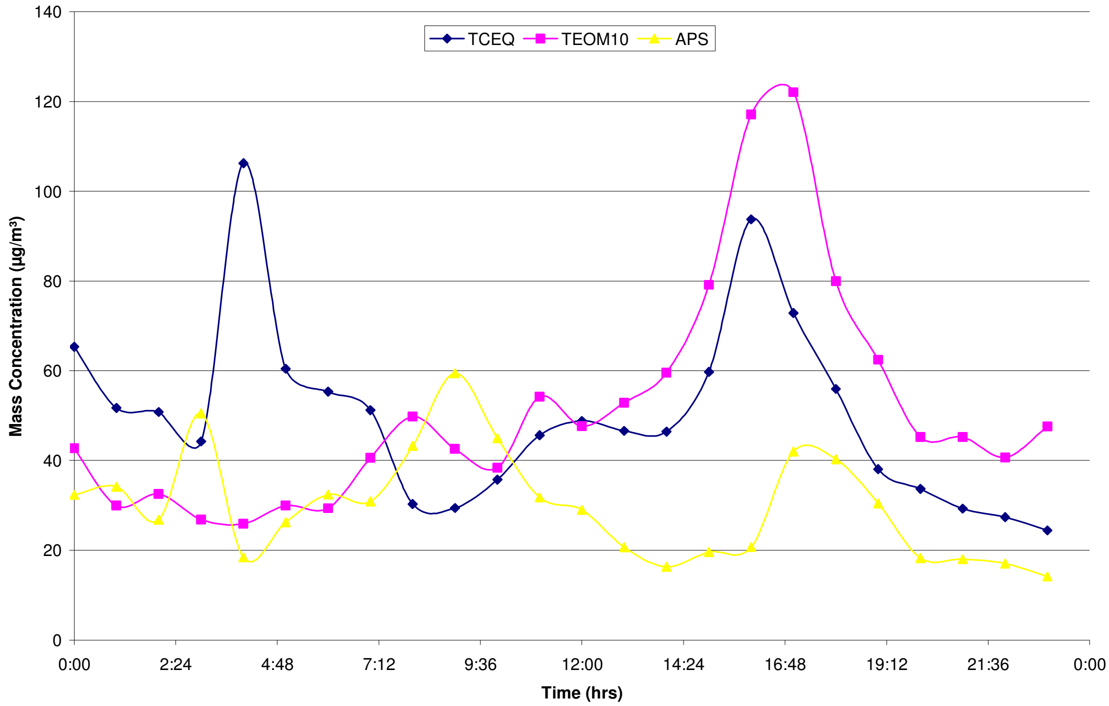
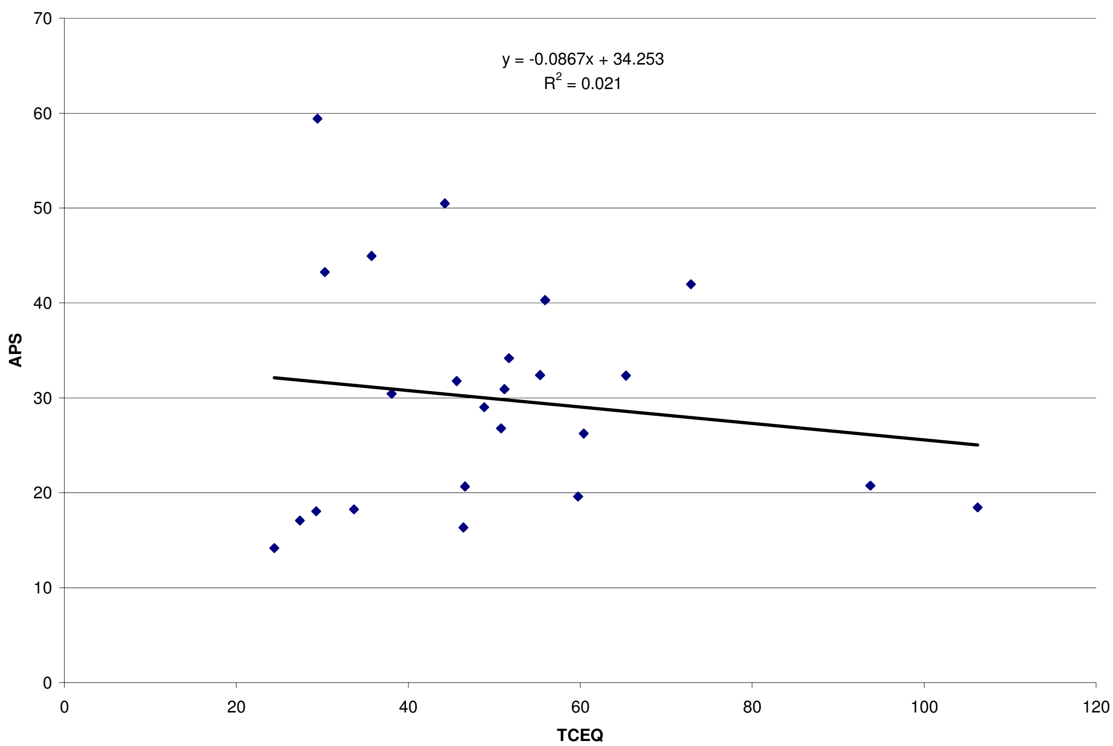
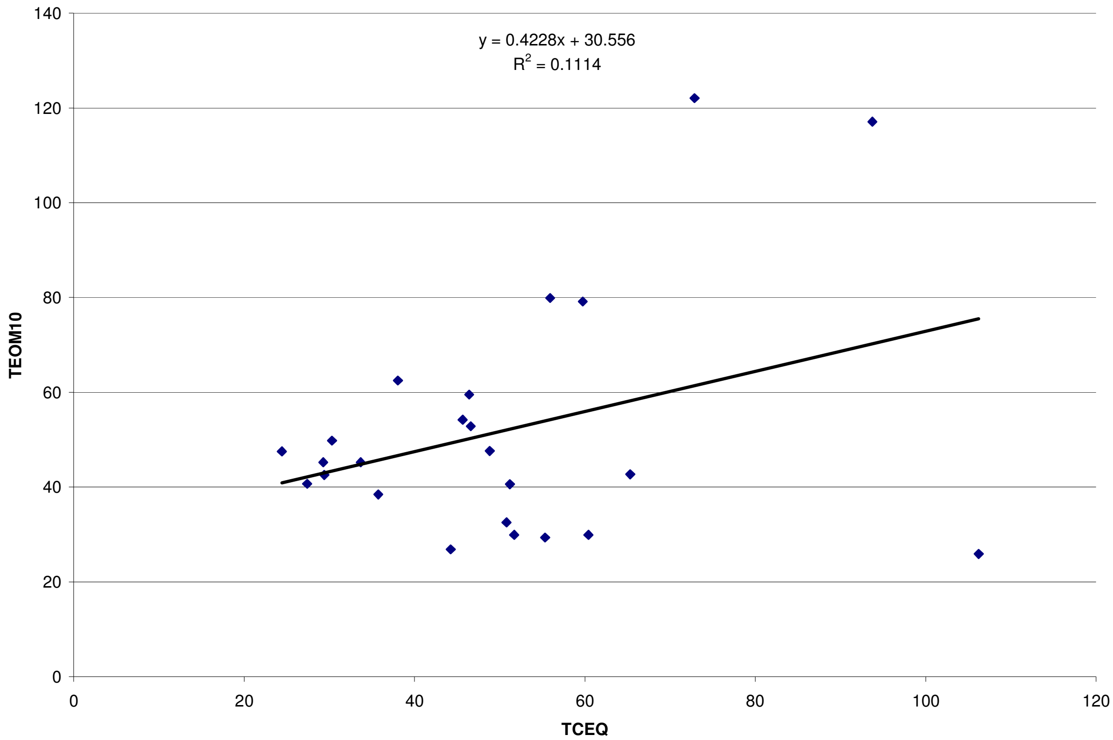
Appendix A

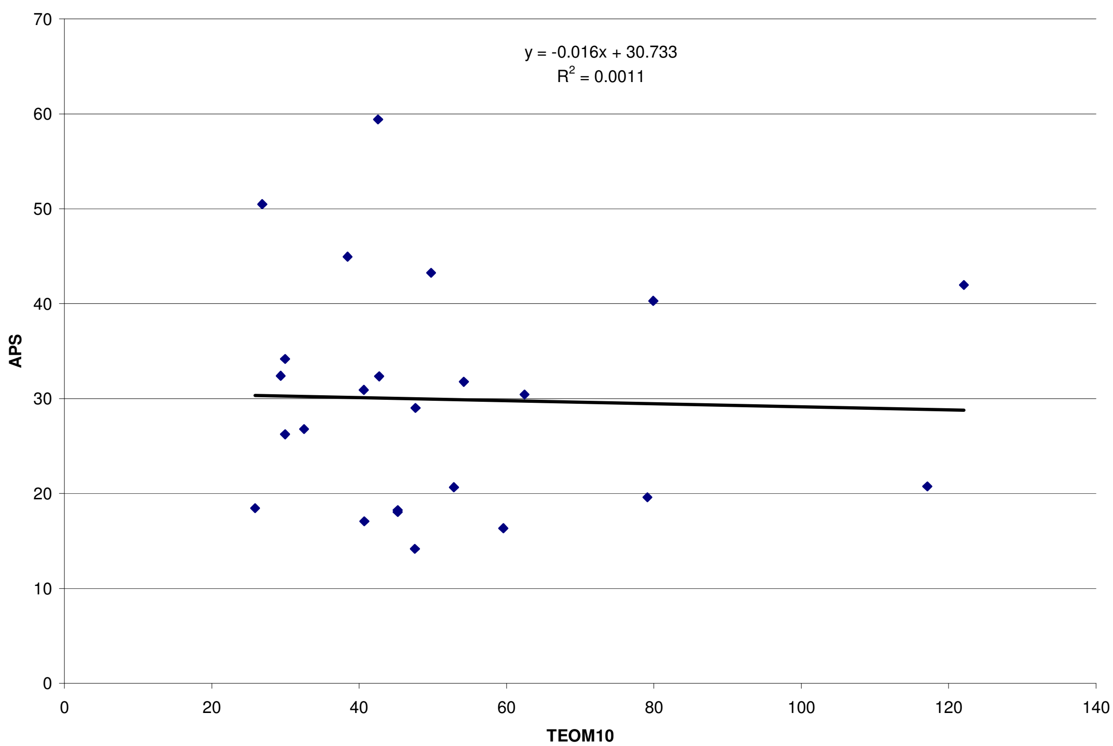
Daily Mass Concentration Comparison of PM_{10} for TCEQ, TEOM10 and APS data for October 27 through November 9, 2008

October 27, 2008

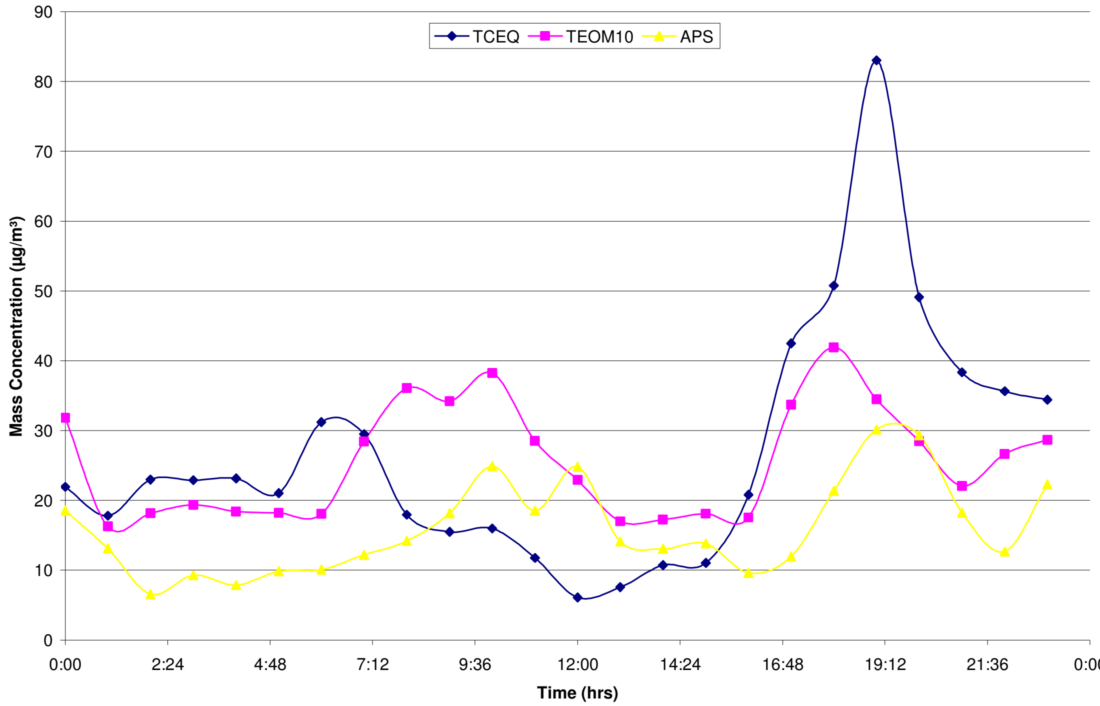


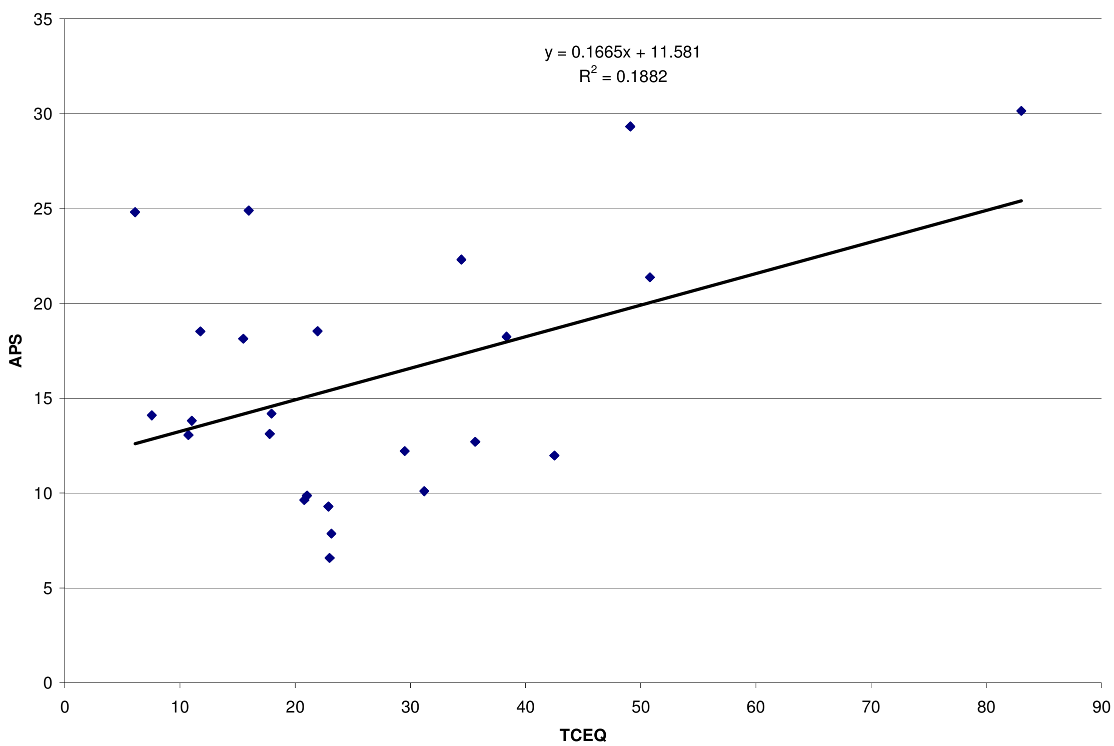


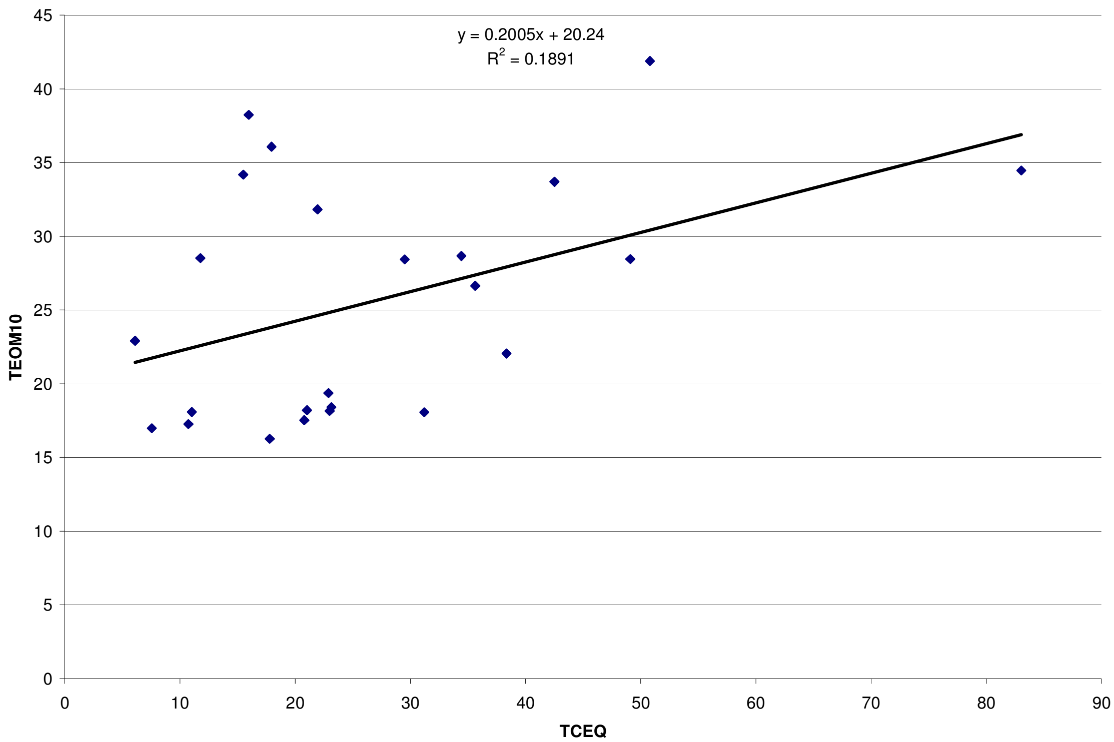

y = 0.4228x + 30.556
R^2 = 0.1114
TEOM10
TCEQ
0
20
40
60
80
100
120
140


y = -0.016x + 30.733
R^2 = 0.0011
APS
TEOM10
0
10
20
30
40
50
60
70
80
100
120
140

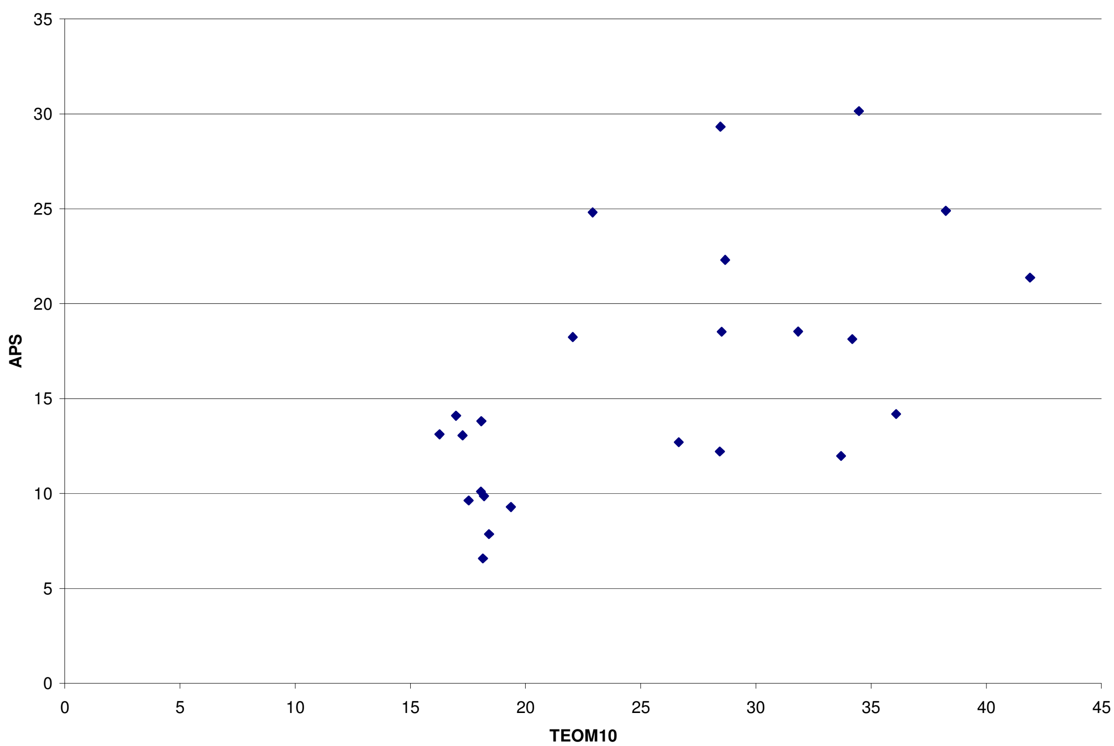
October 28, 2008





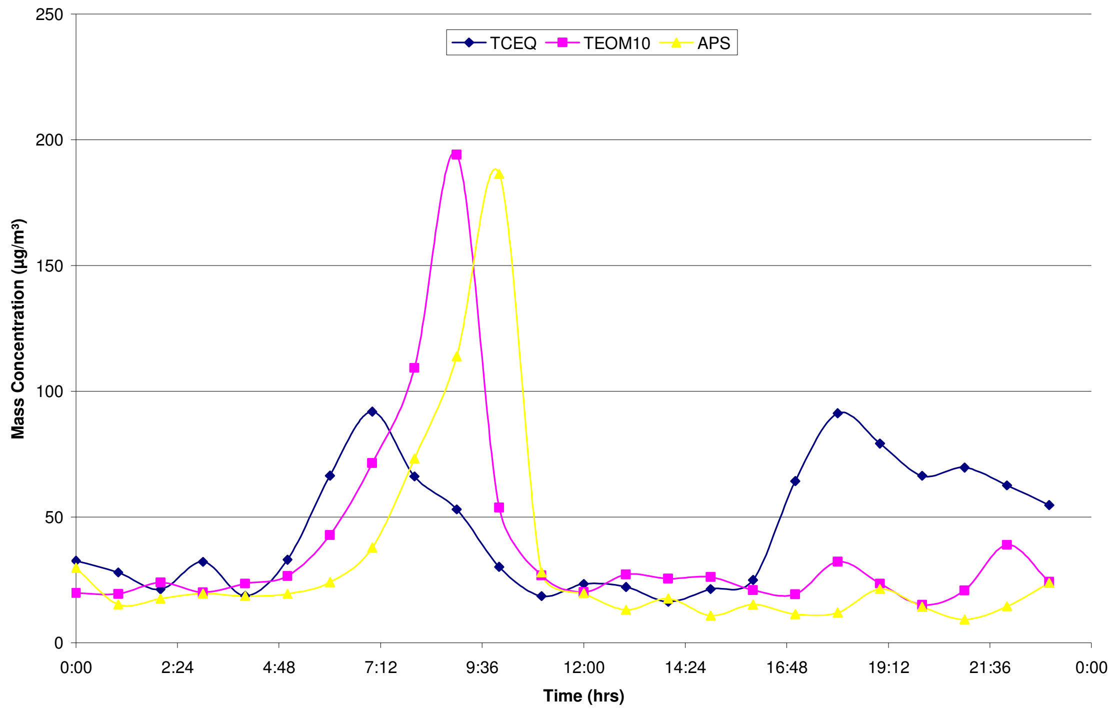


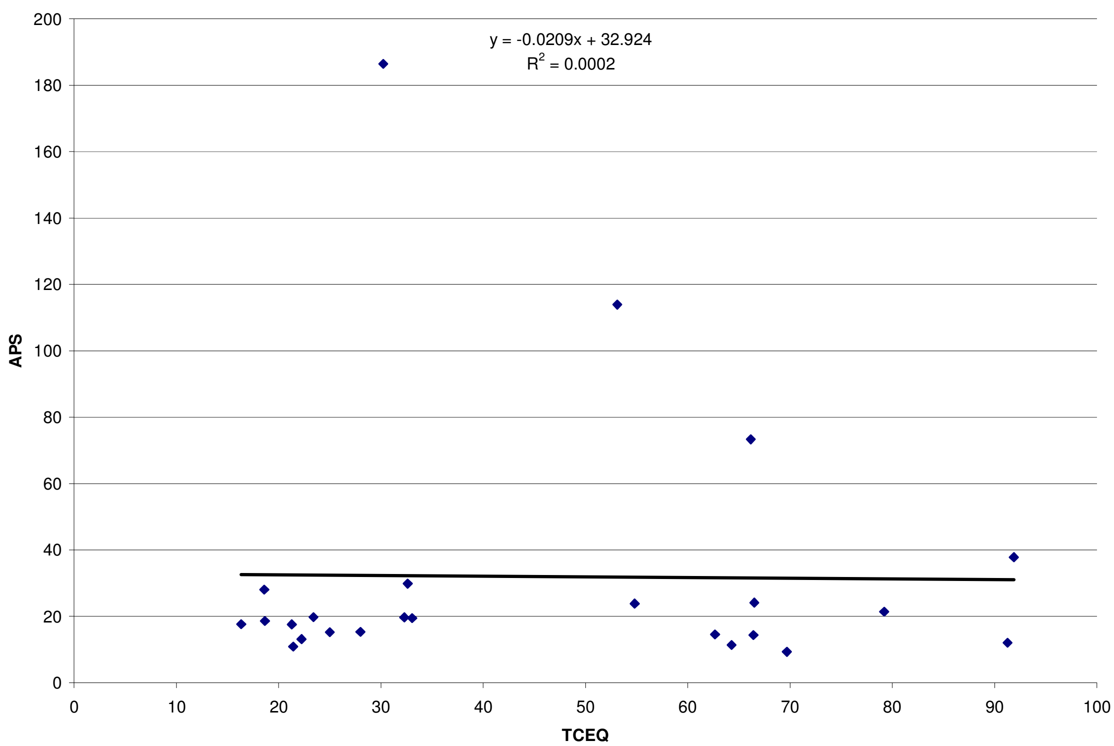
y = 0.2005x + 20.24
R^2 = 0.1891
TEOM10
TCEQ

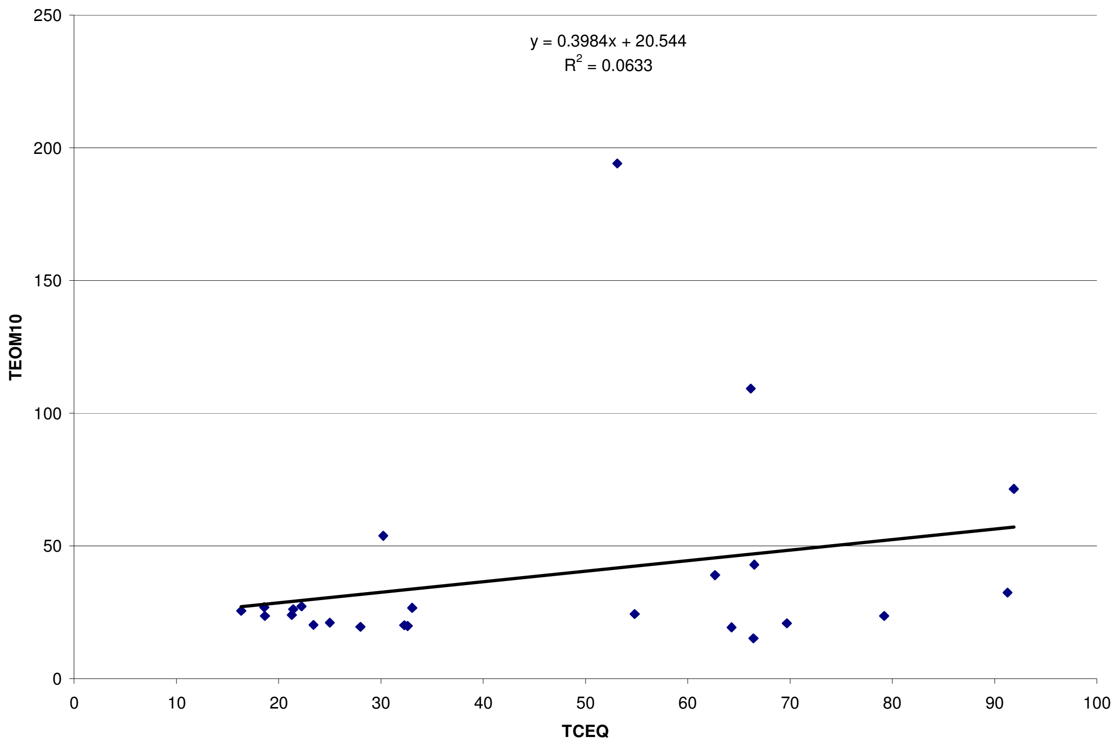


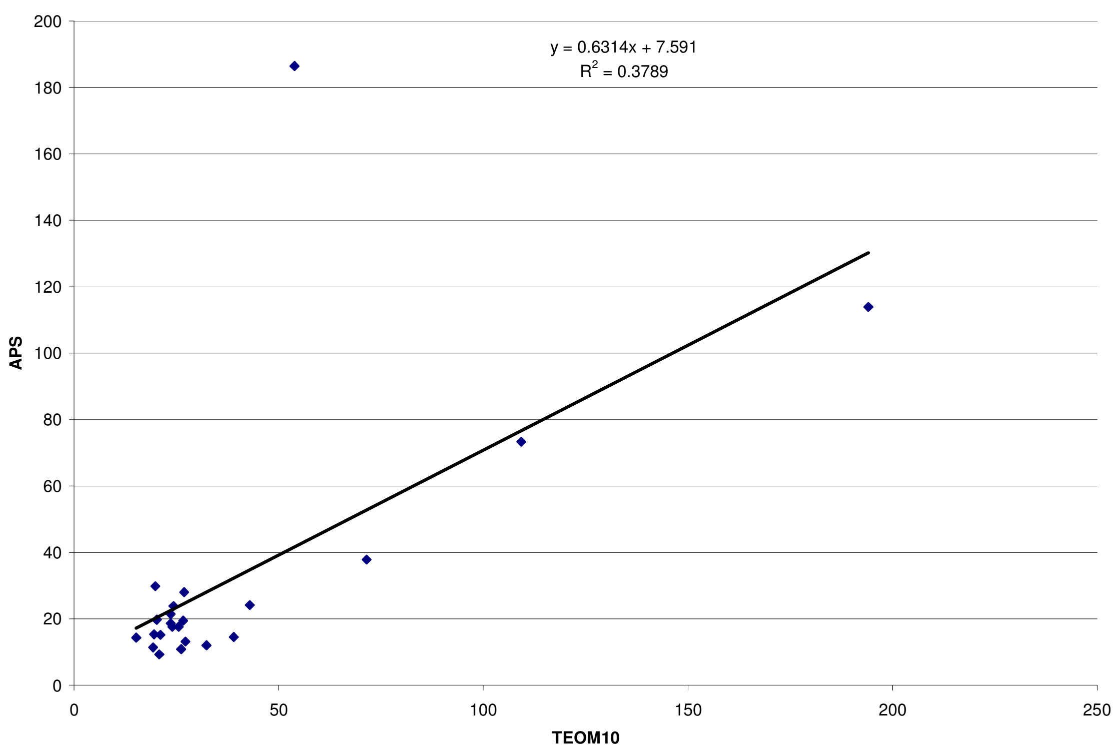
APS
TEOM10

October 29, 2008

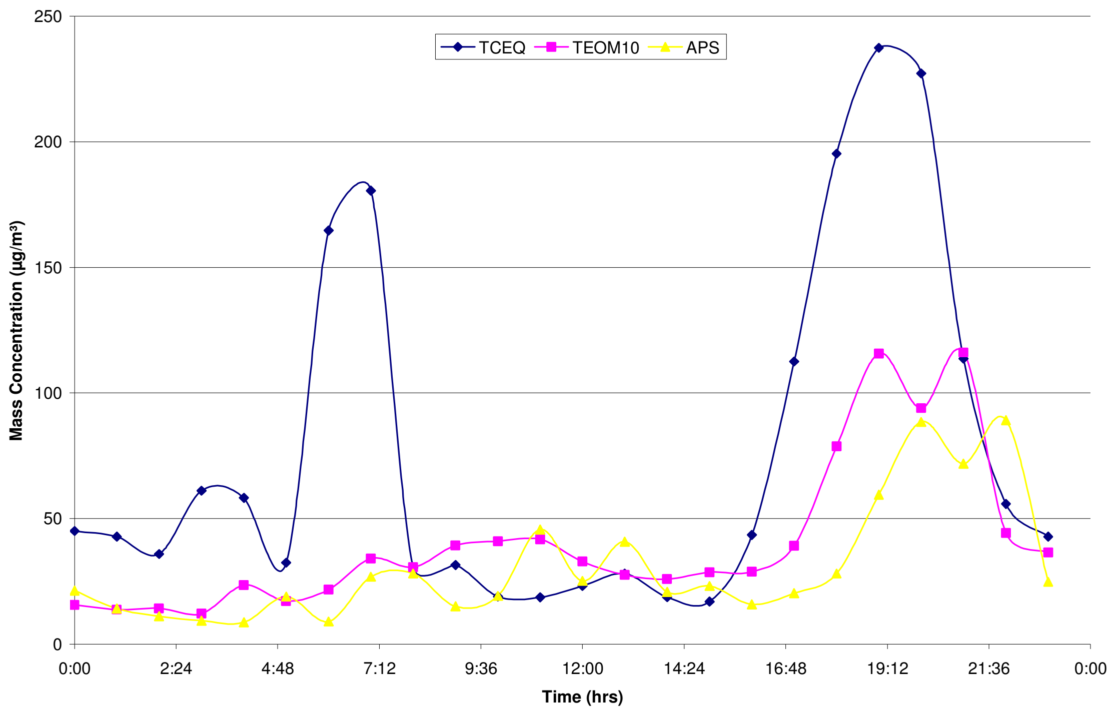


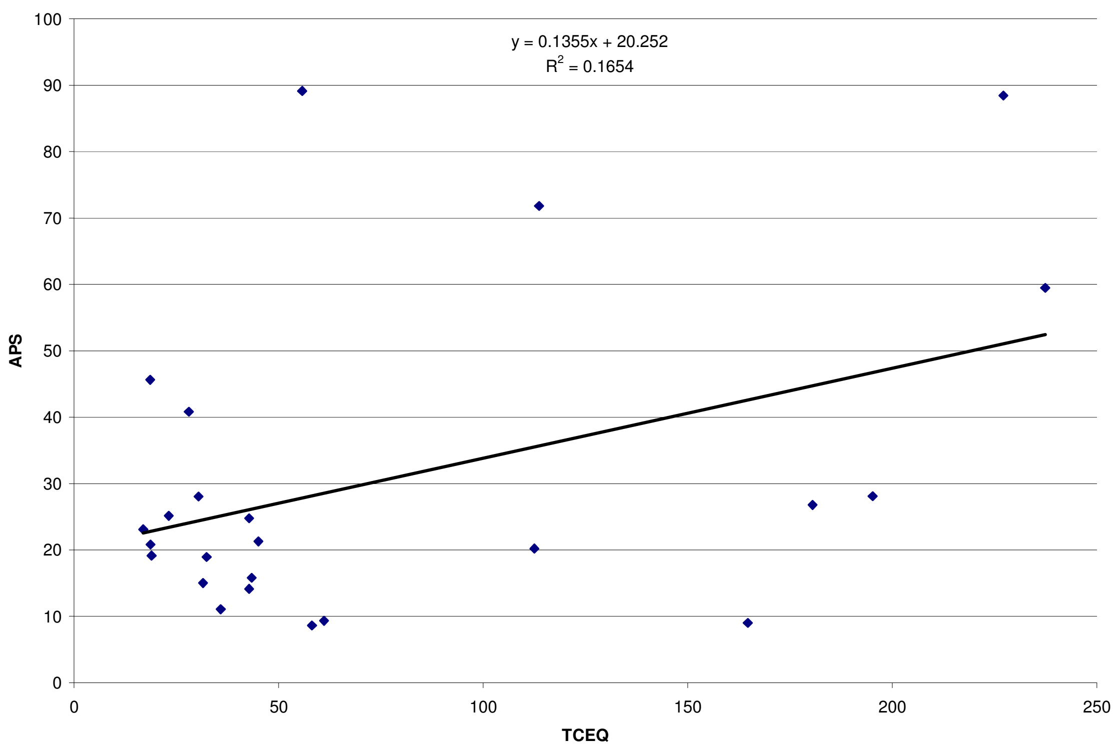


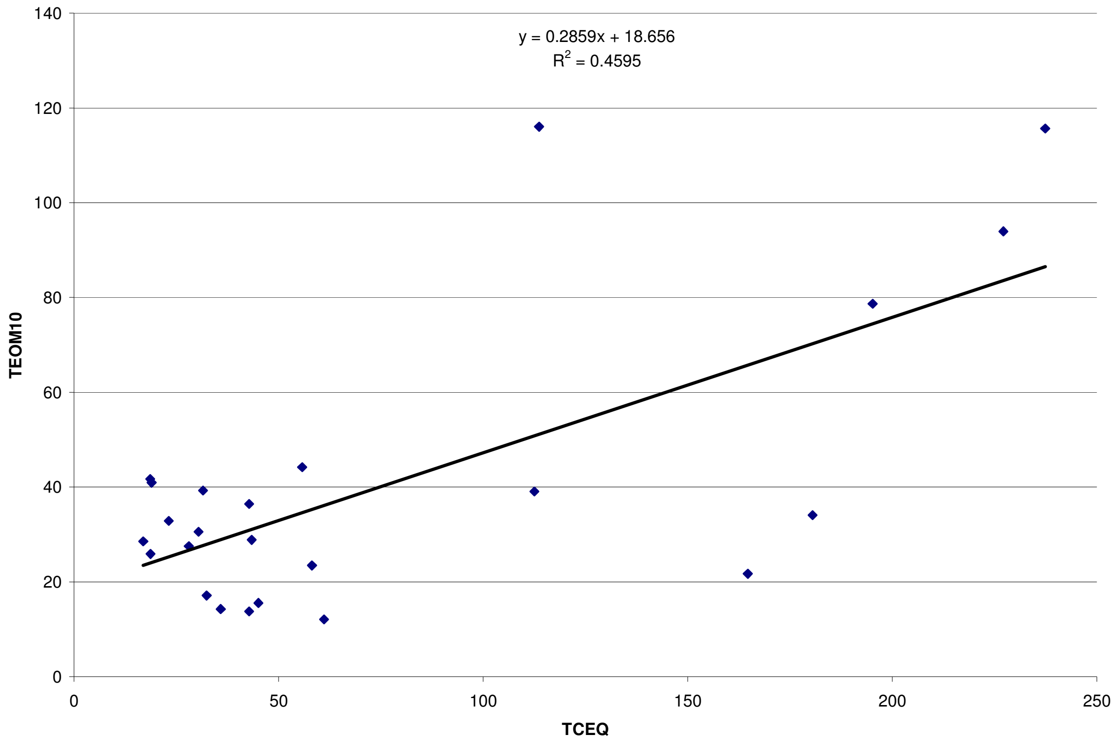

y = 0.3984x + 20.544
R^2 = 0.0633
TEOM10
TCEQ
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
100

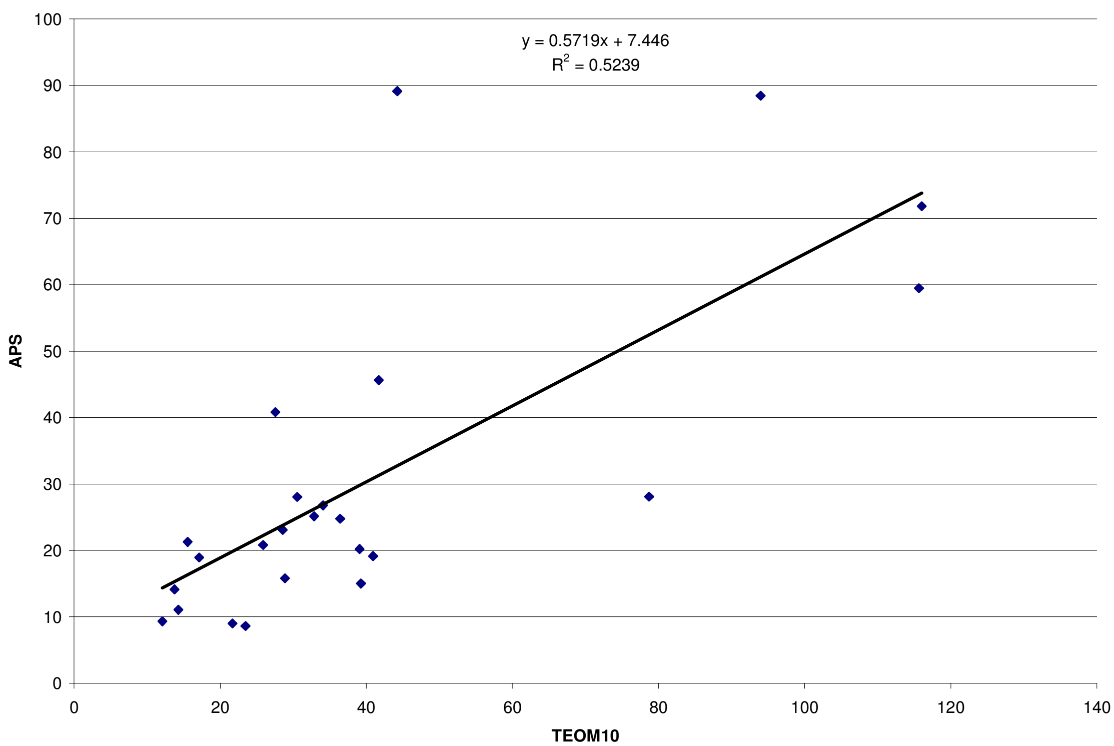

y = 0.6314x + 7.591
R^2 = 0.3789
APS
TEOM10
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250

October 30, 2008

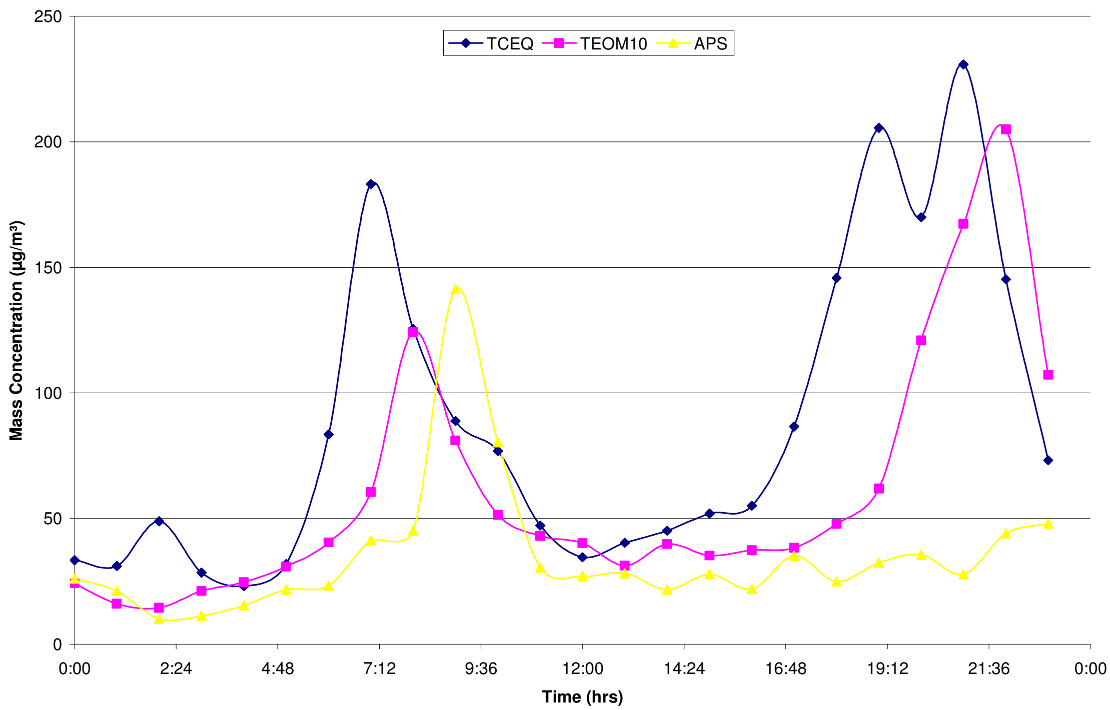


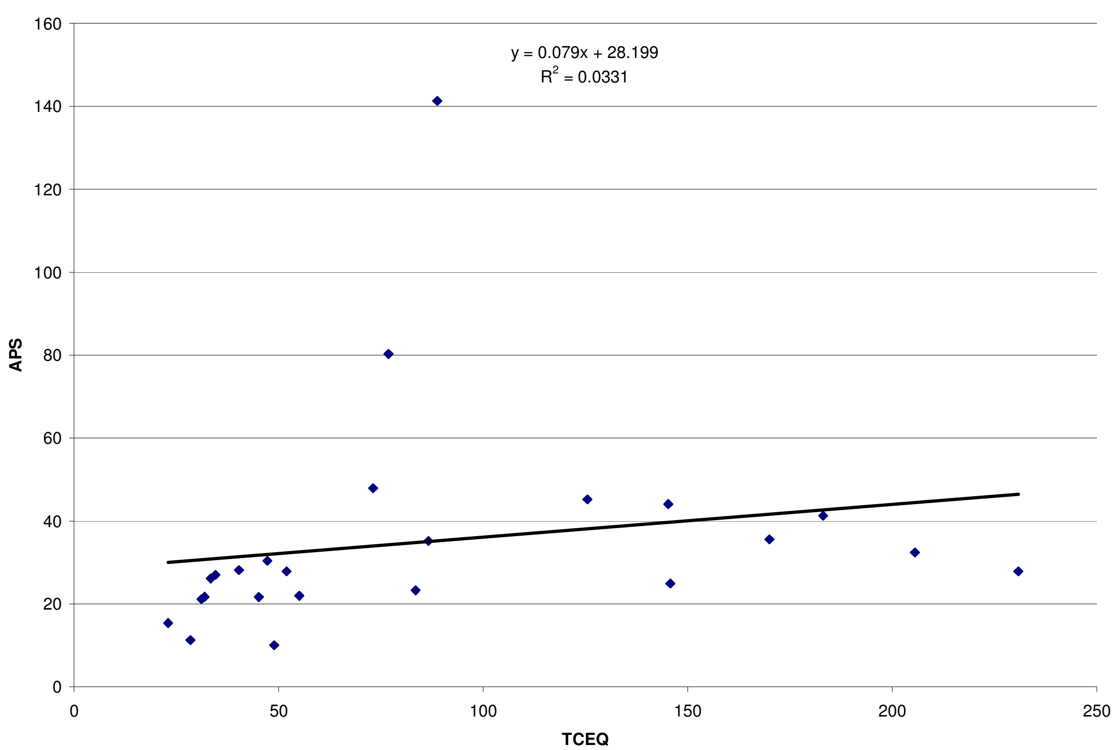


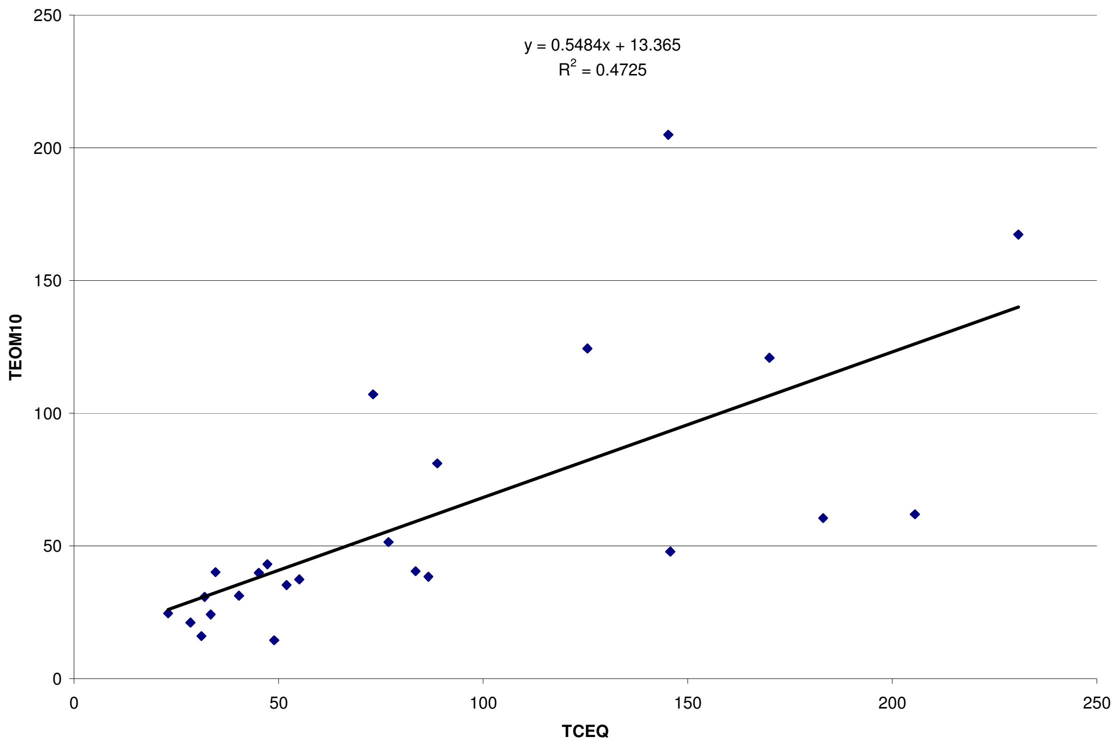

y = 0.2859x + 18.656
R^2 = 0.4595
TEOM10
TCEQ
0
20
40
60
80
100
120
140
0
50
100
150
200
250

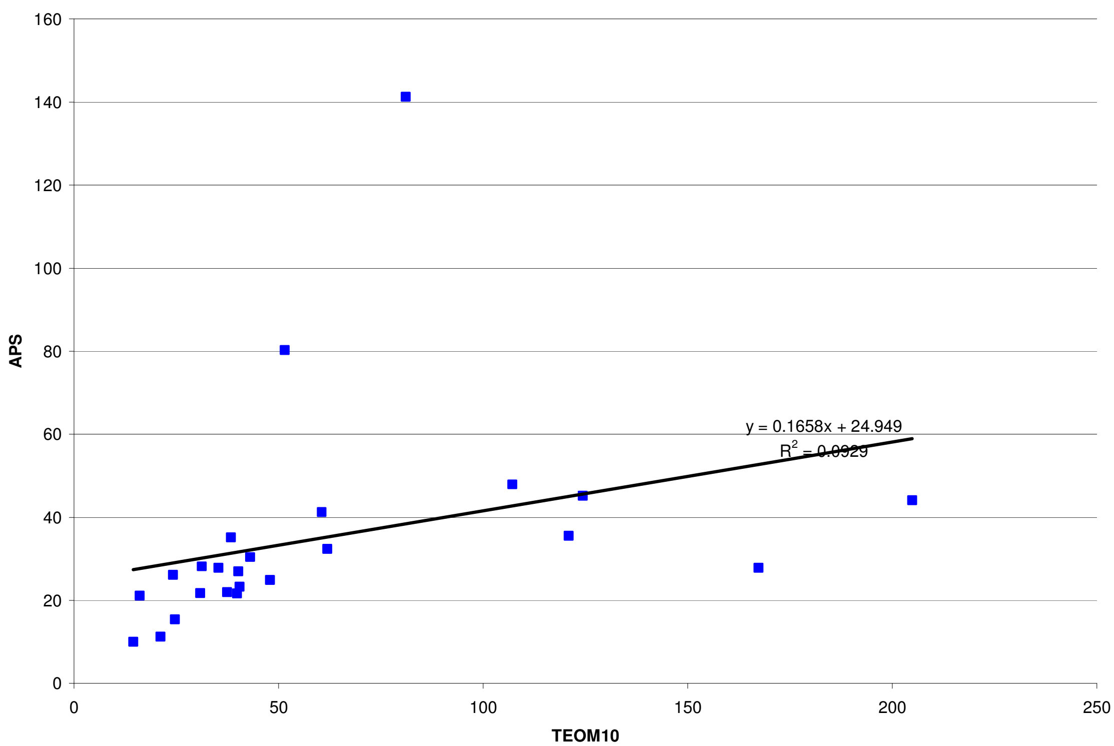

y = 0.5719x + 7.446
R^2 = 0.5239
APS
TEOM10
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140

October 31, 2008

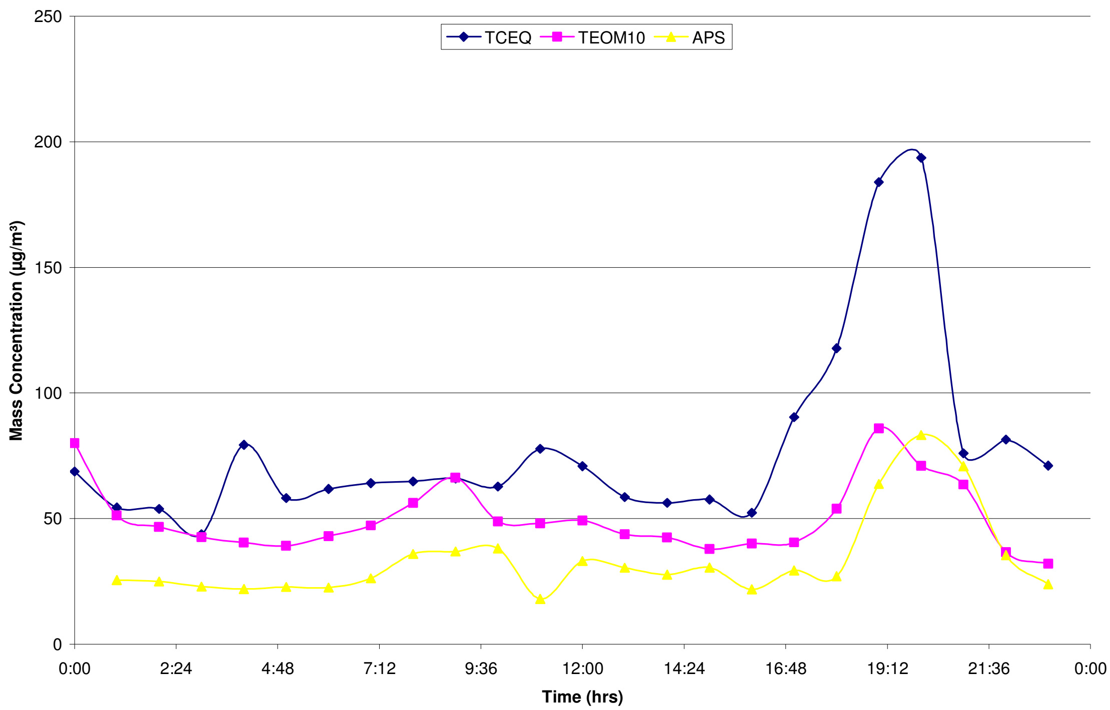


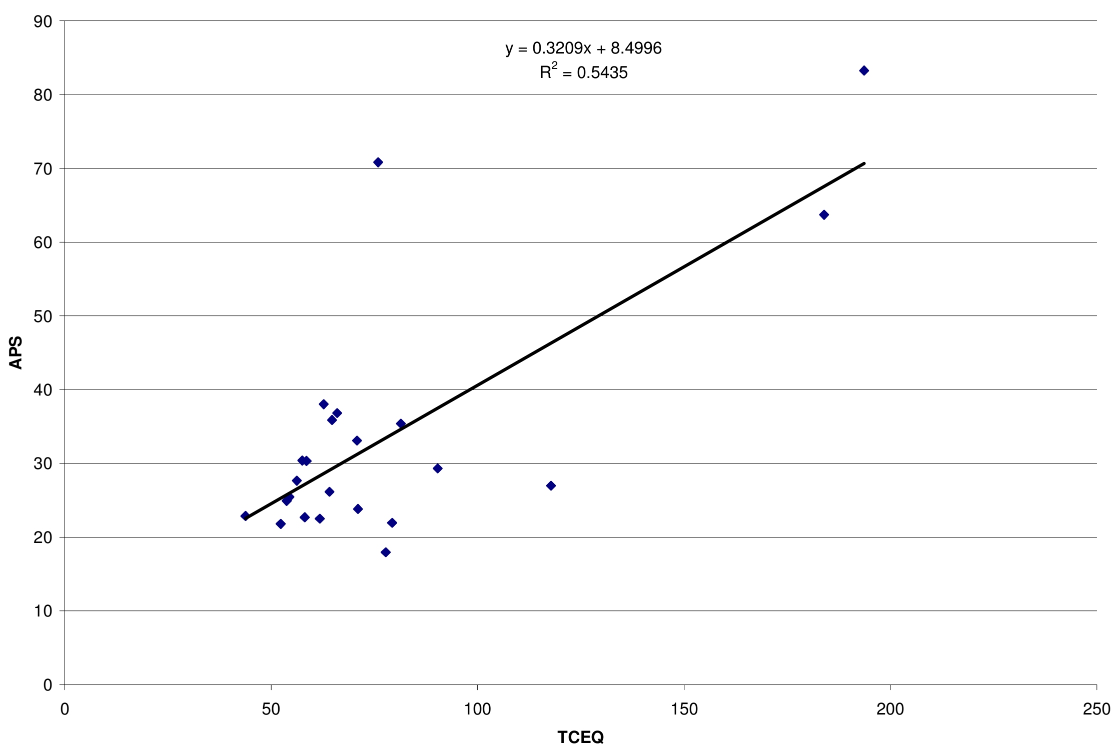


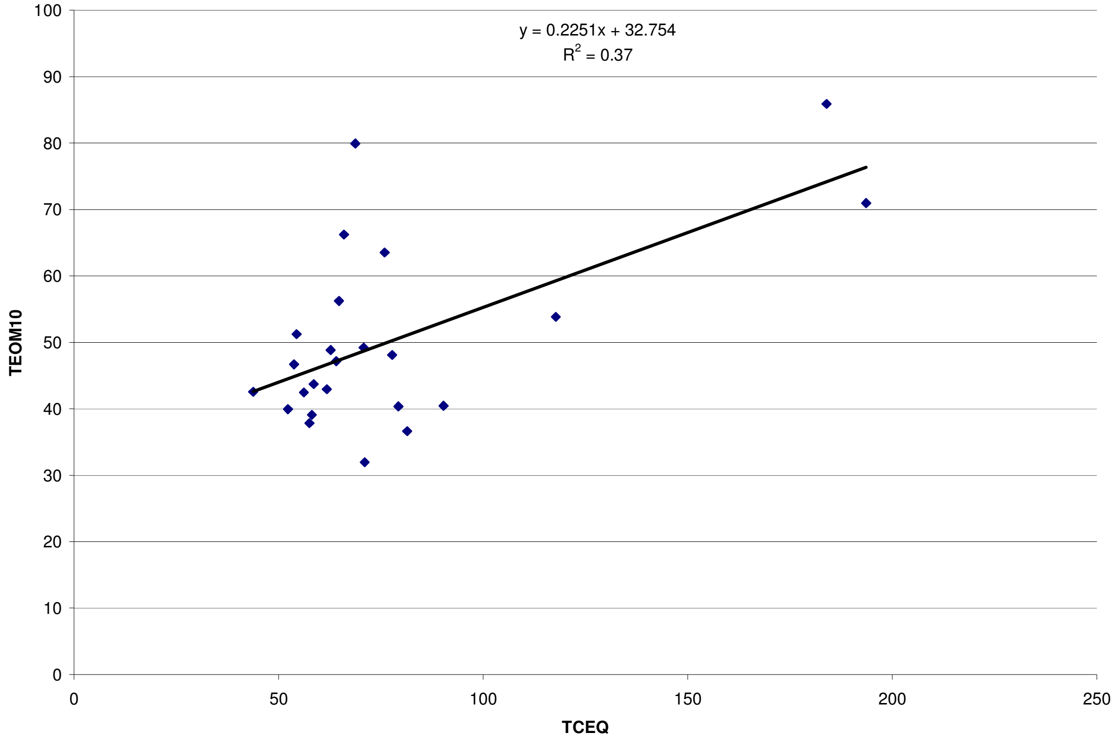

y = 0.5484x + 13.365
R^2 = 0.4725
TEOM10
TCEQ

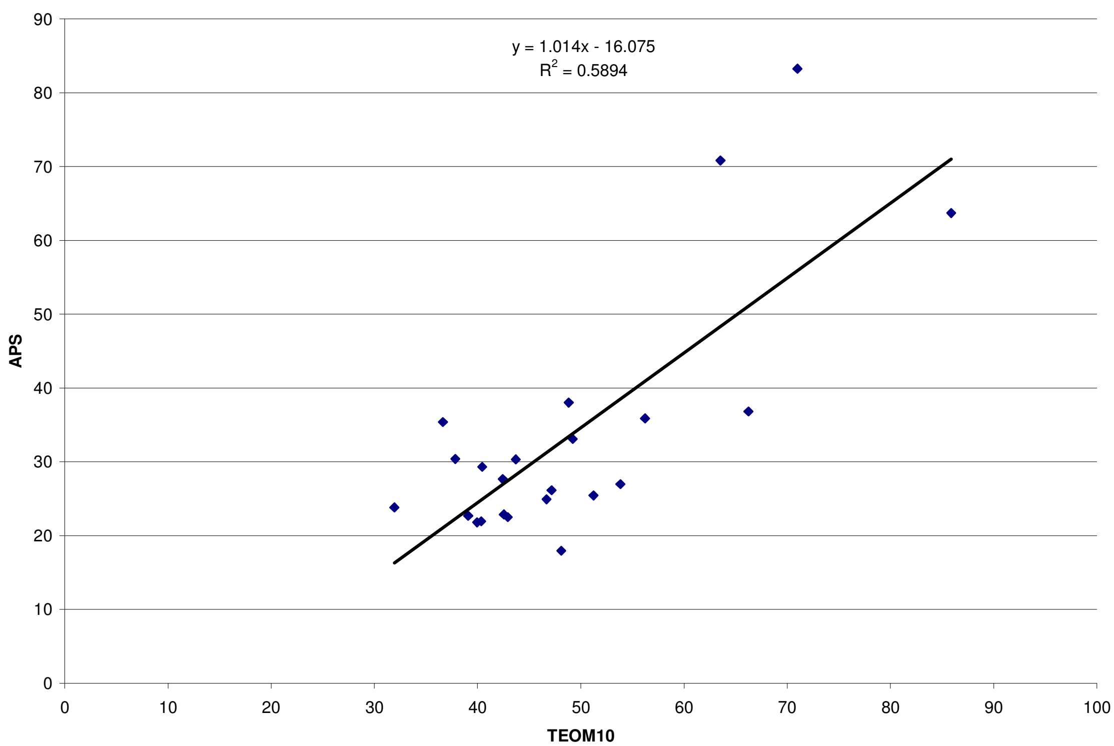

y = 0.1658x + 24.949
R^2 = 0.0929
APS
TEOM10

November 1, 2008

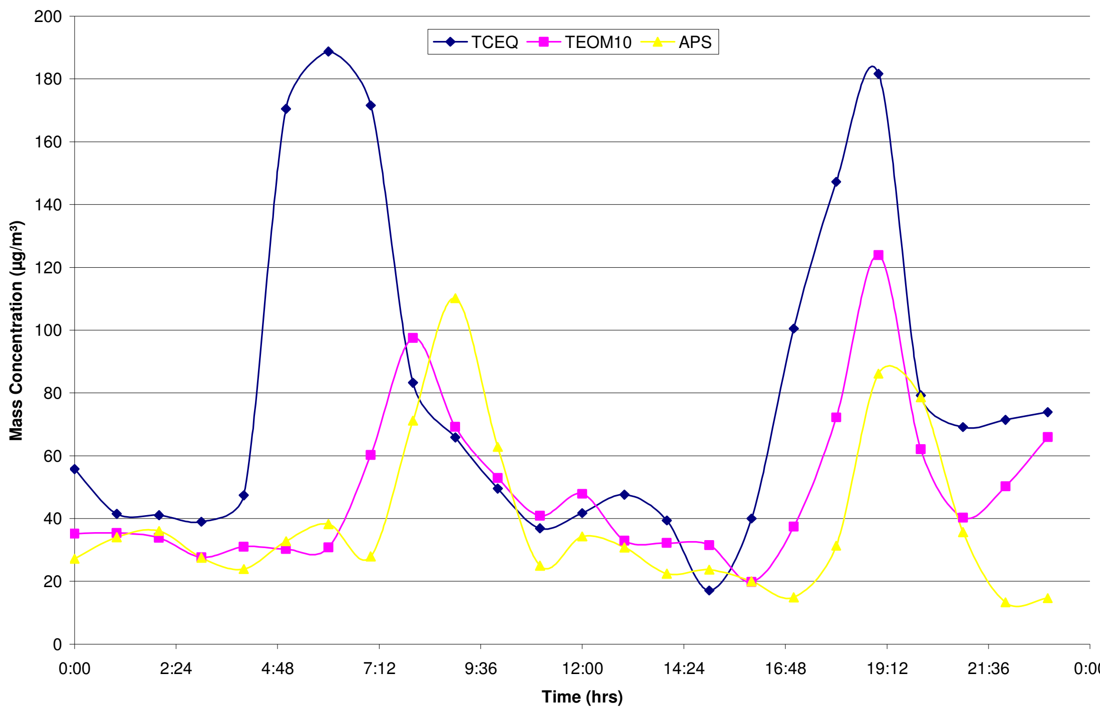


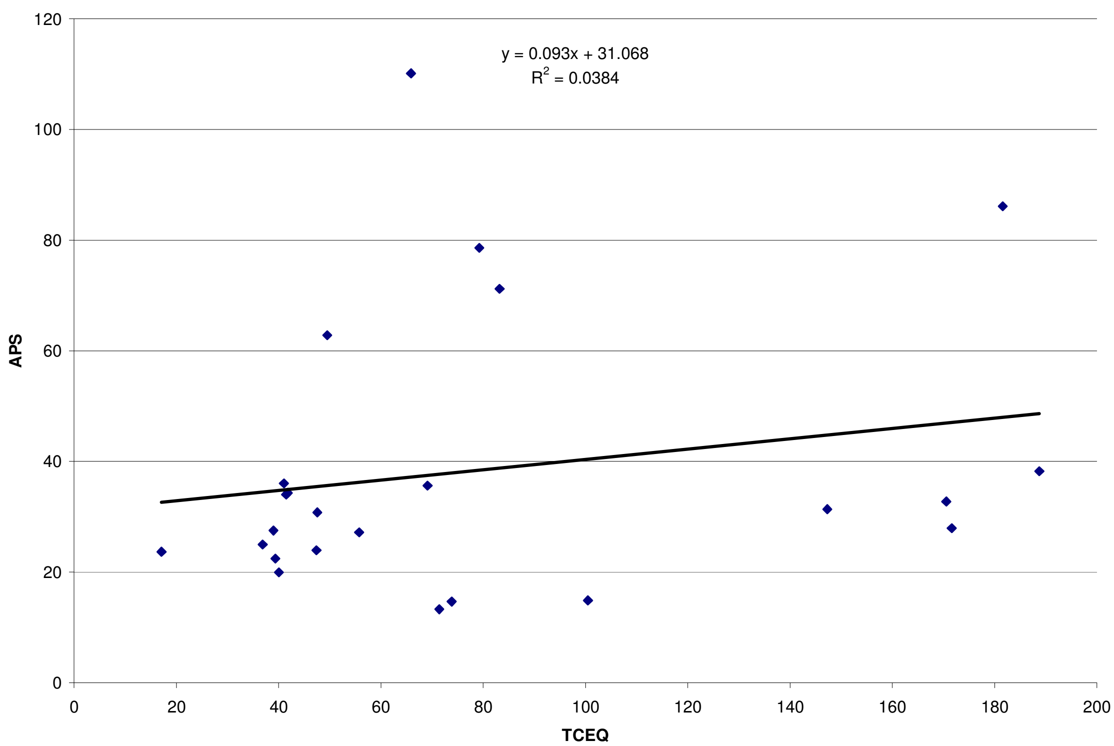


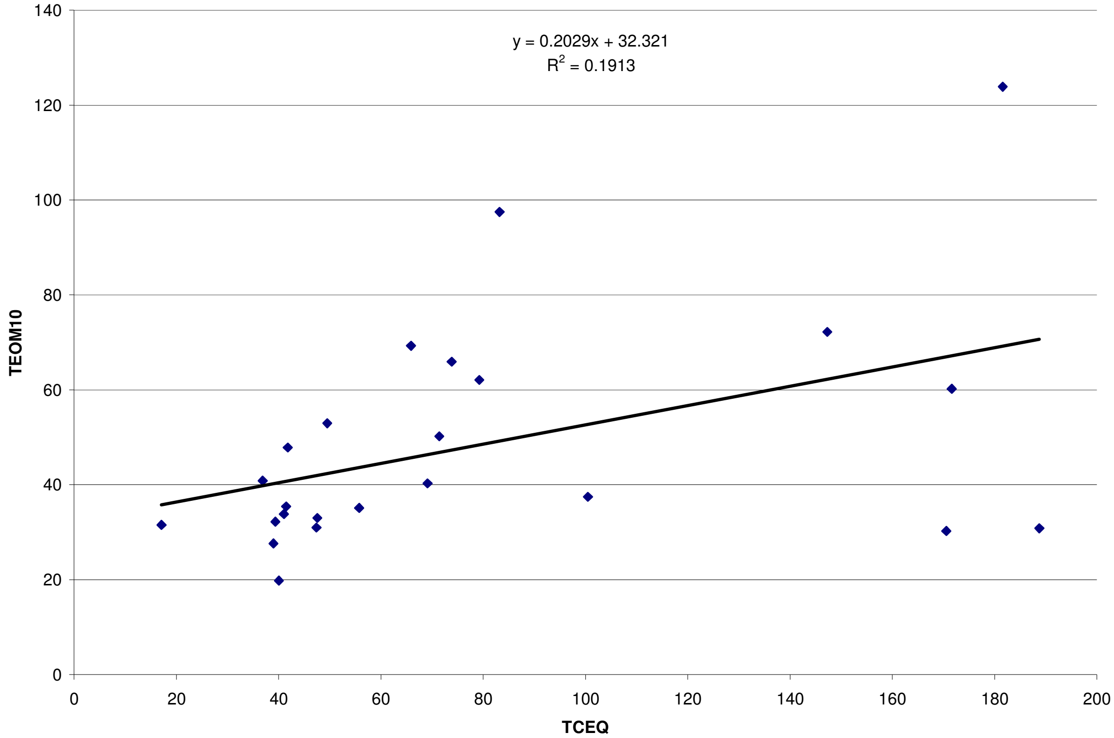

y = 0.2251x + 32.754
R^2 = 0.37
TEOM10
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
TCEQ


y = 1.014x - 16.075
R^2 = 0.5894
APS
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
TEOM10

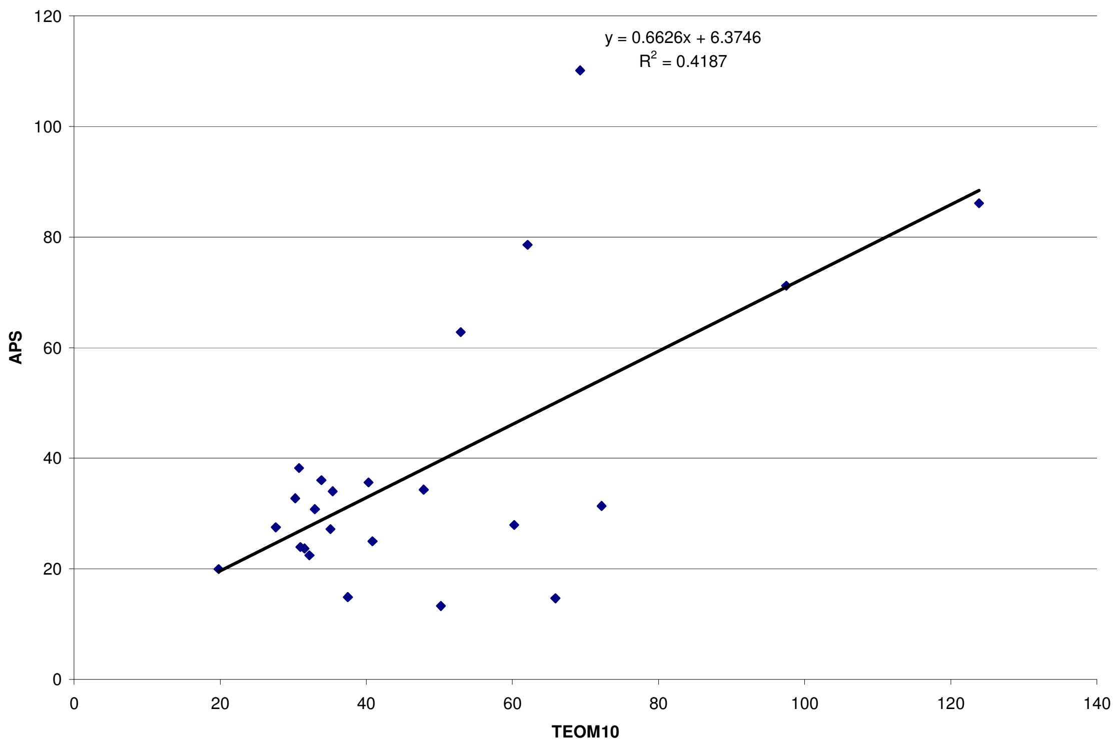
November 2, 2008





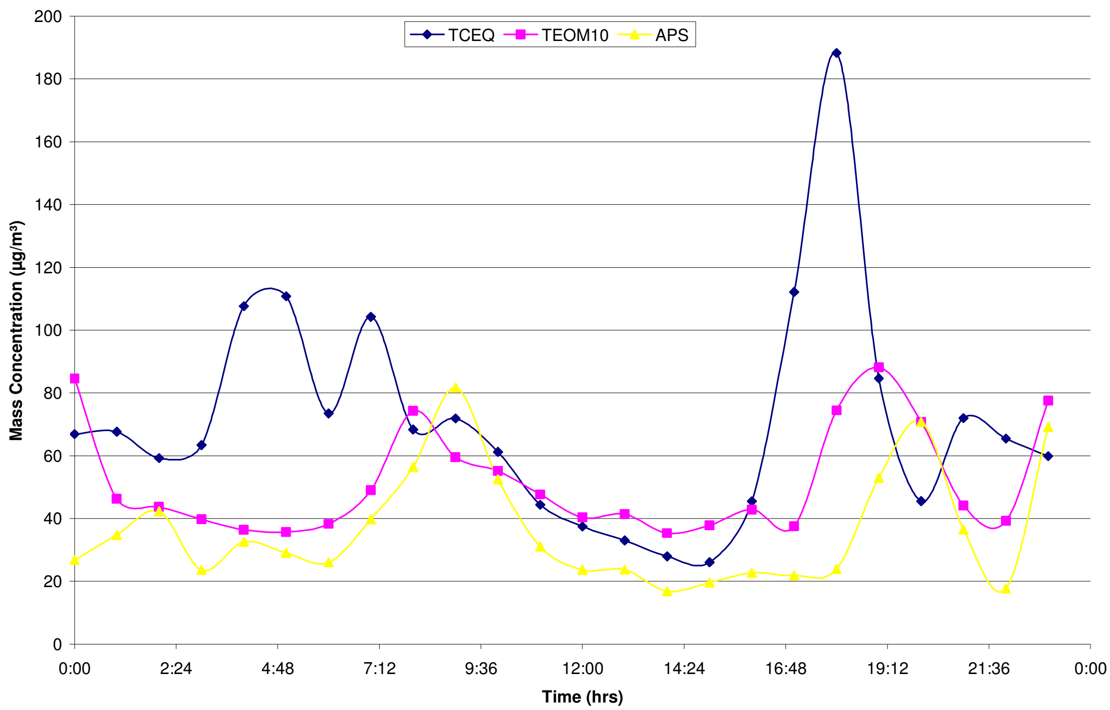


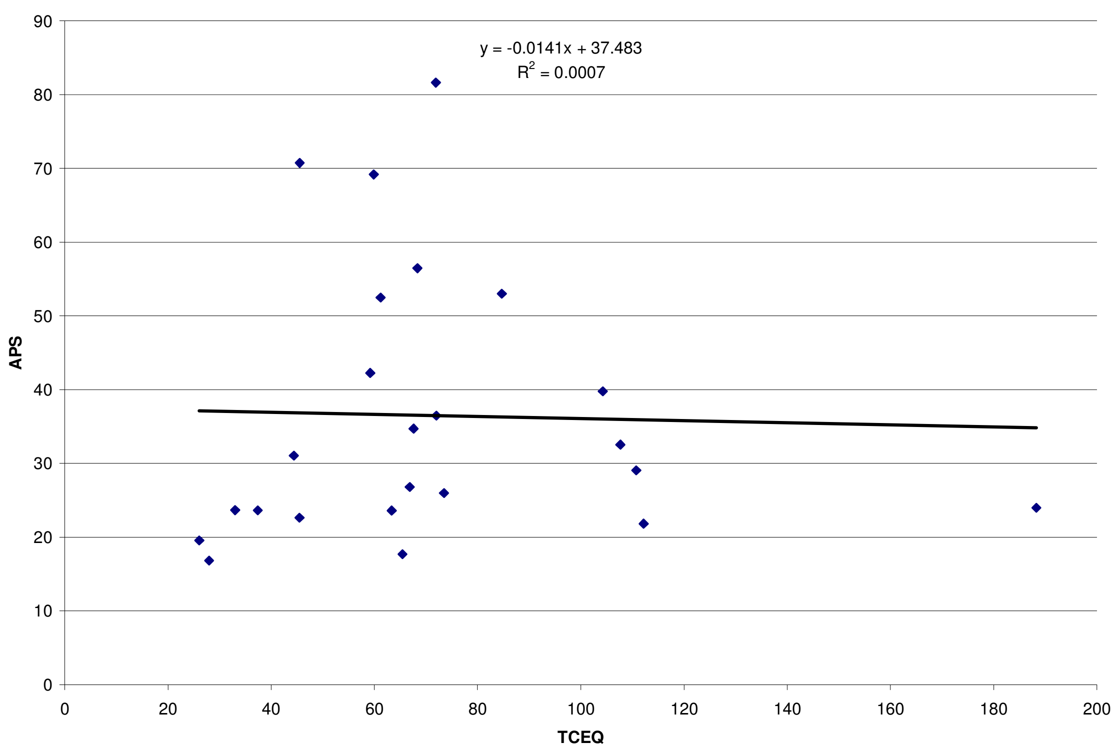
y = 0.2029x + 32.321
R^2 = 0.1913
TEOM10
TCEQ
0
20
40
60
80
100
120
140
160
180
200

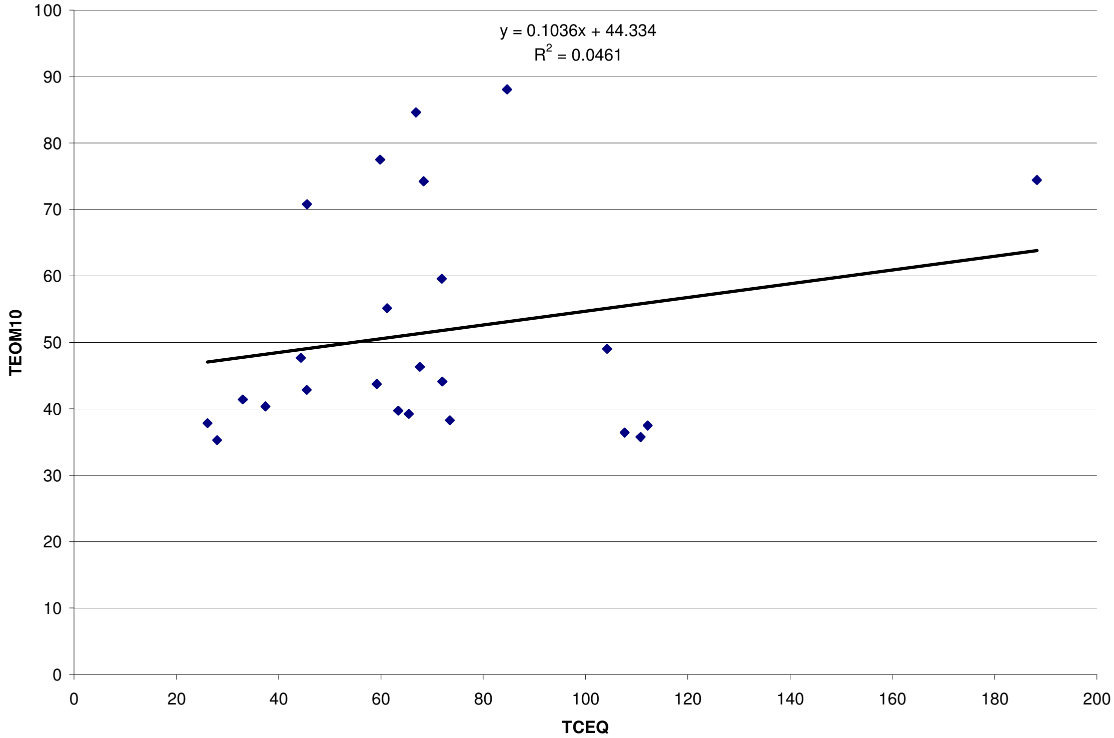


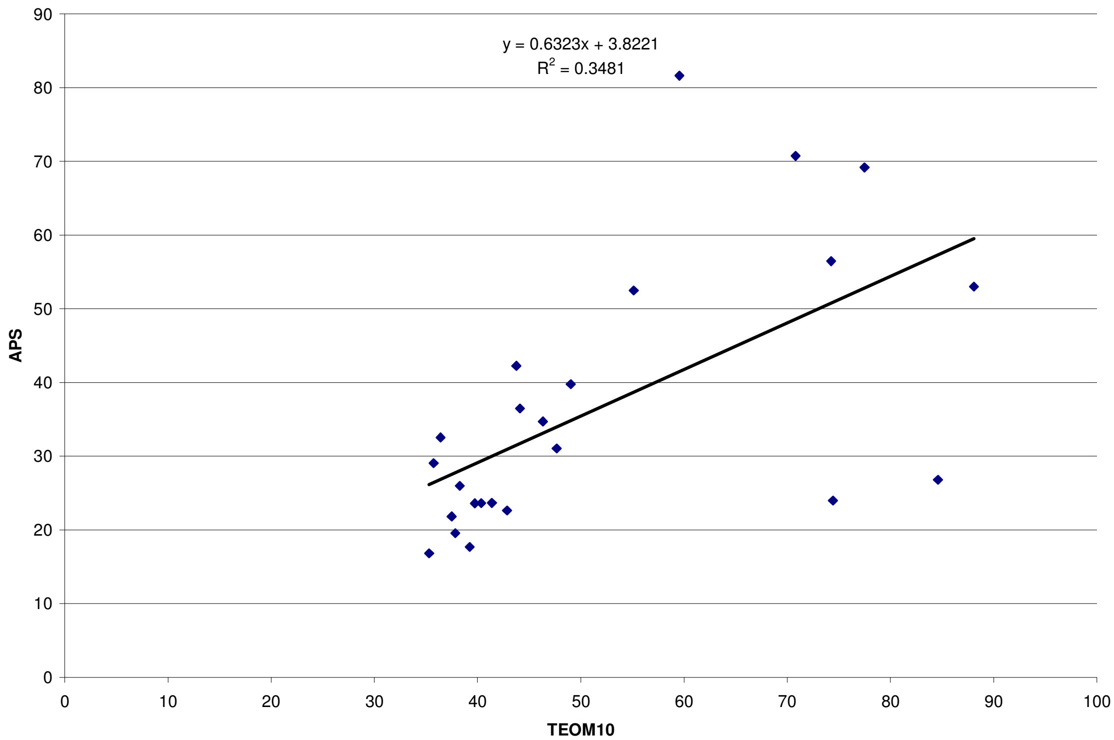
y = 0.6626x + 6.3746
R^2 = 0.4187
APS
TEOM10
0
20
40
60
80
100
120
140

November 3, 2008

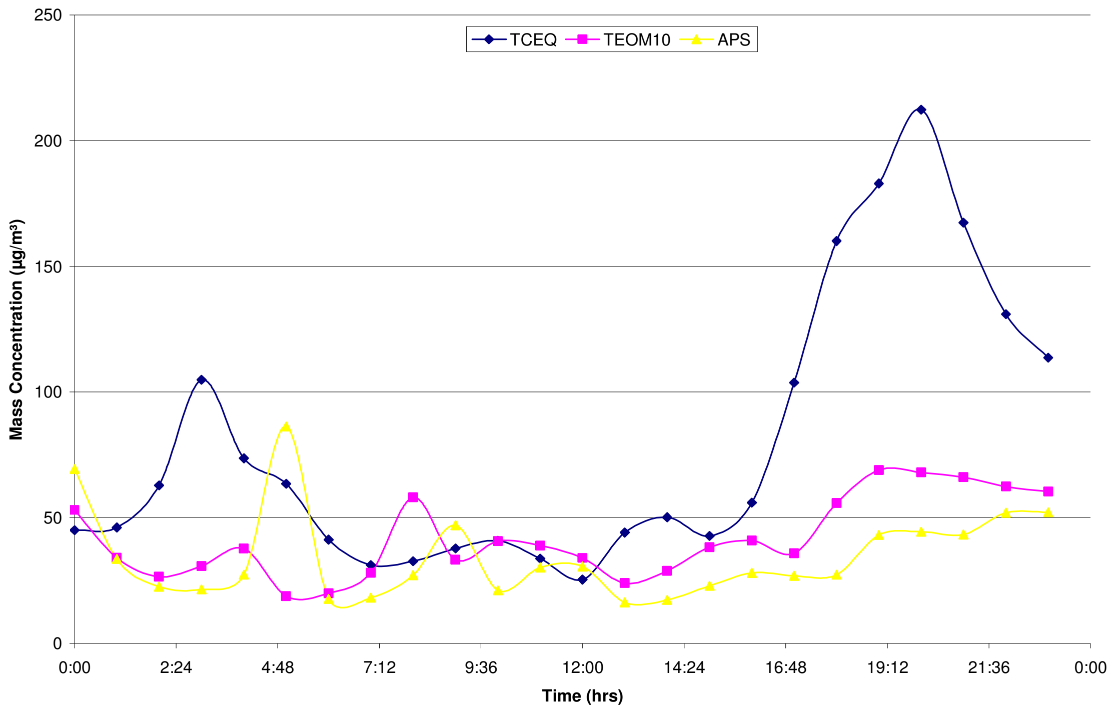


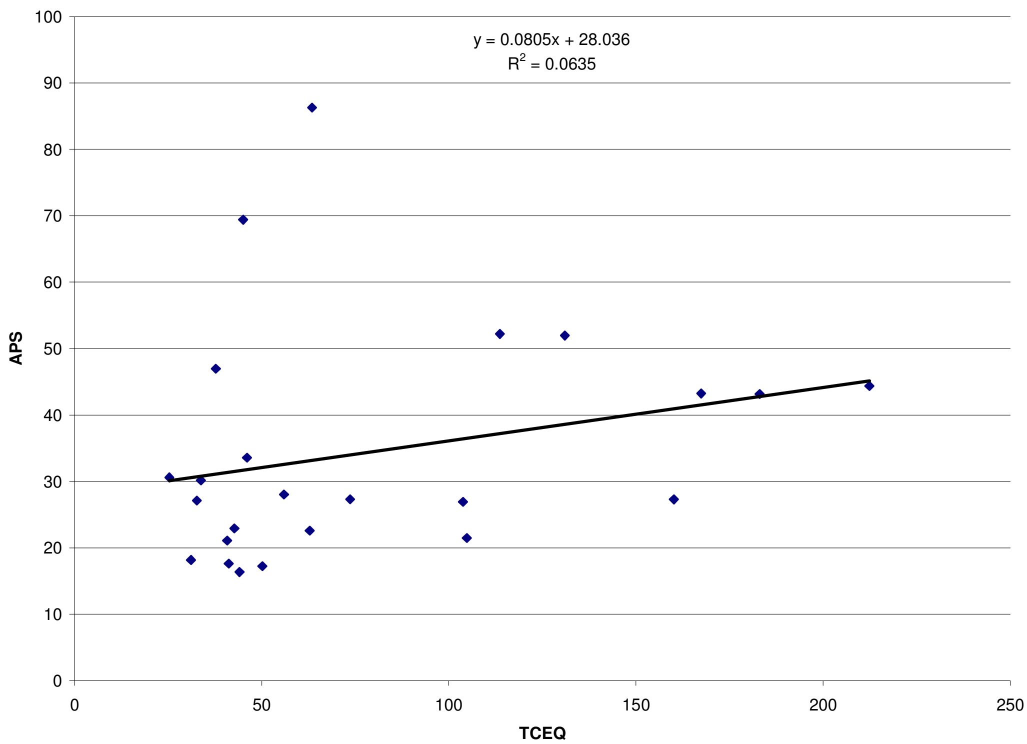


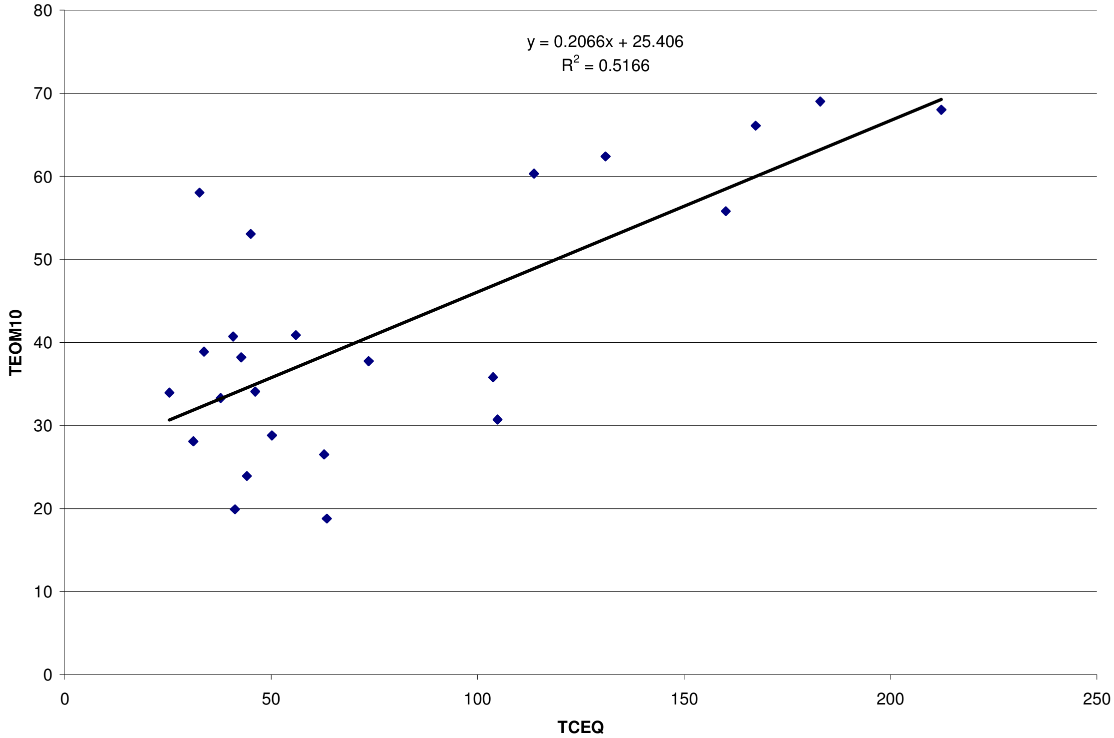

y = 0.1036x + 44.334
R2 = 0.0461
TEOM10
TCEQ
0
10
20
30
40
50
60
70
80
90
100
0
20
40
60
80
100
120
140
160
180
200

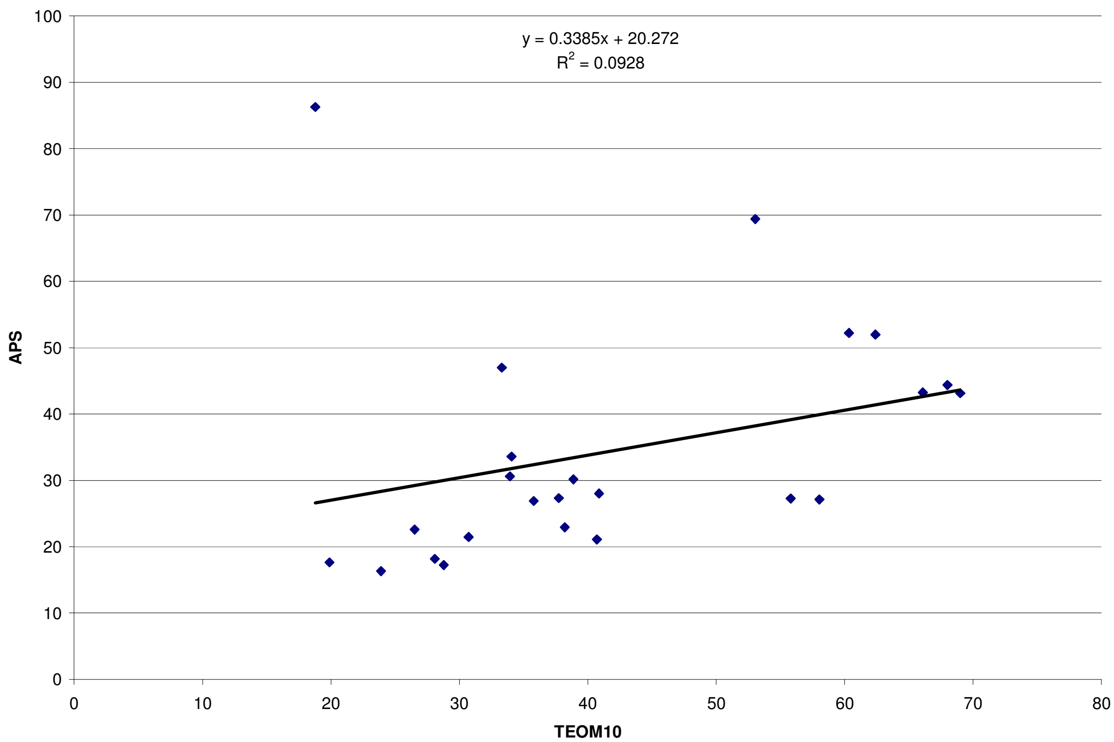

y = 0.6323x + 3.8221
R2 = 0.3481
APS
TEOM10
0
10
20
30
40
50
60
70
80
90
100

November 4, 2008

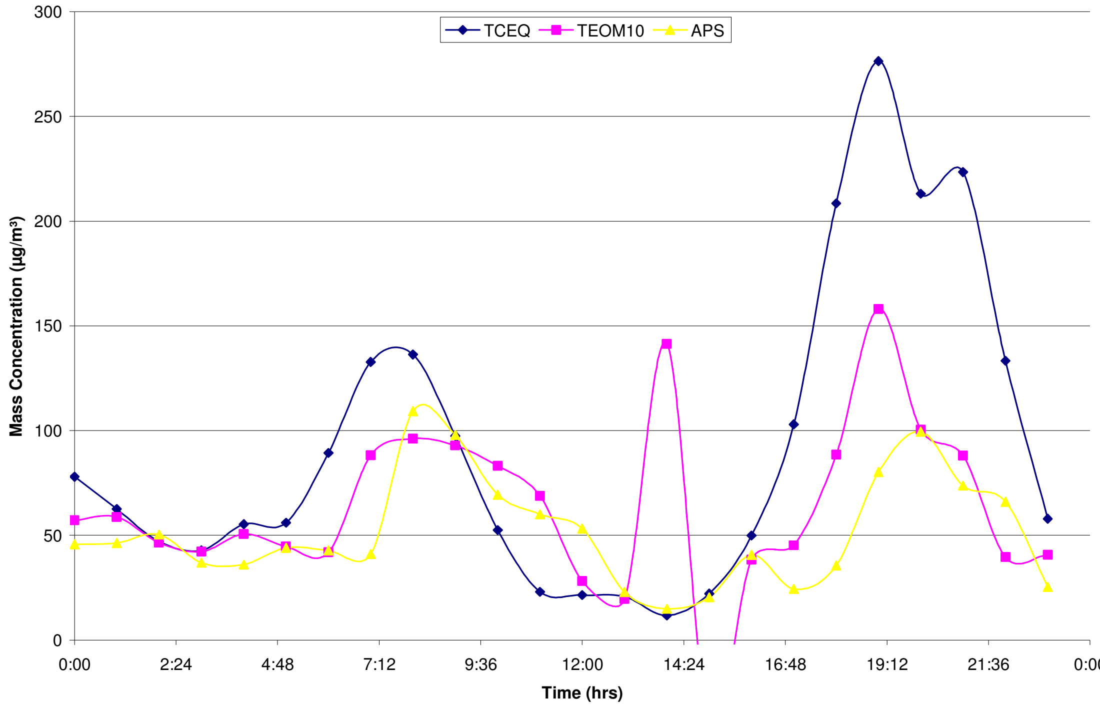


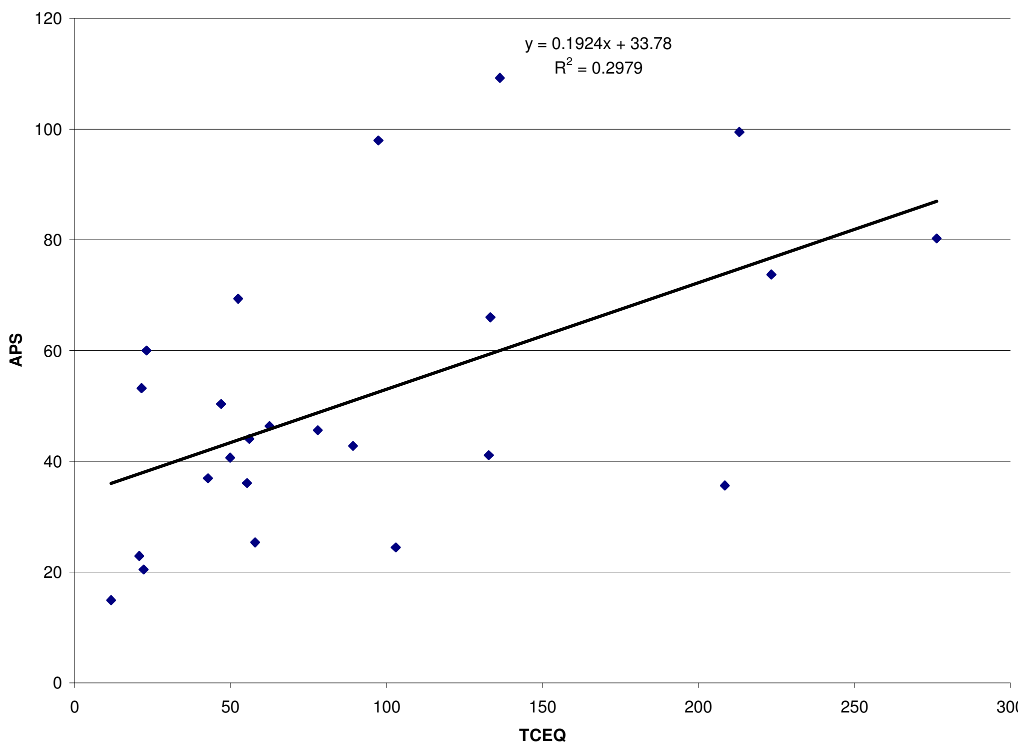


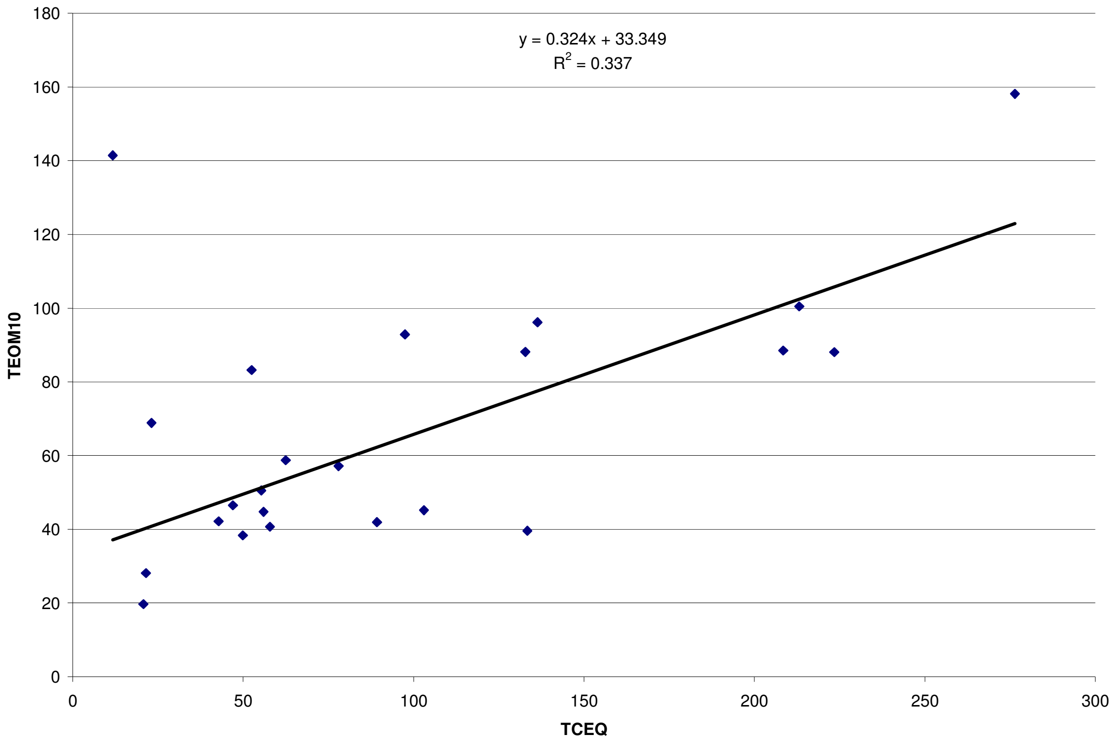

y = 0.2066x + 25.406
R^2 = 0.5166
TEOM10
TCEQ
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250

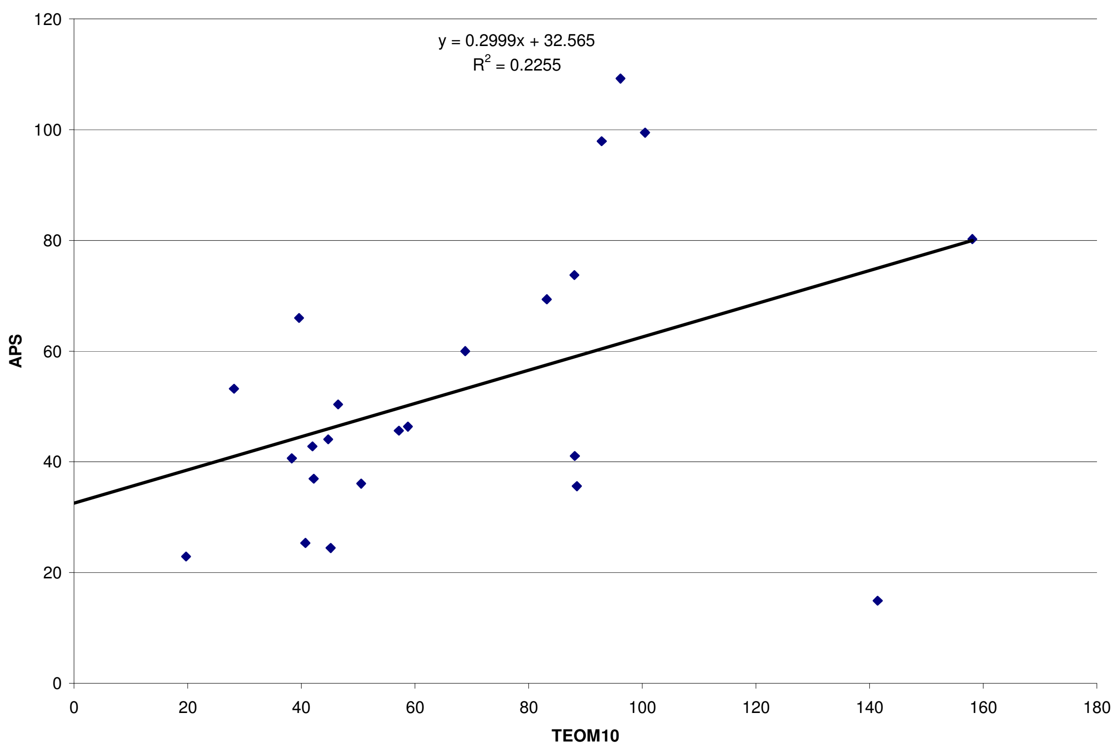

y = 0.3385x + 20.272
R^2 = 0.0928
APS
TEOM10
0
10
20
30
40
50
60
70
80
90
100
0
10
20
30
40
50
60
70
80

November 5, 2008

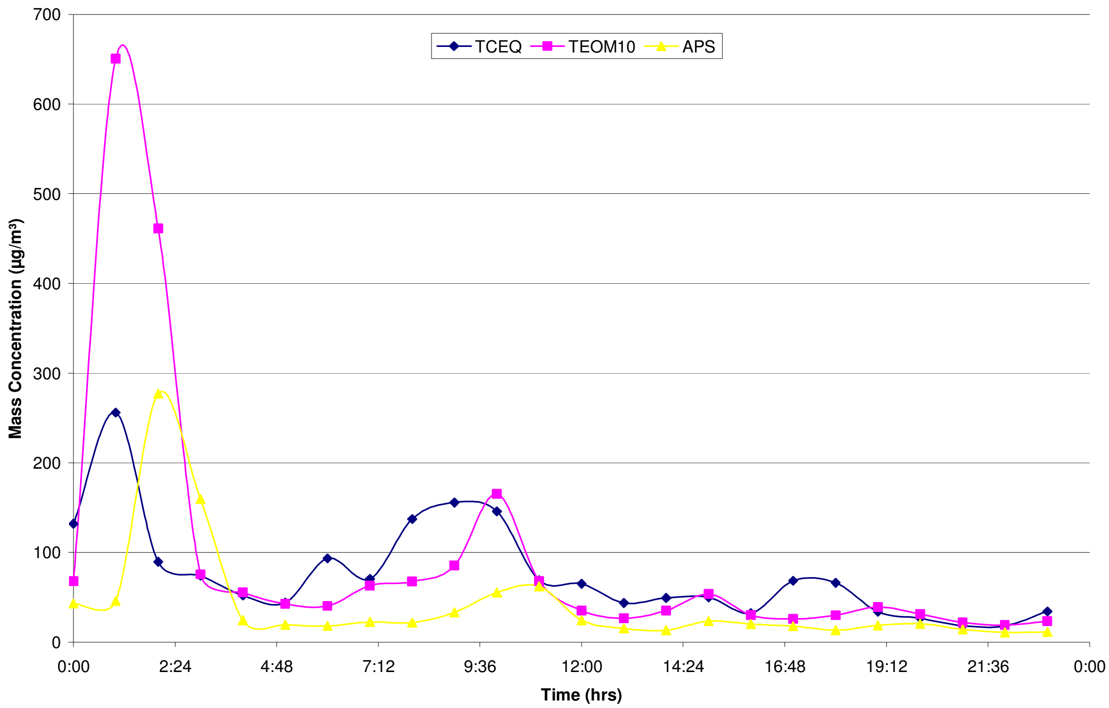


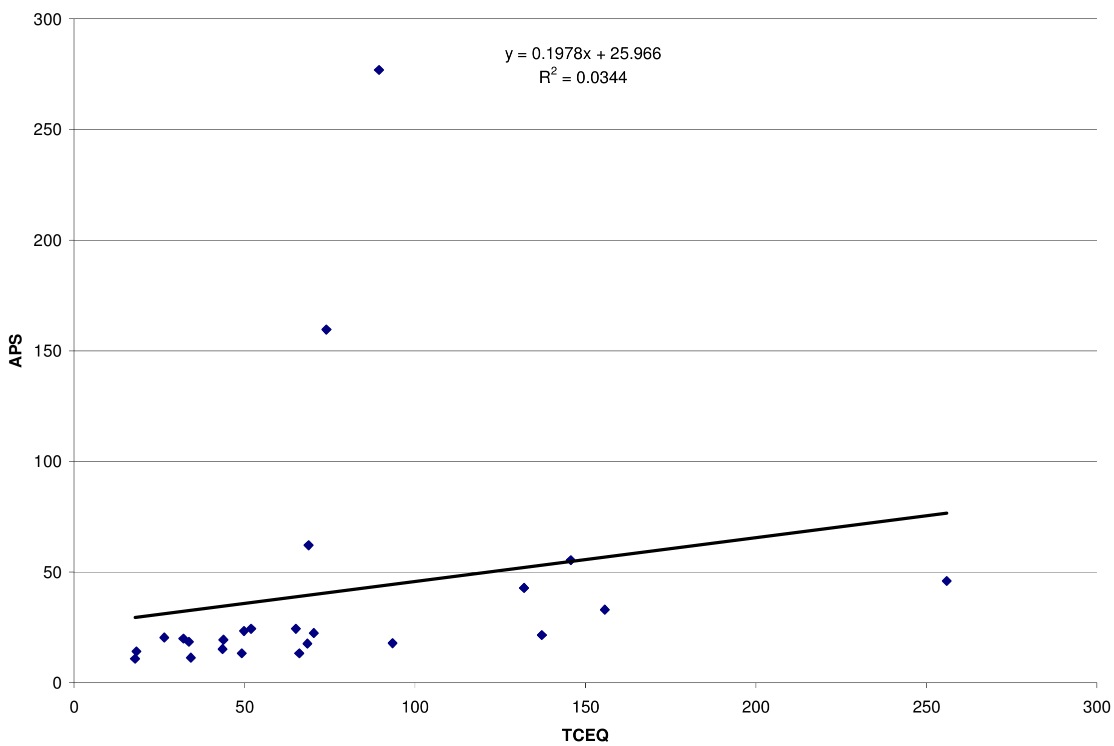


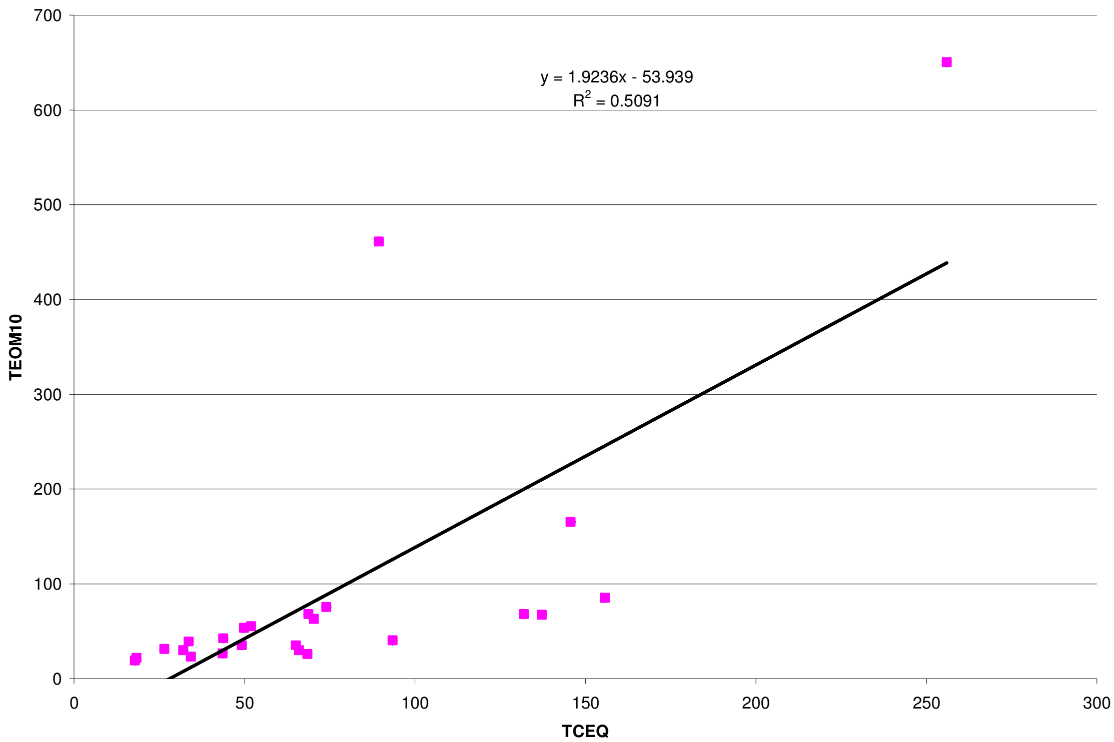

y = 0.324x + 33.349
R² = 0.337
TEOM10
TCEQ
0
20
40
60
80
100
120
140
160
180
0
50
100
150
200
250
300

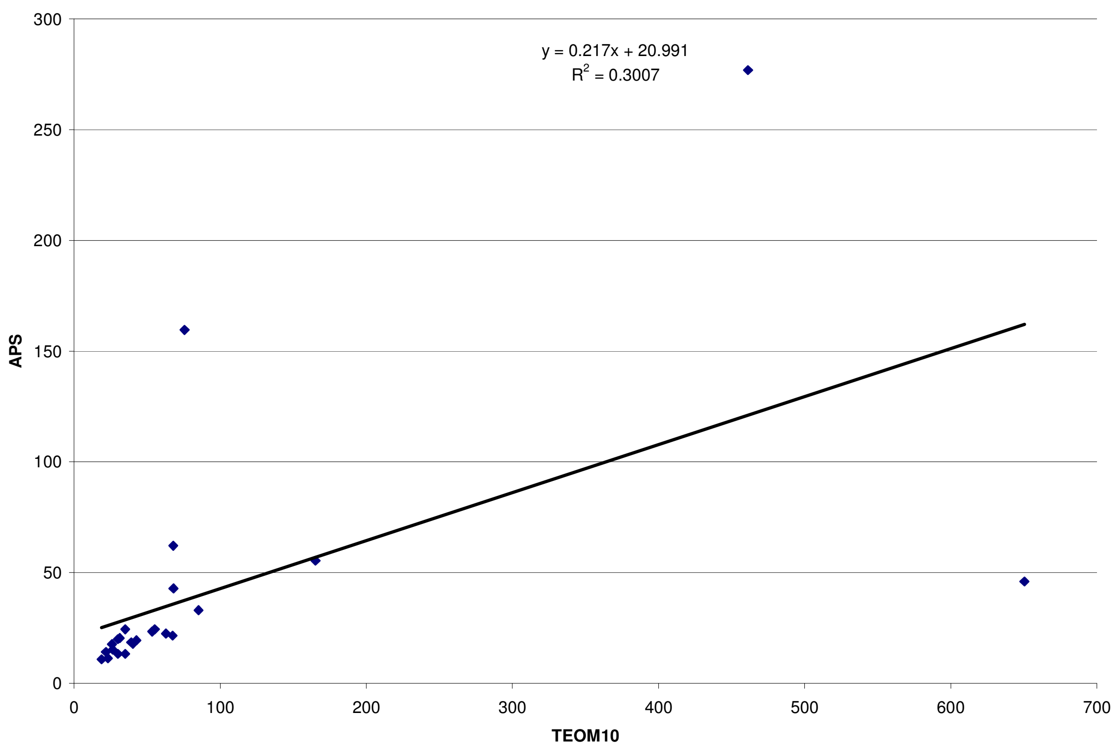

y = 0.2999x + 32.565
R² = 0.2255
APS
TEOM10
0
20
40
60
80
100
120
0
20
40
60
80
100
120
140
160
180

November 6, 2008

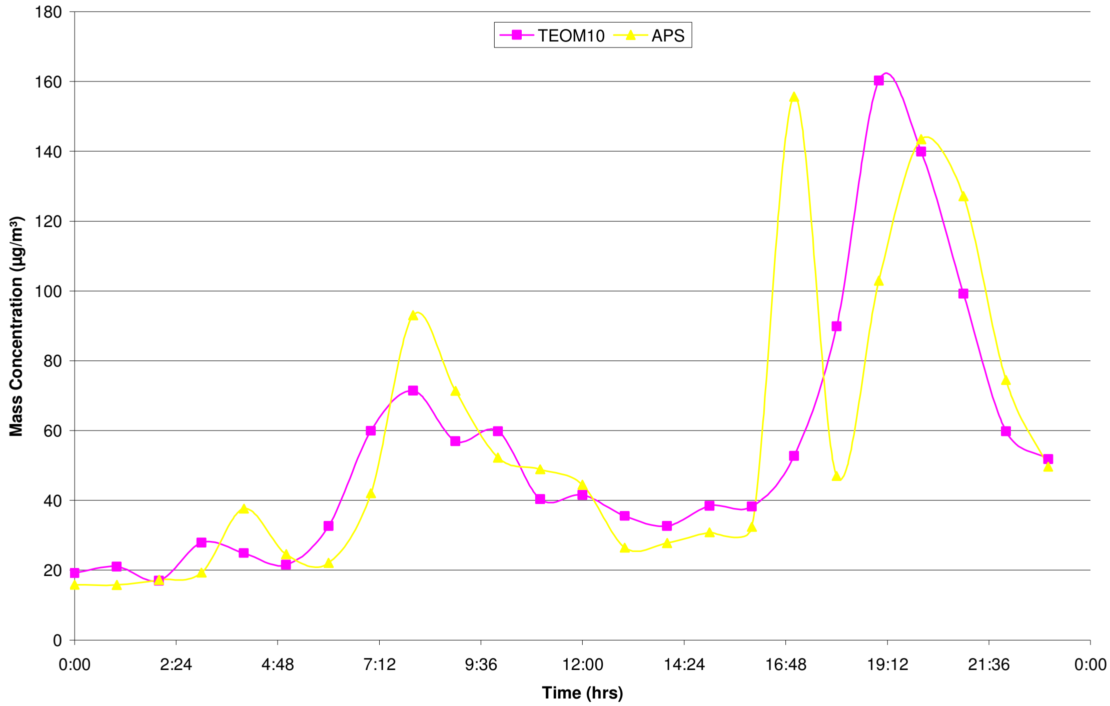


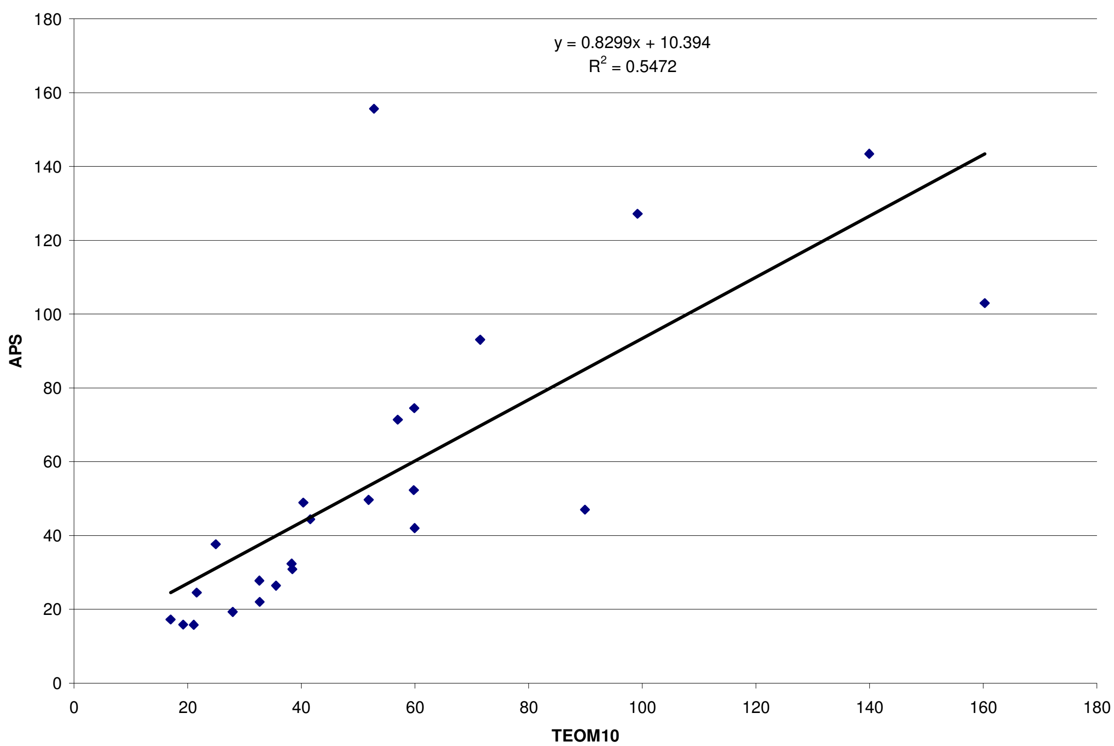



y = 1.9236x - 53.939
R2 = 0.5091
TEOM10
TCEQ
0
100
200
300
400
500
600
700
0
50
100
150
200
250
300

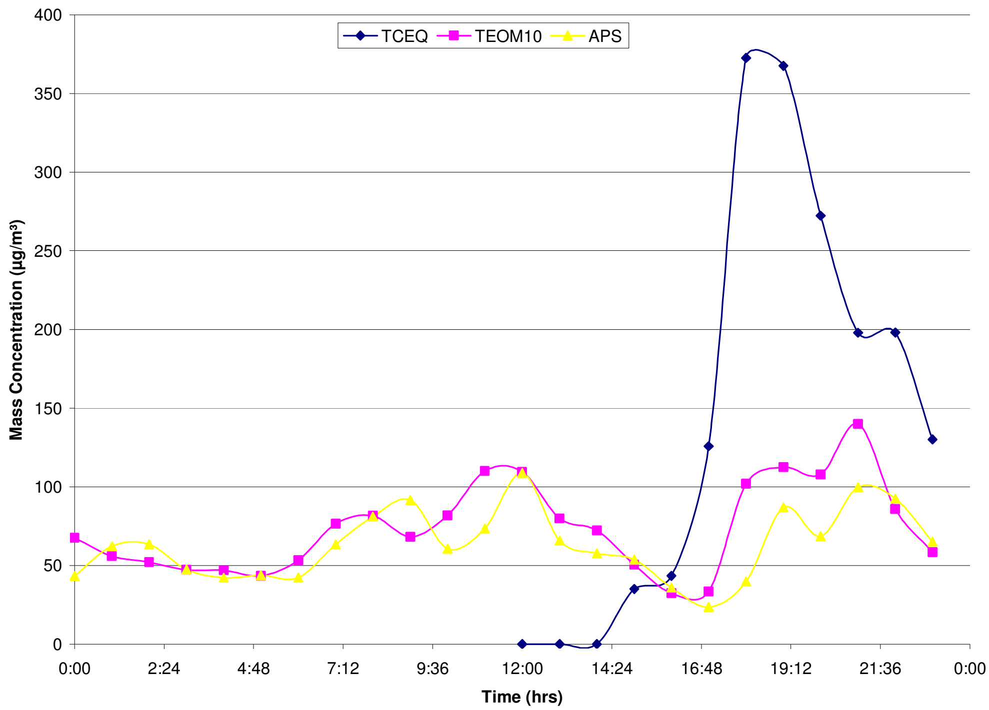

y = 0.217x + 20.991
R2 = 0.3007
APS
TEOM10
0
50
100
150
200
250
300
0
100
200
300
400
500
600
700

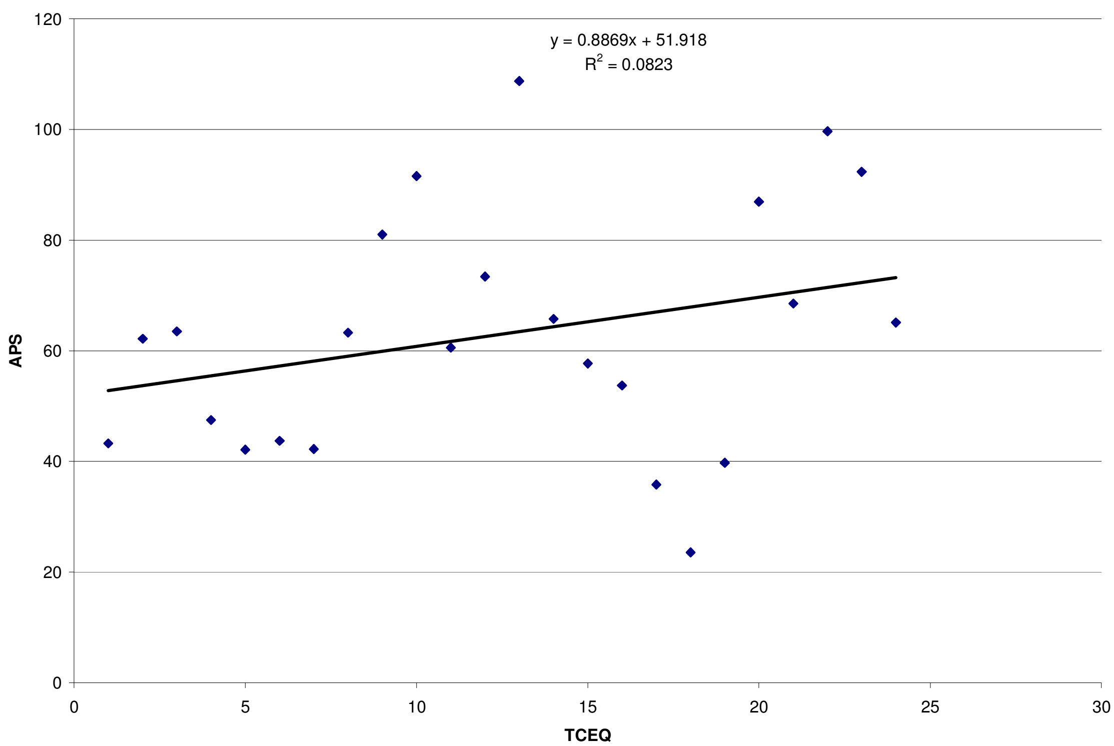
November 7, 2008

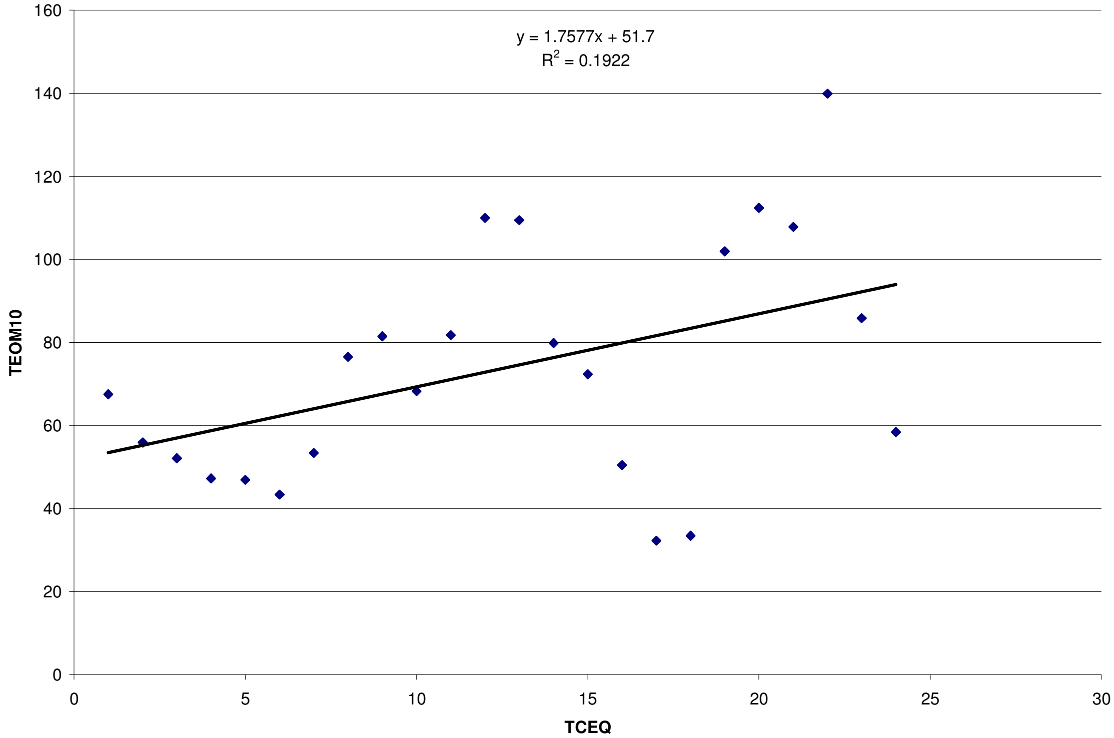




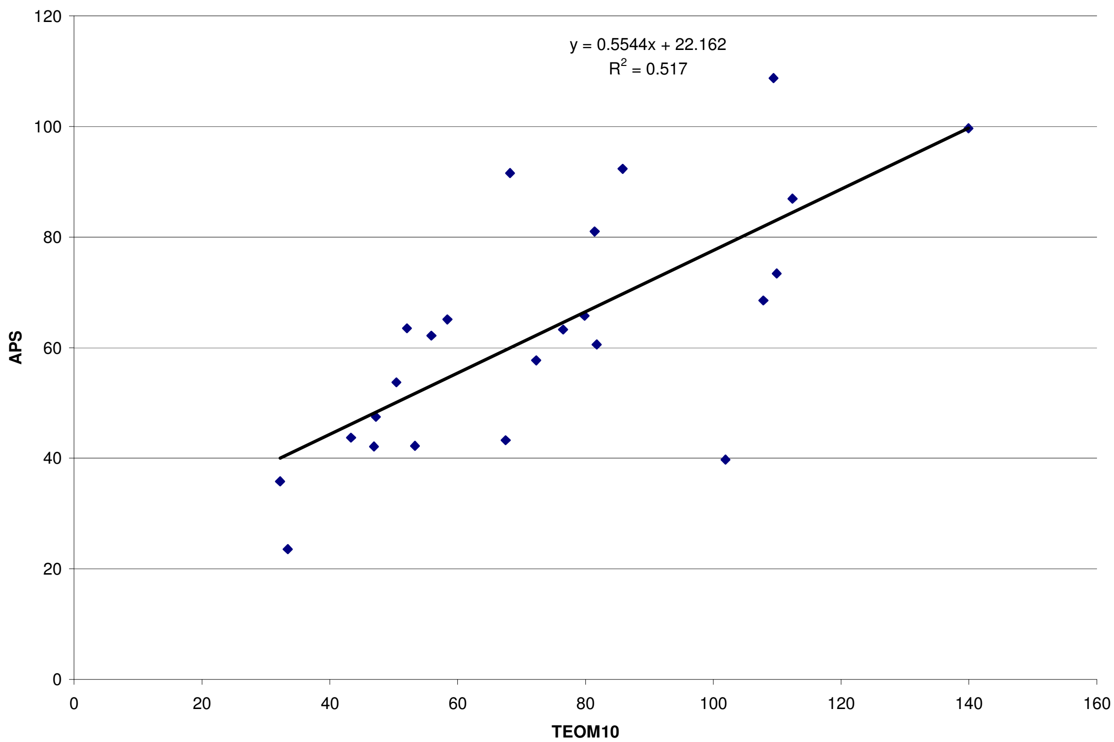
November 8, 2008





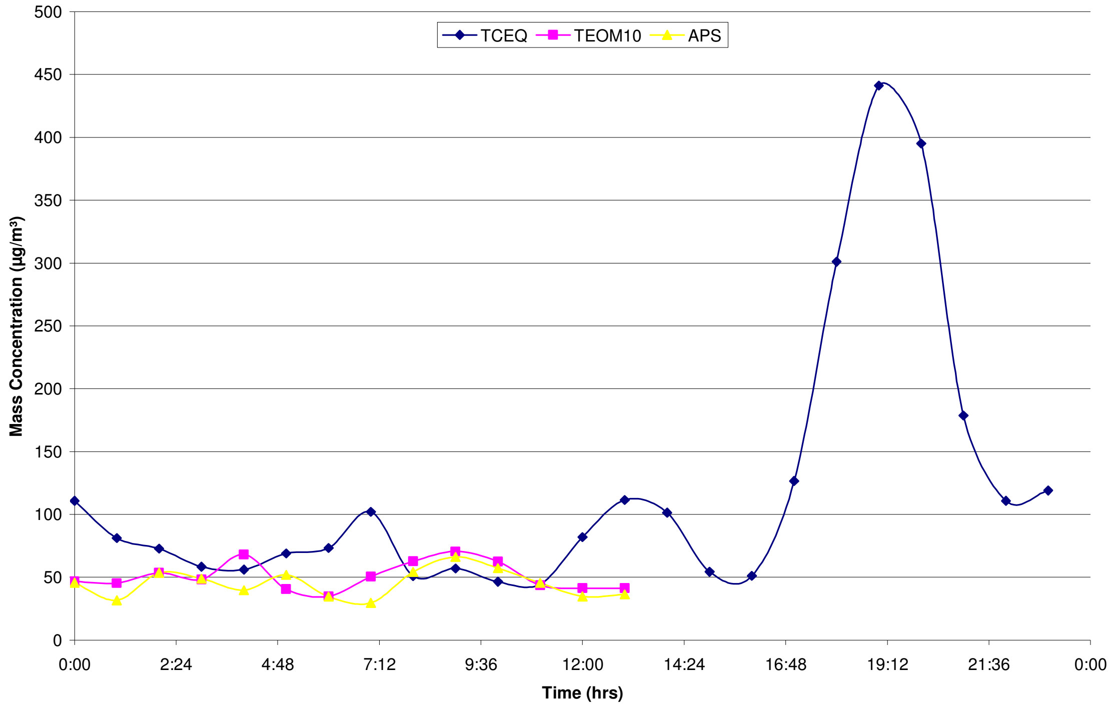


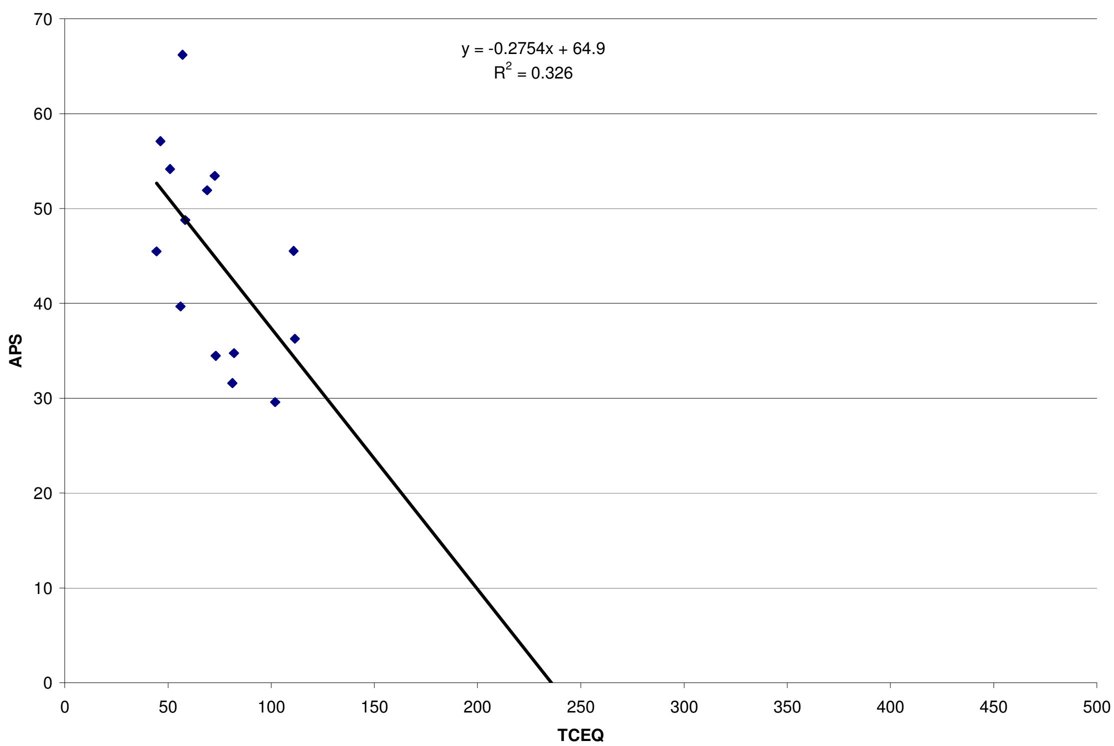
y = 1.7577x + 51.7
R2 = 0.1922
TEOM10
TCEQ
160
140
120
100
80
60
40
20
0
0
5
10
15
20
25
30

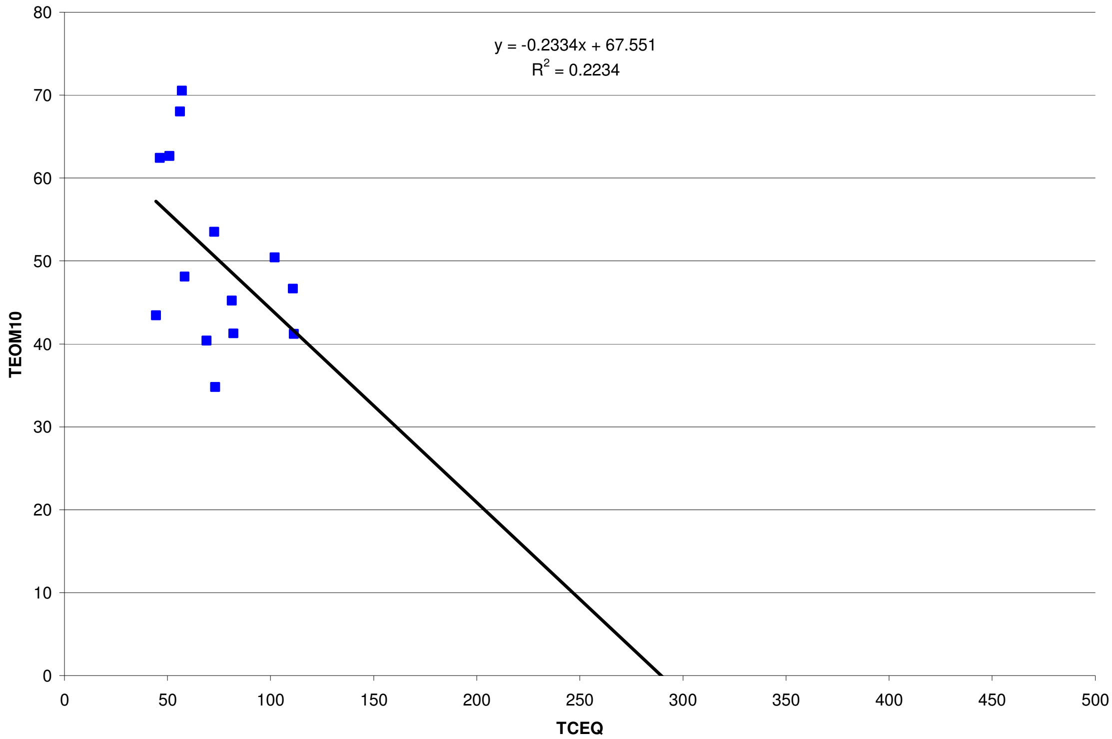


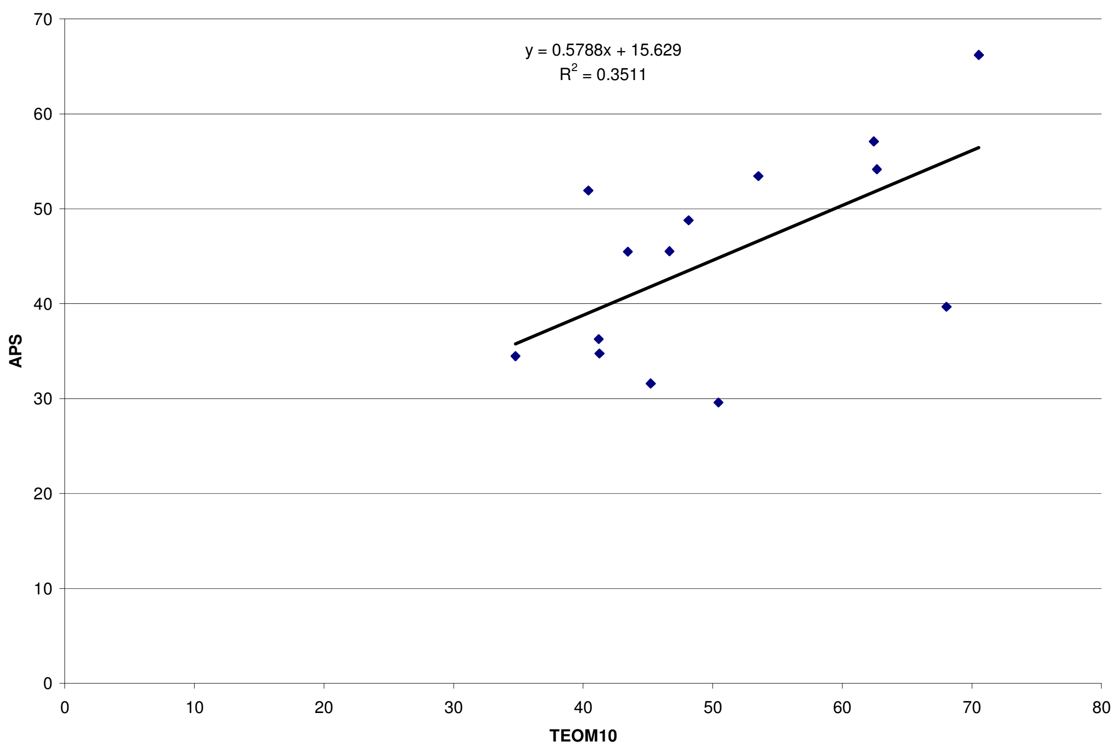
y = 0.5544x + 22.162
R2 = 0.517
APS
TEOM10
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160

November 9, 2008





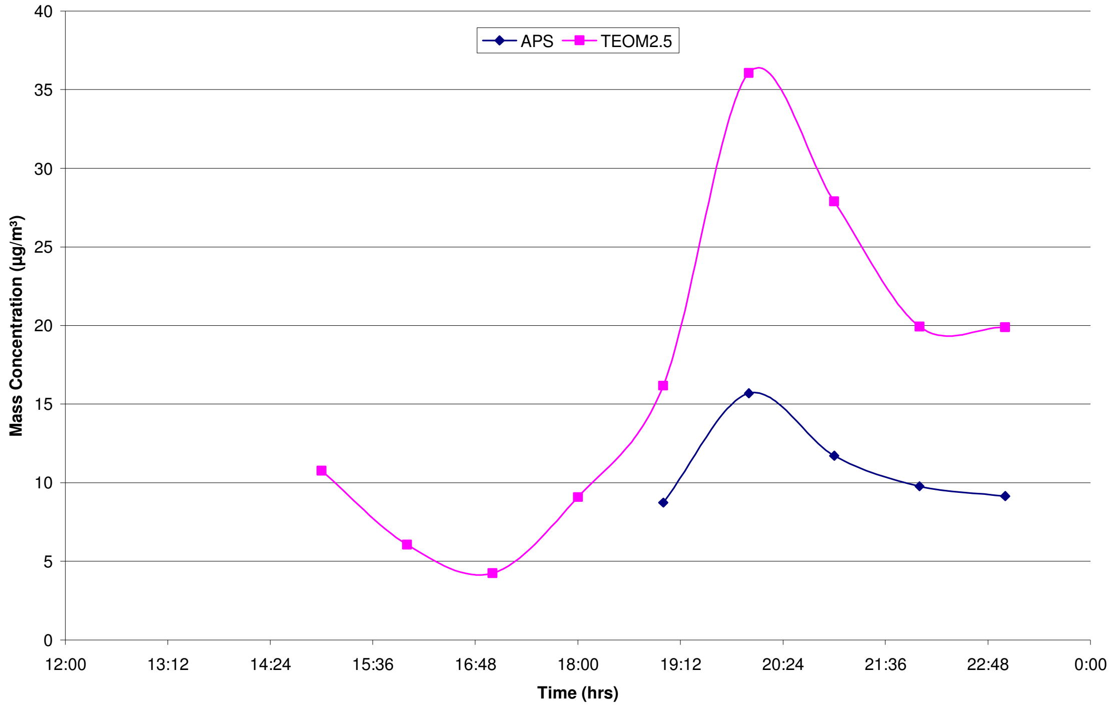

y = -0.2334x + 67.551
R^2 = 0.2234
TEOM10
TCEQ
0
10
20
30
40
50
60
70
80
0
50
100
150
200
250
300
350
400
450
500

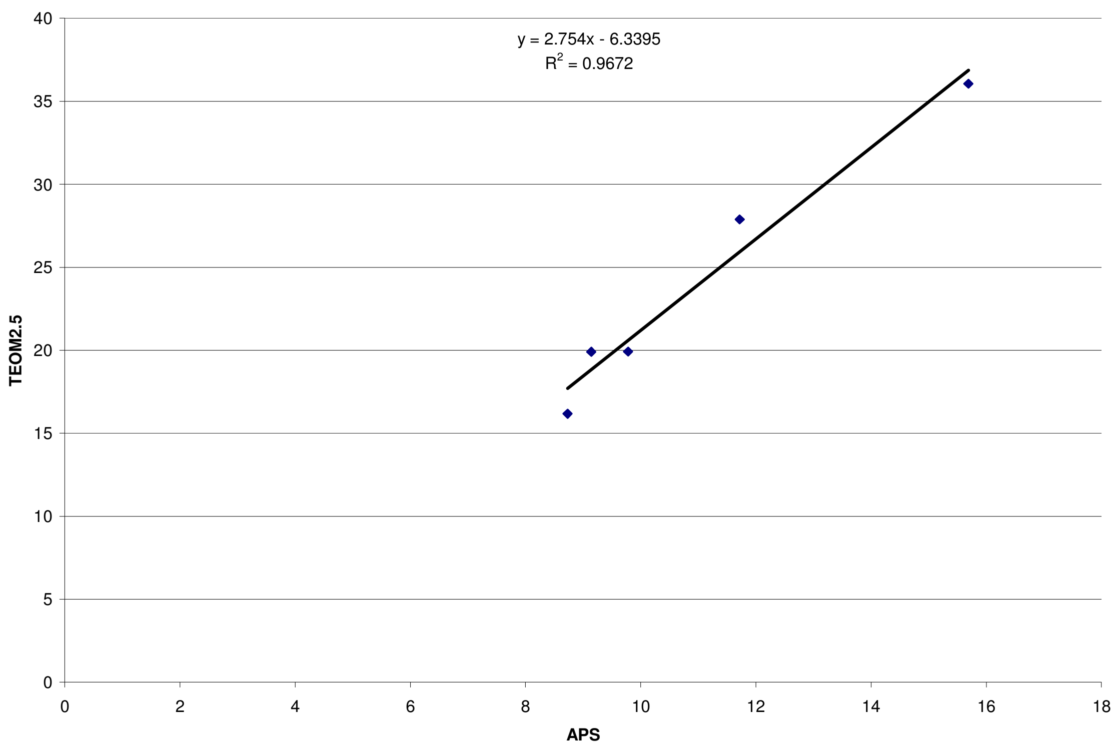

y = 0.5788x + 15.629
R^2 = 0.3511
APS
TEOM10
0
10
20
30
40
50
60
70
0
10
20
30
40
50
60
70
80

Appendix B

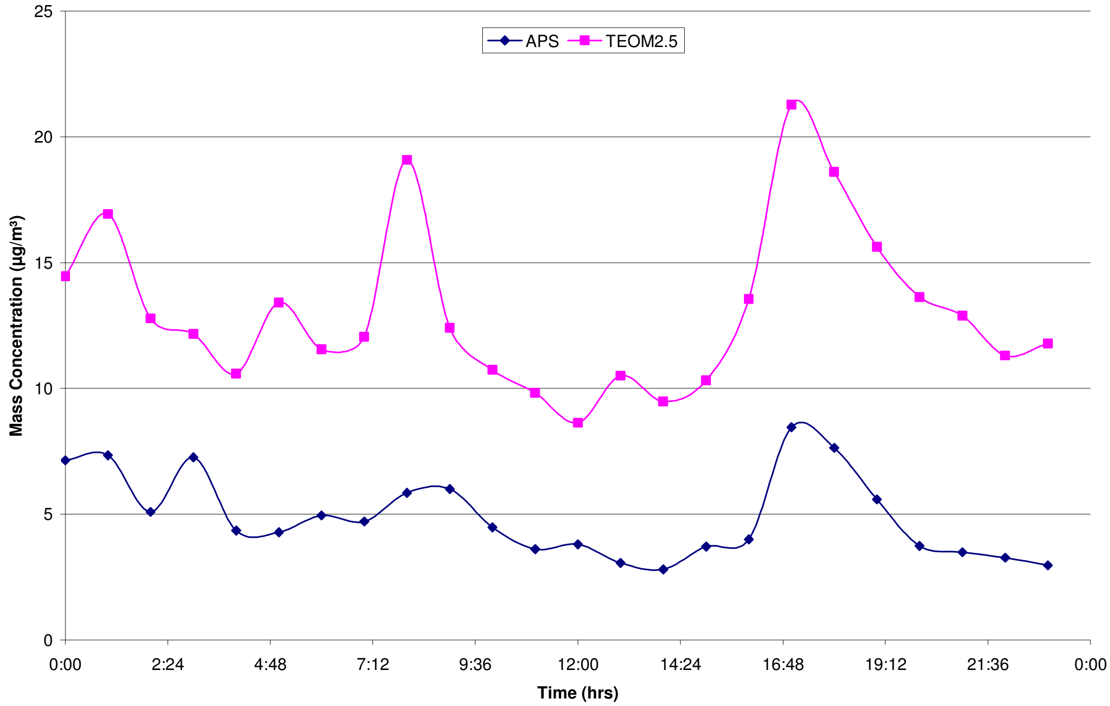
Daily Mass Concentration Comparison of $PM_{2.5}$ for TEOM10 and APS data for October 26 through November 9, 2008

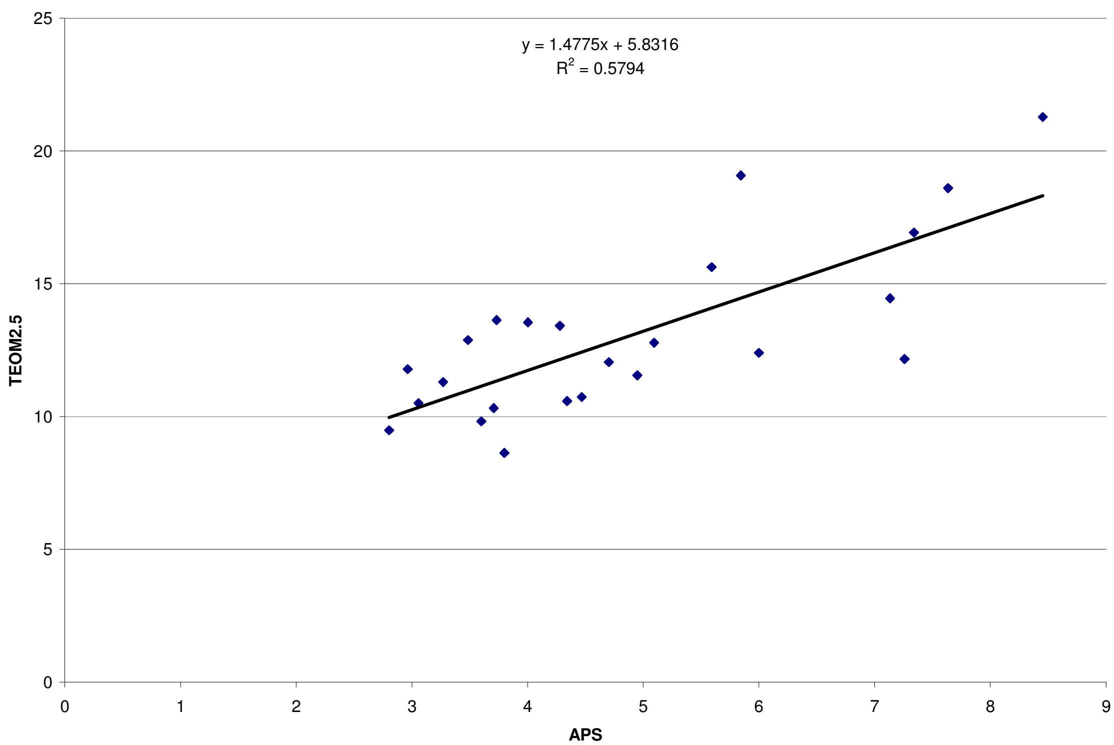
October 26, 2008



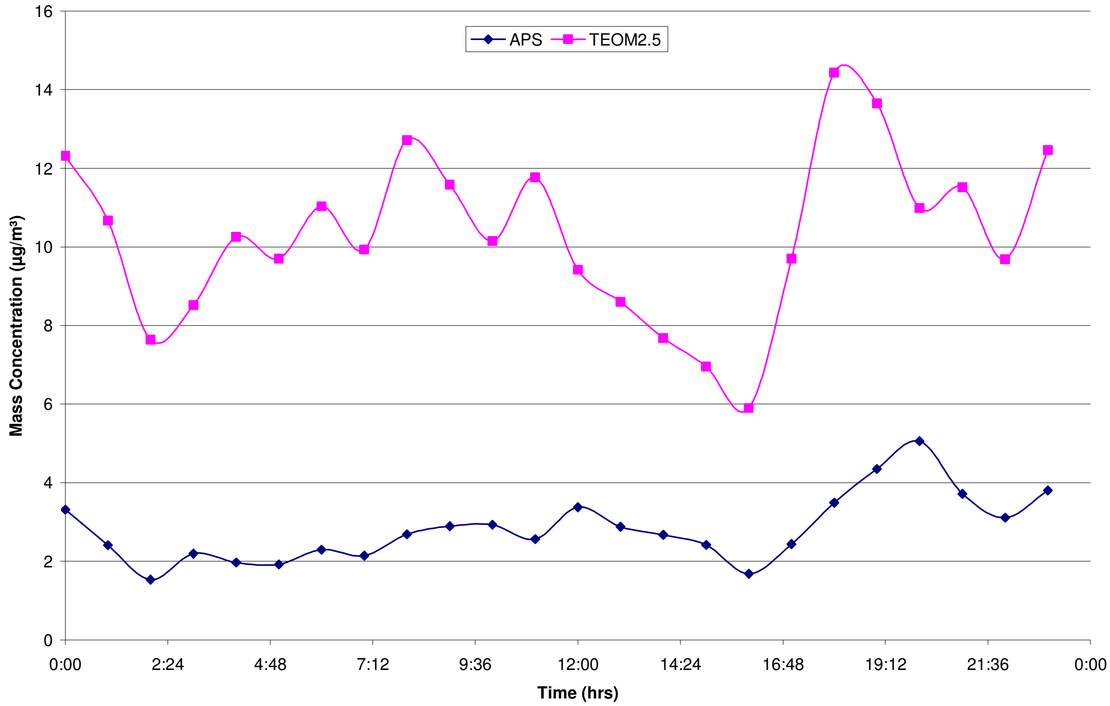


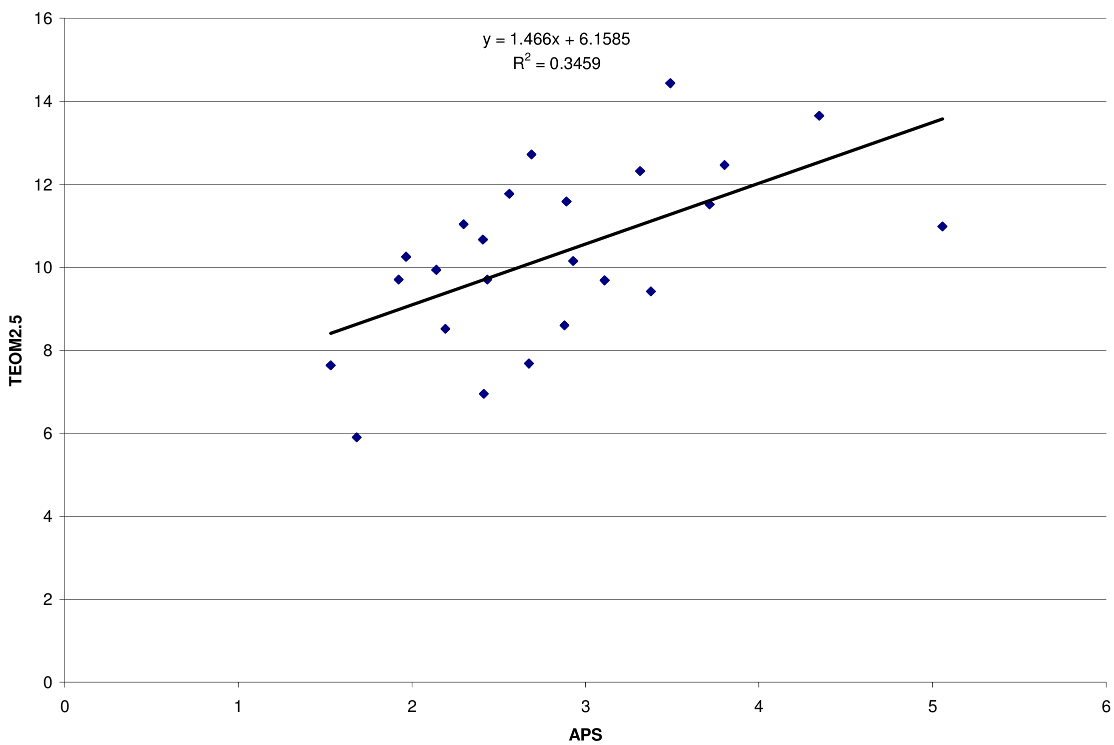
October 27, 2008



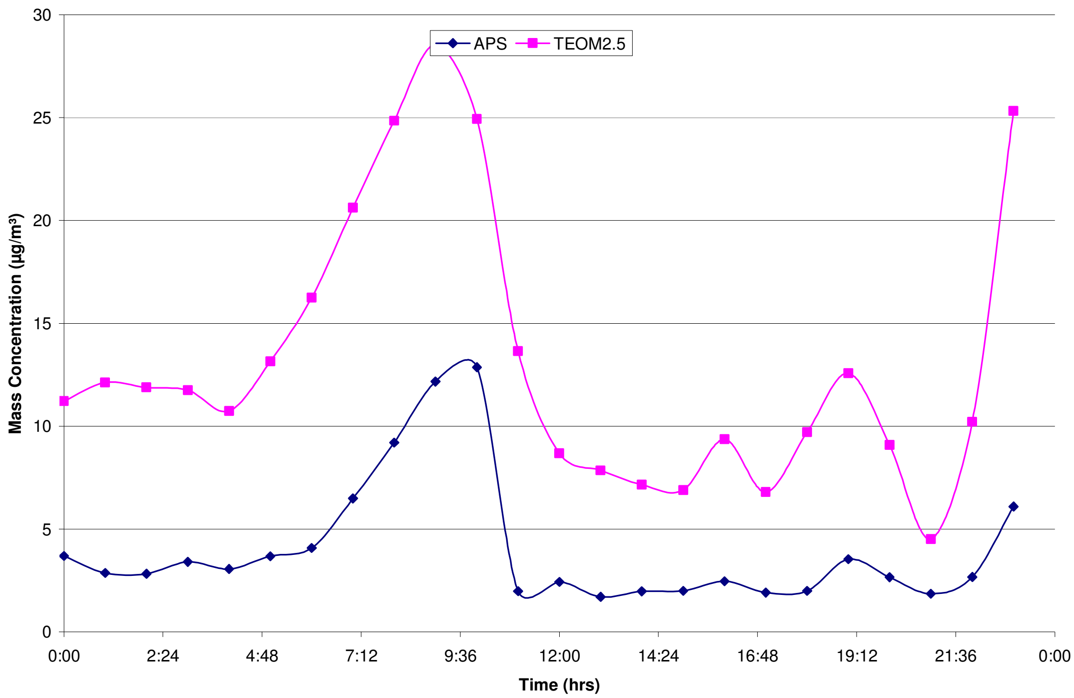


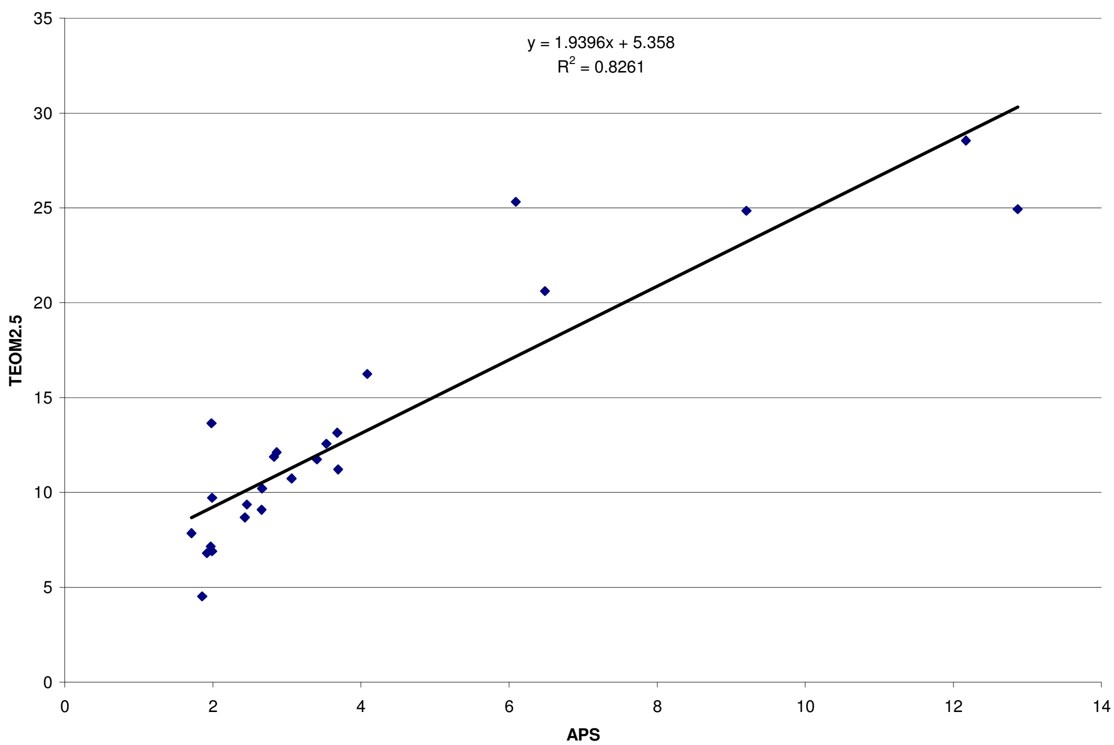
October 28, 2008



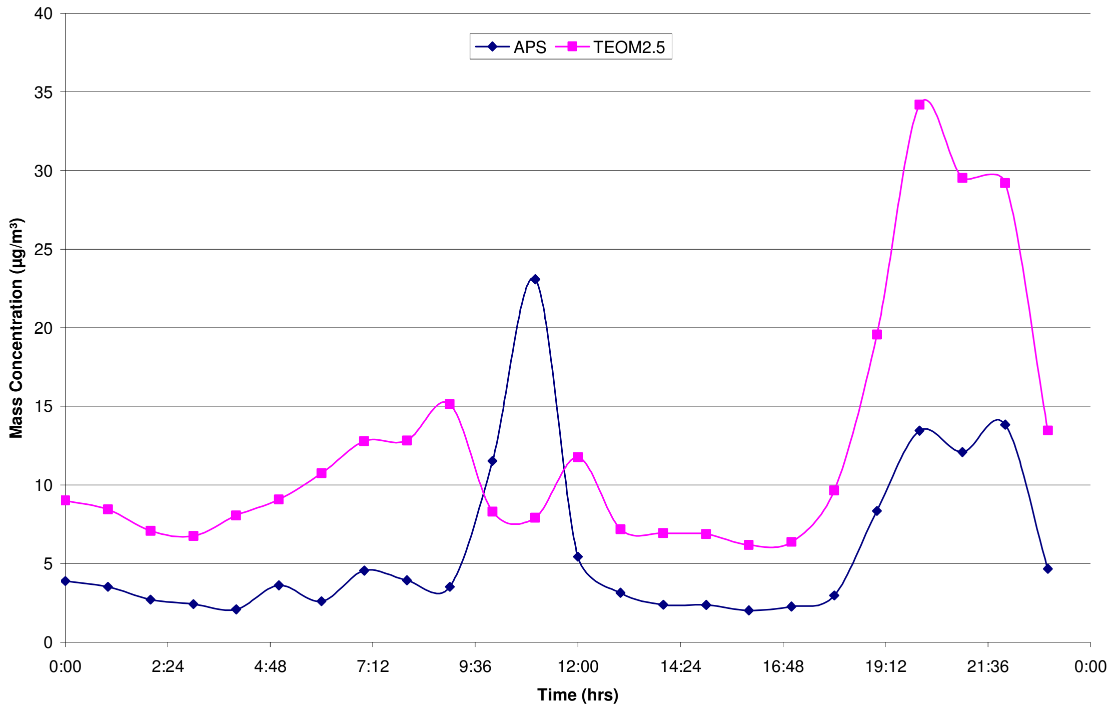


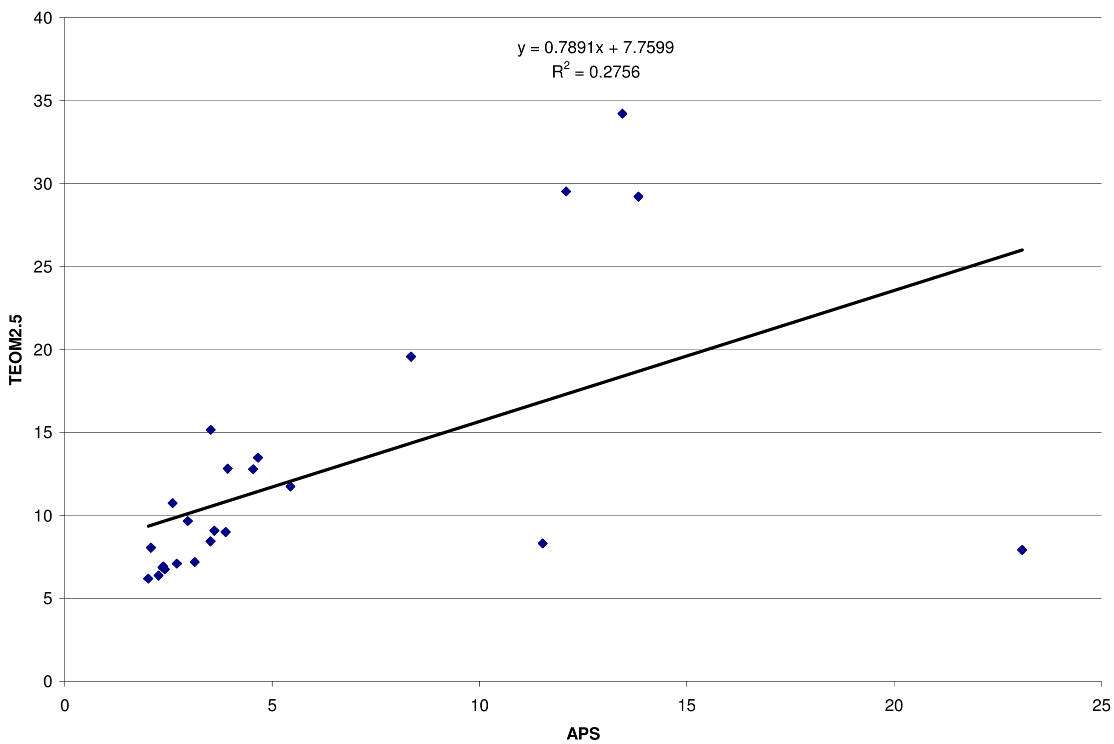
October 29, 2008



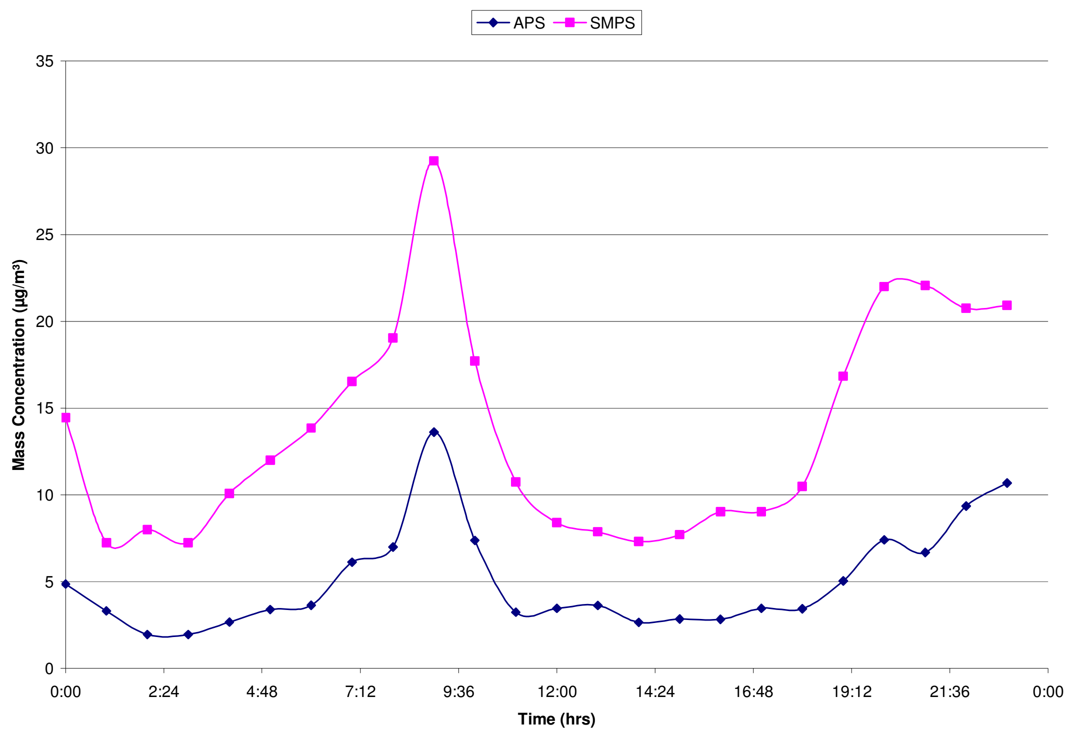


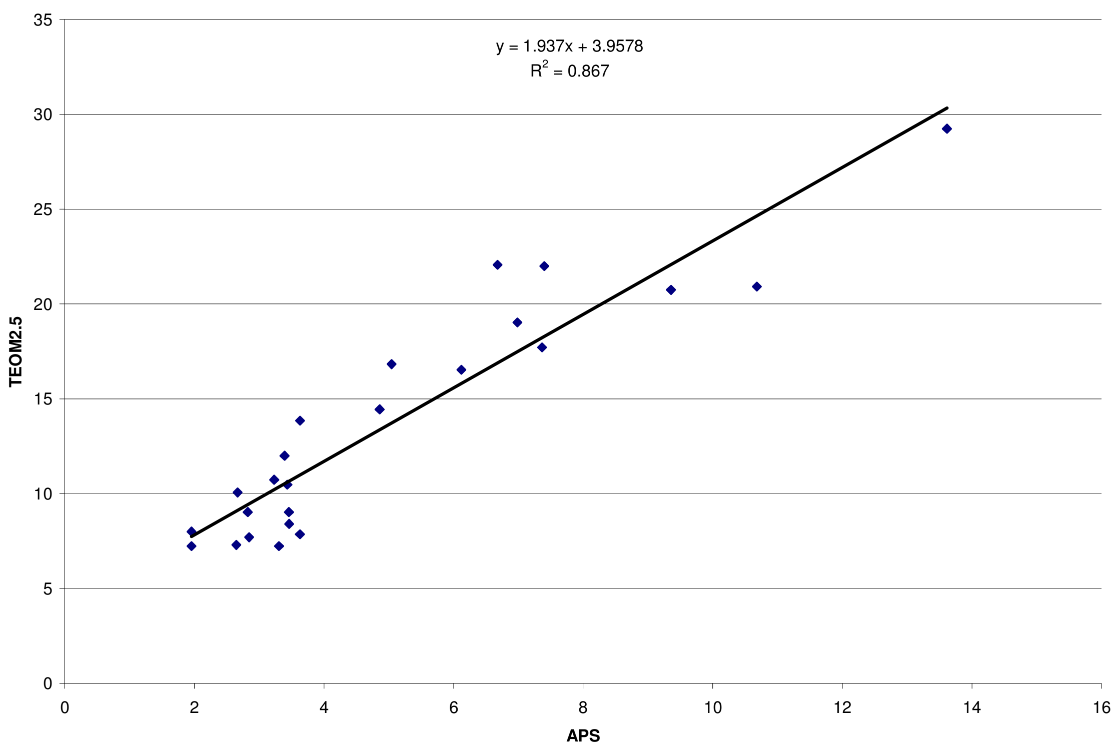
October 30, 2008



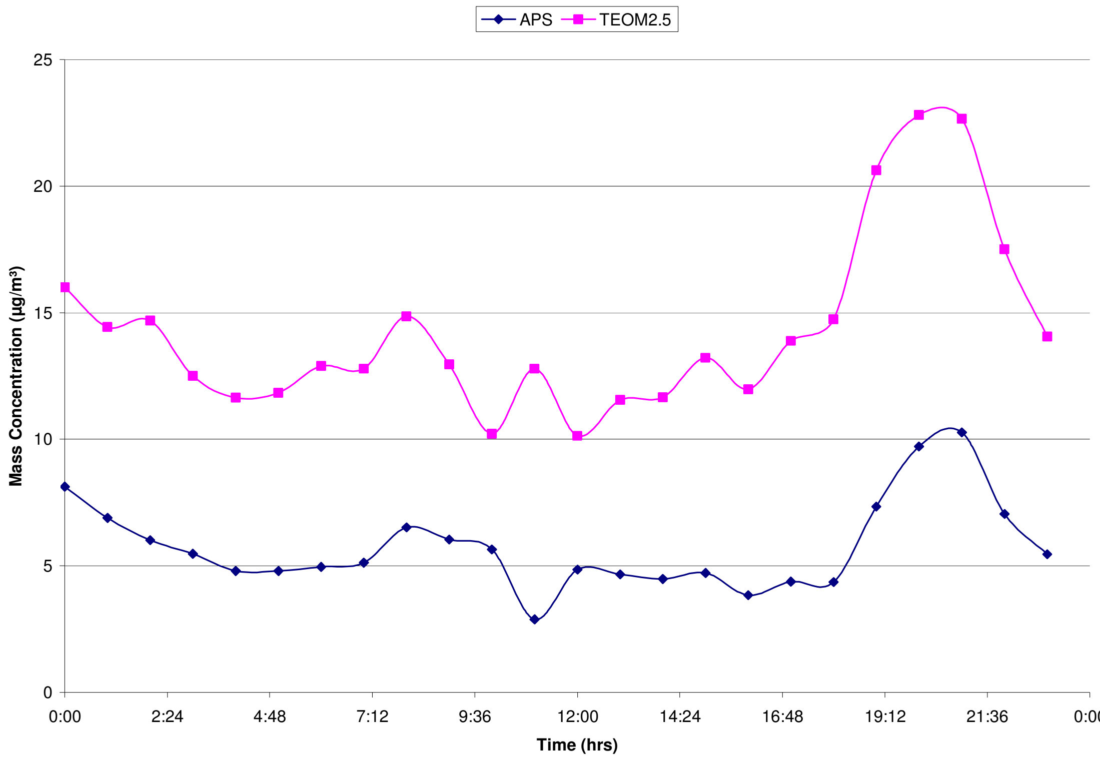


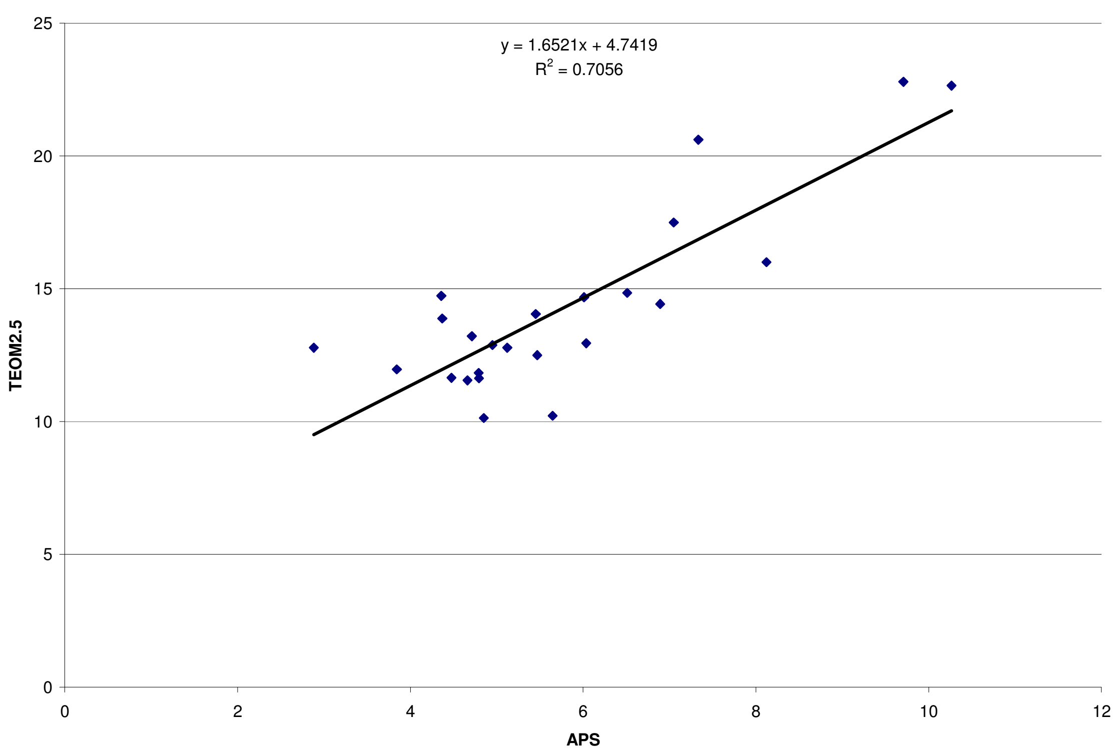
October 31, 2008



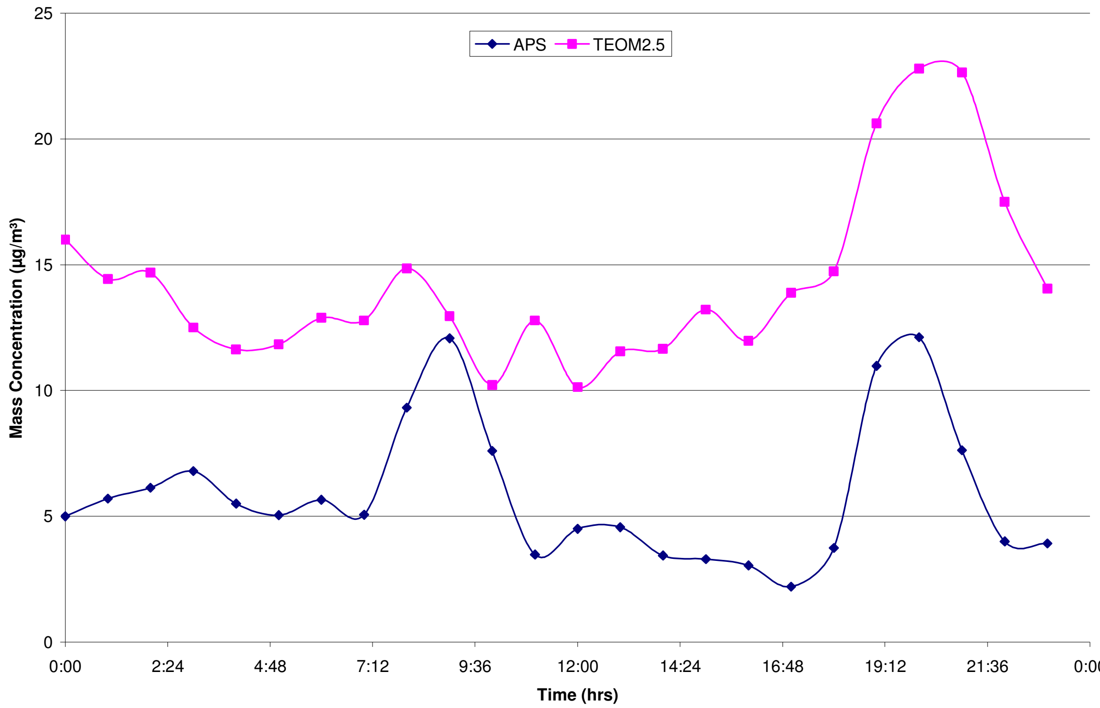


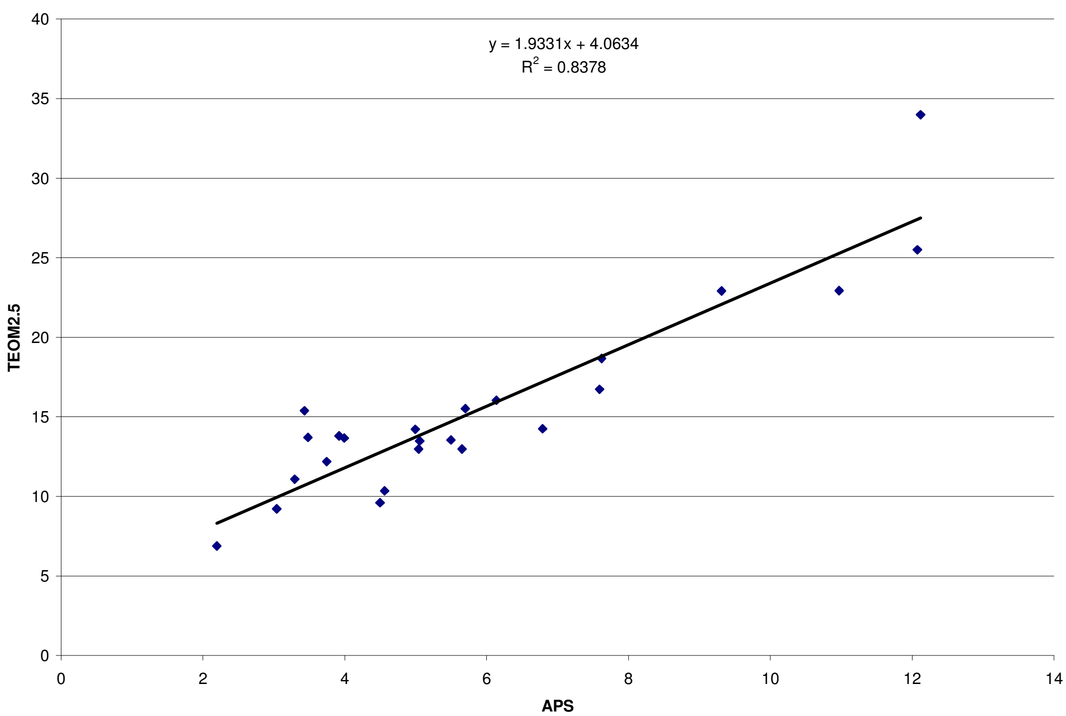
November 1, 2008



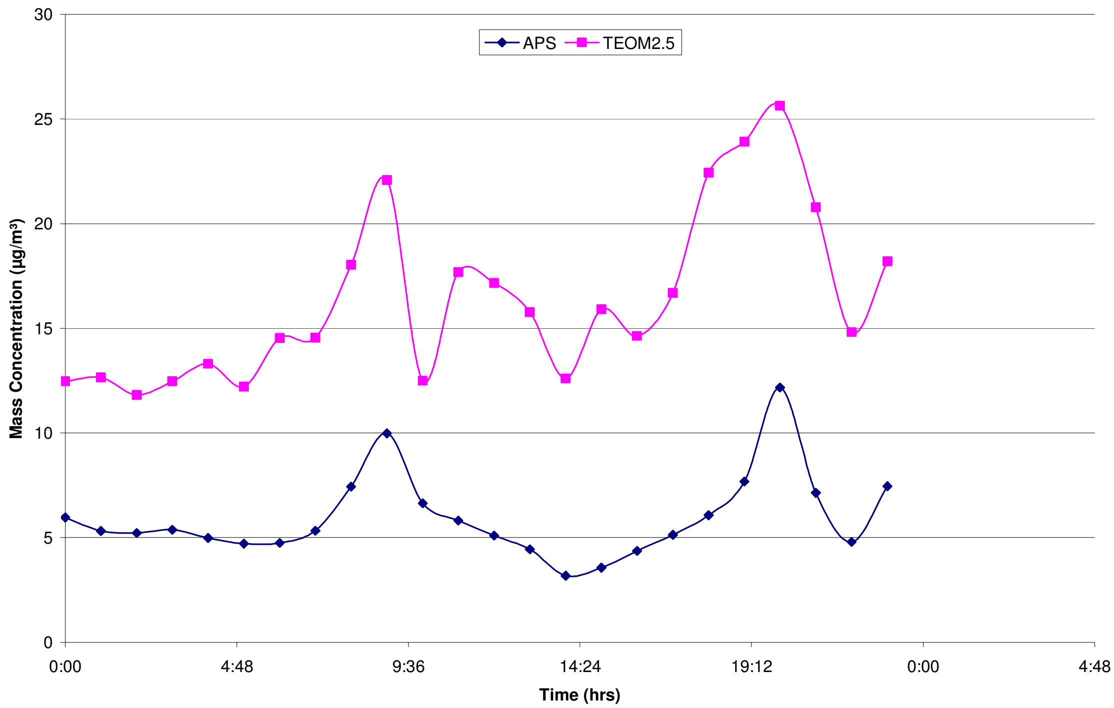


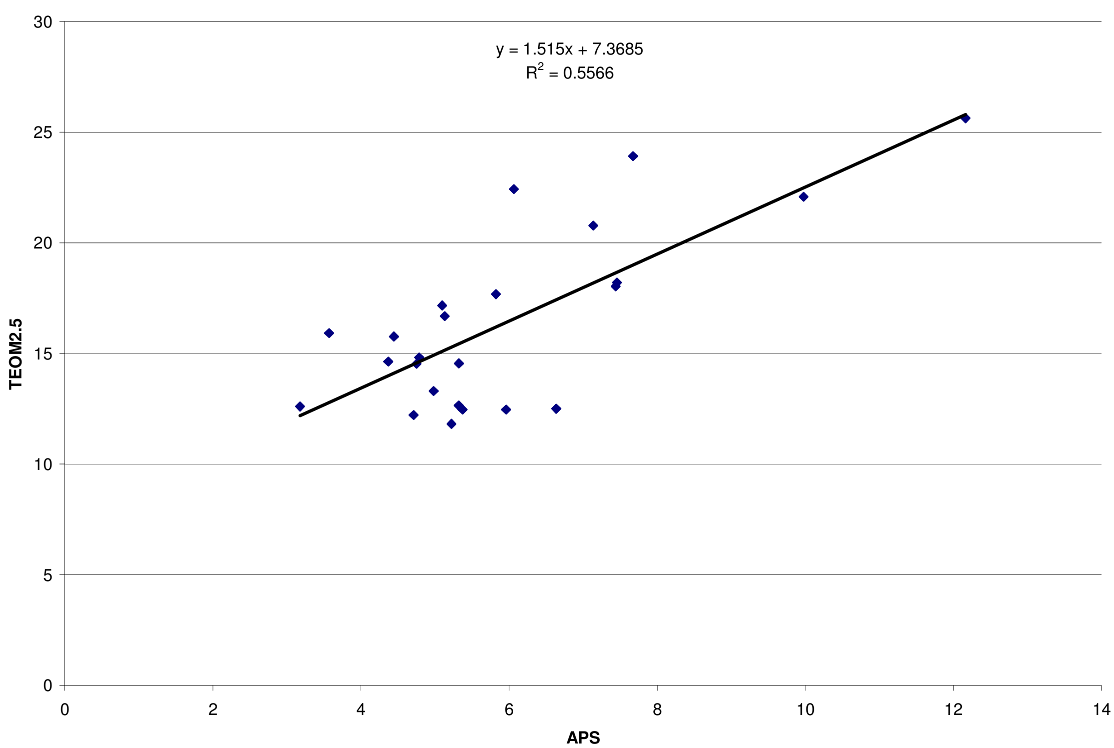
November 2, 2008



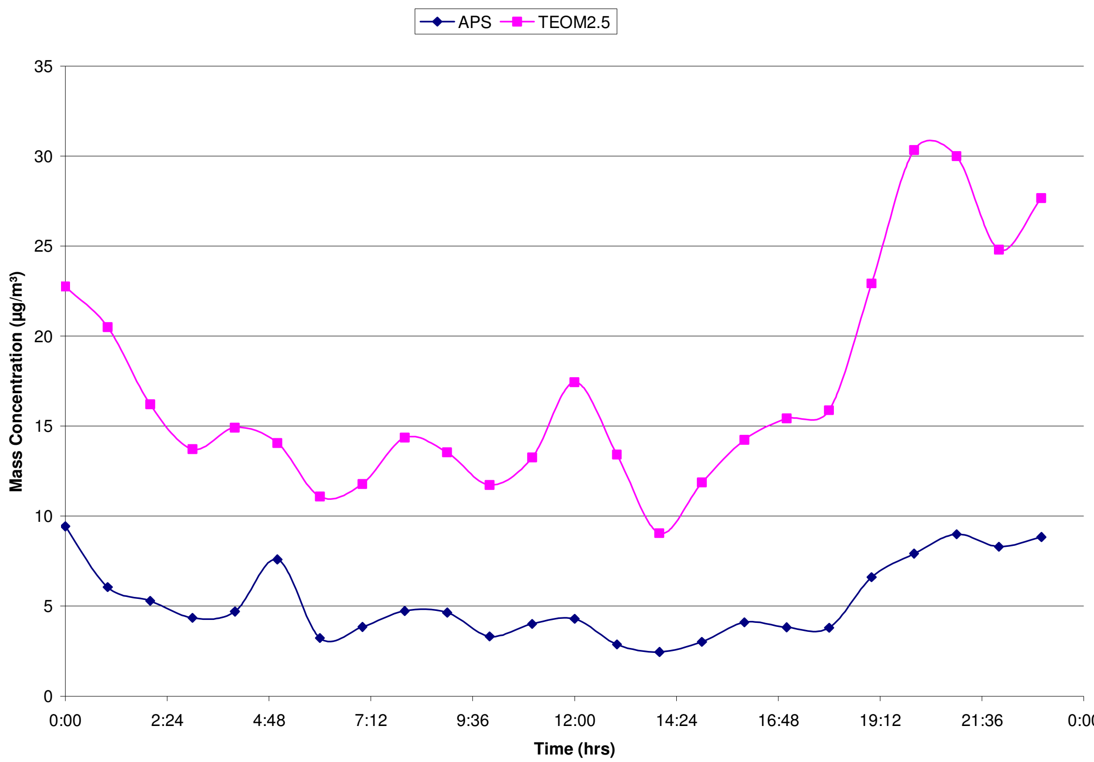


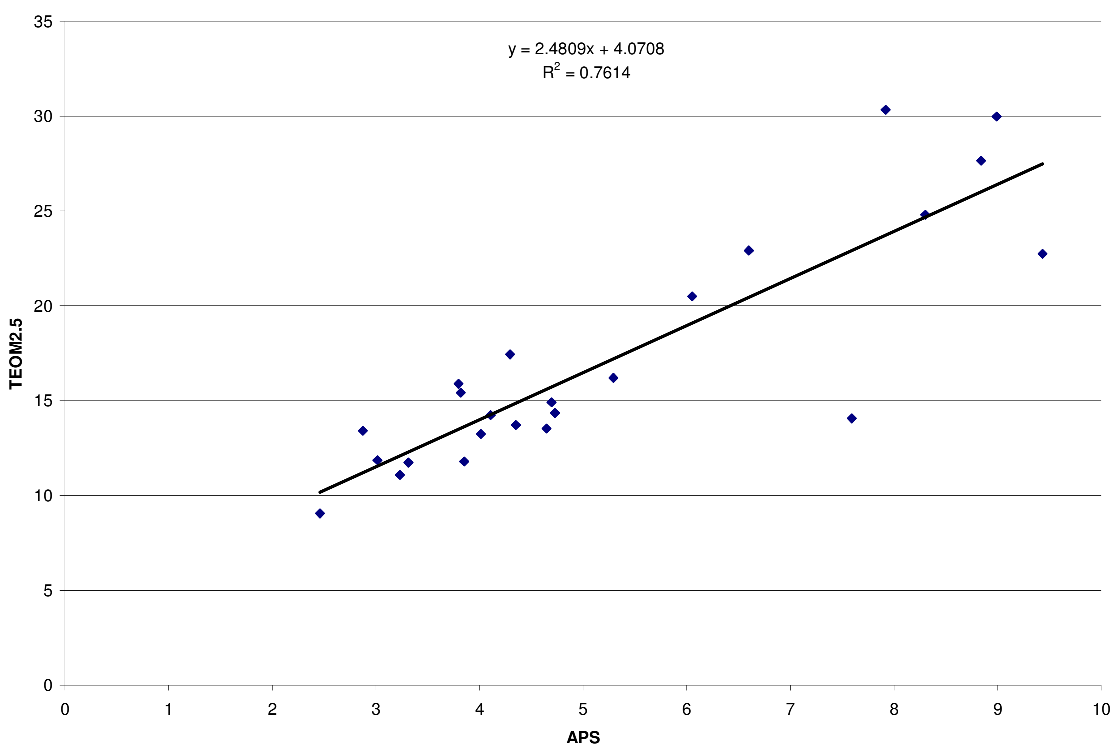
November 3, 2008



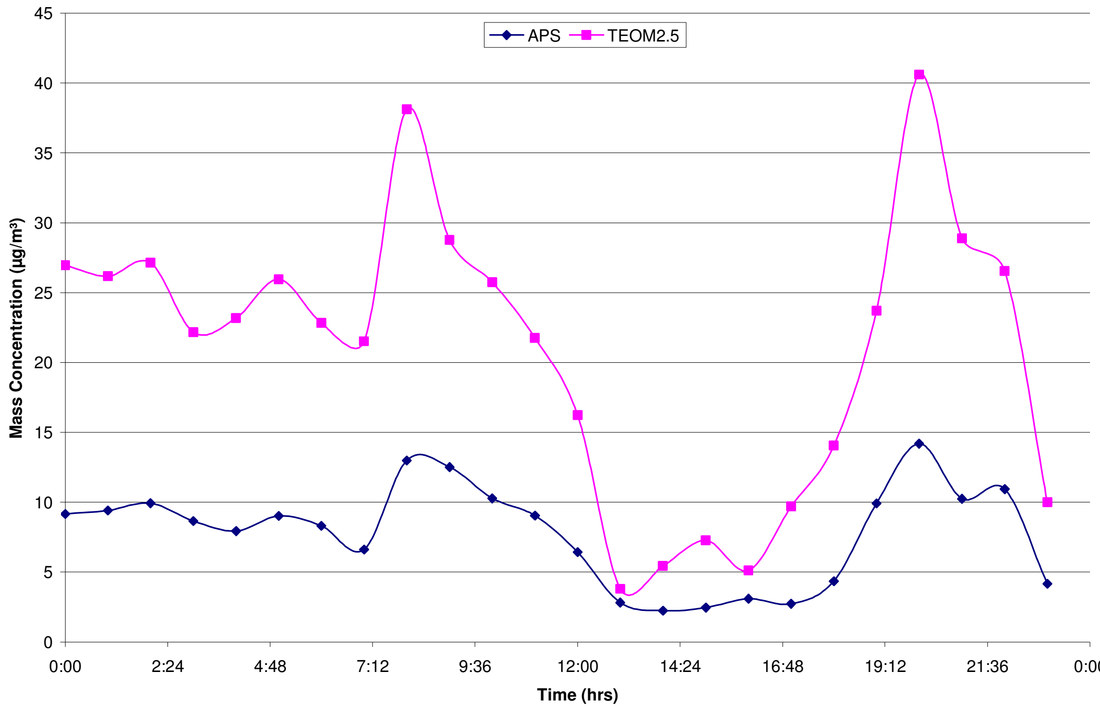


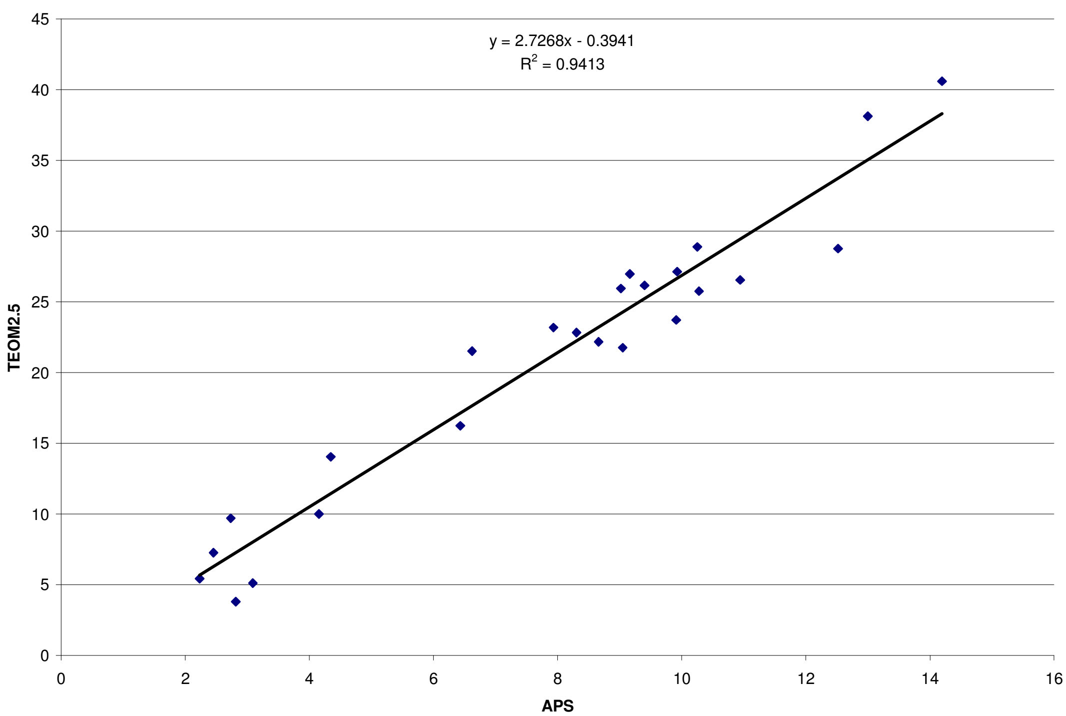
November 4, 2008



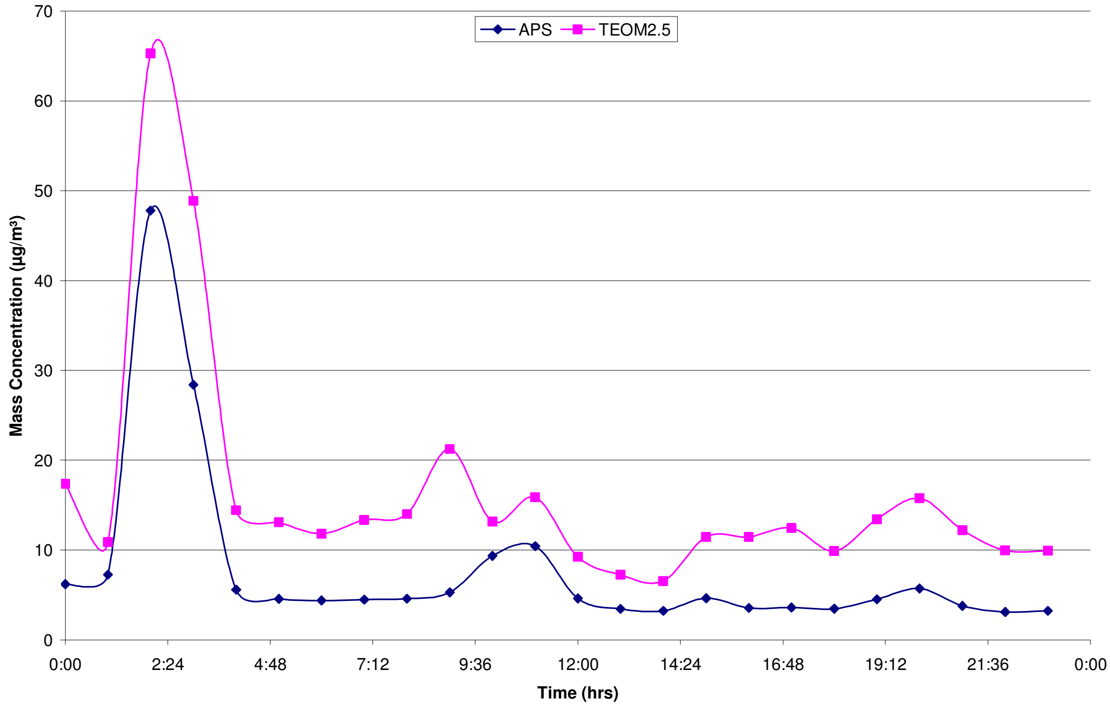


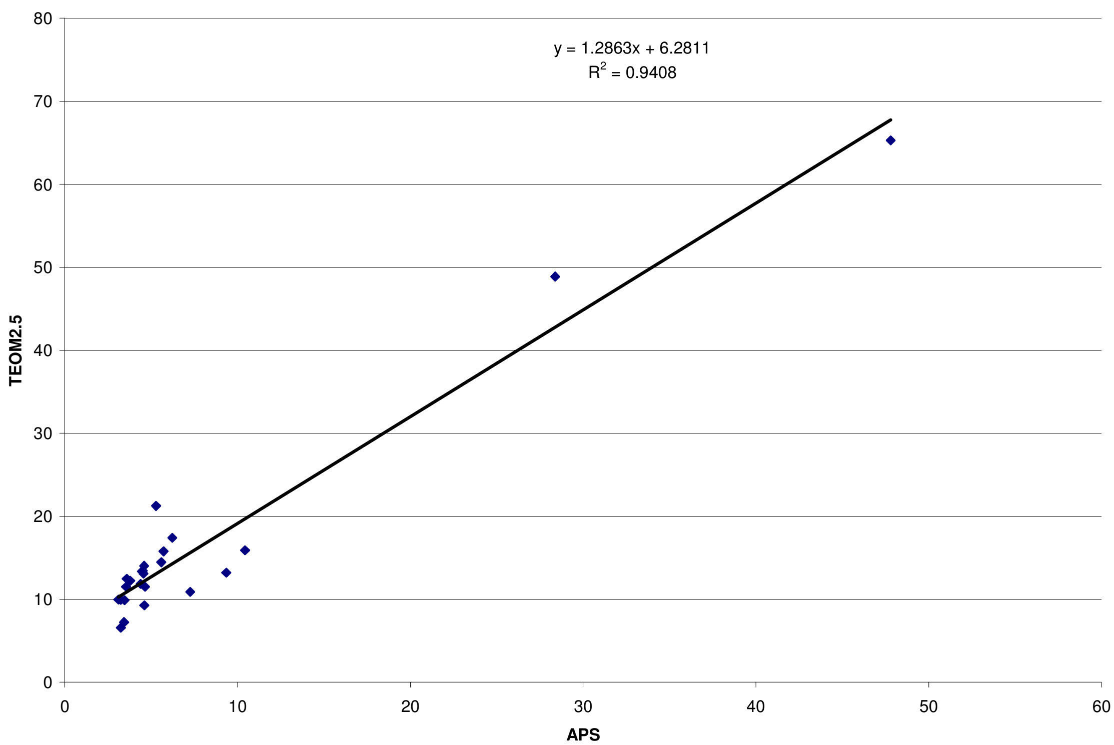
November 5, 2008



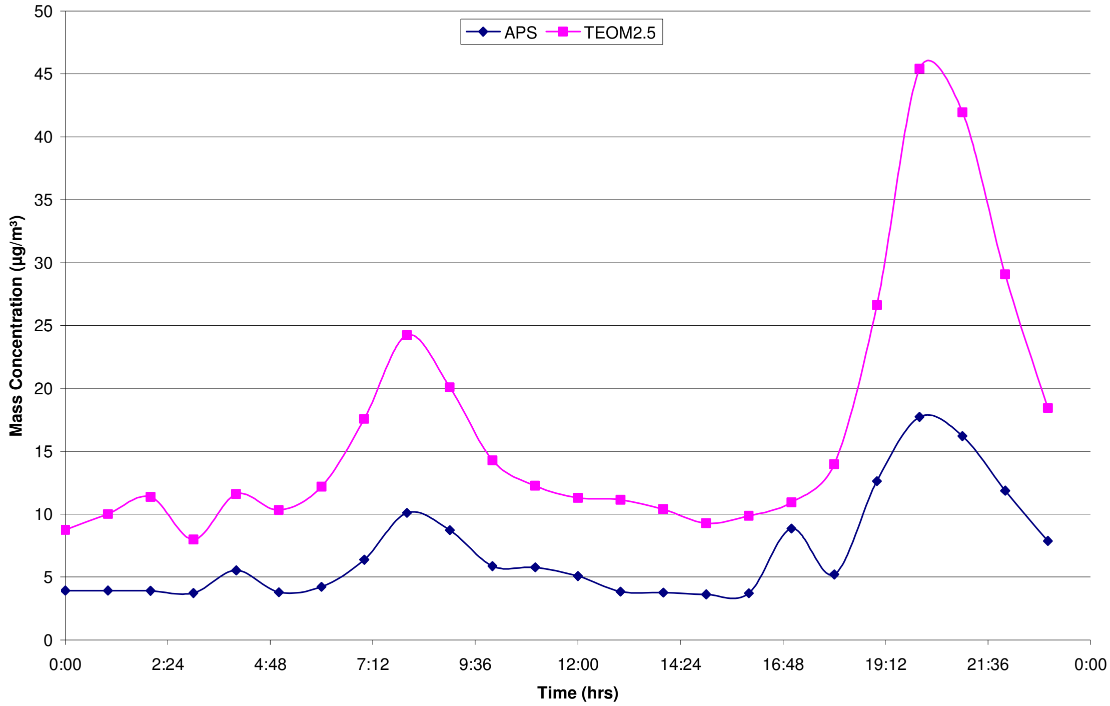


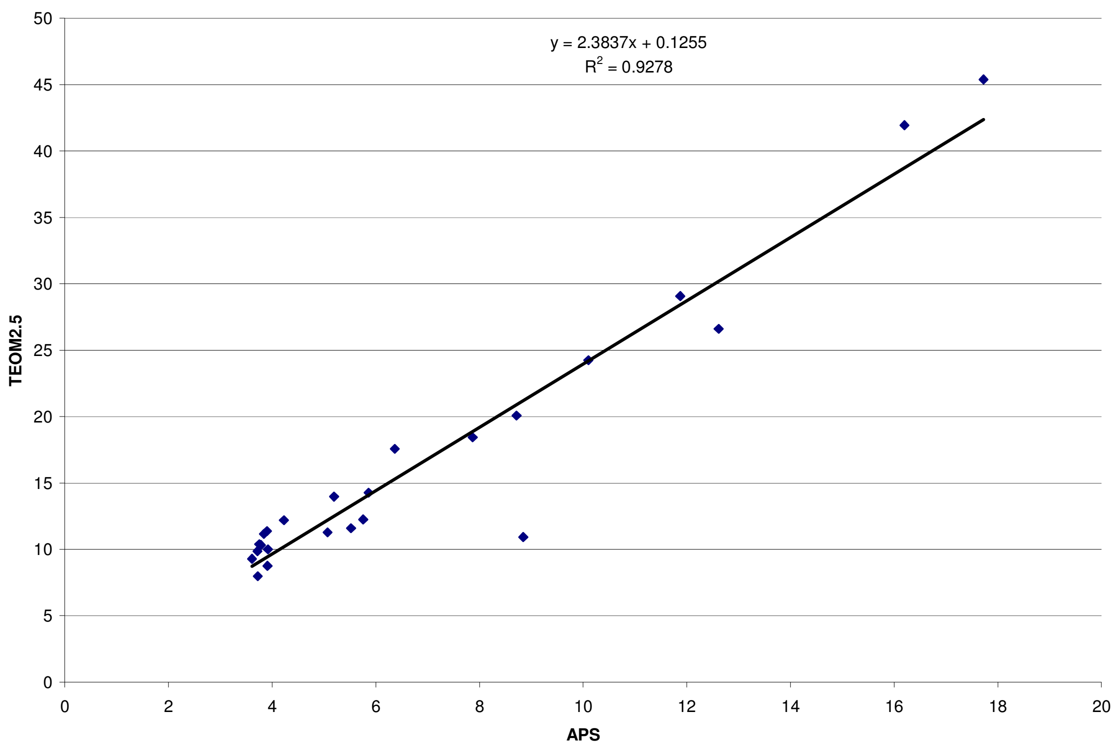
November 6, 2008



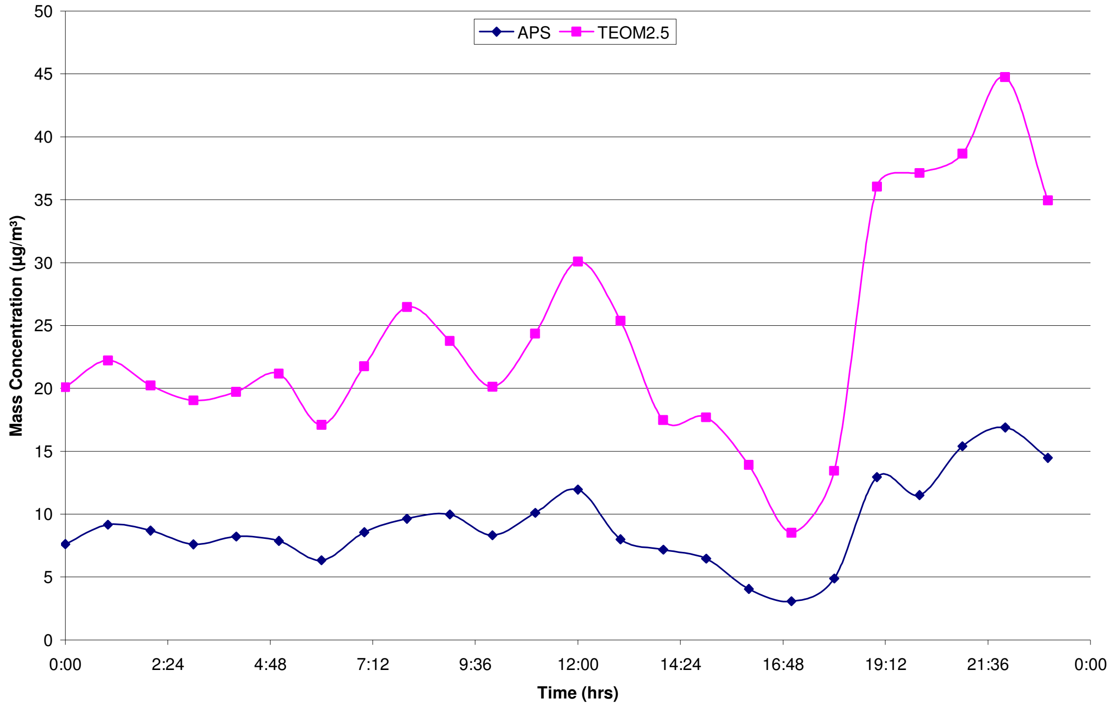


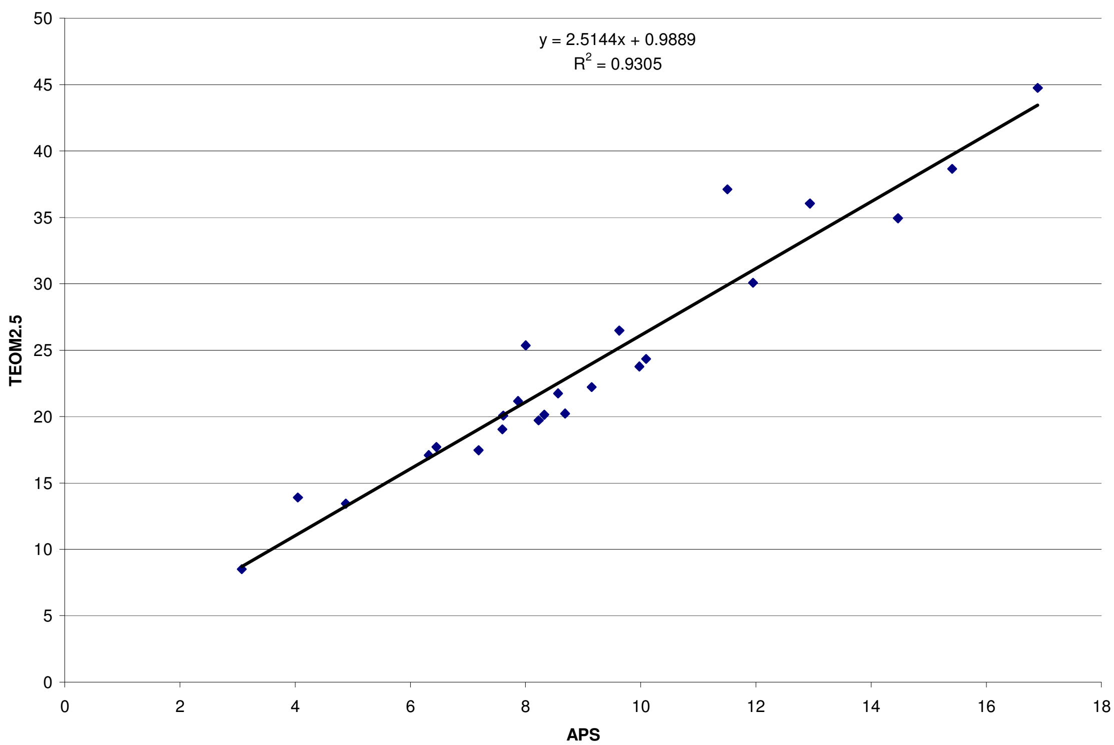
November 7, 2008



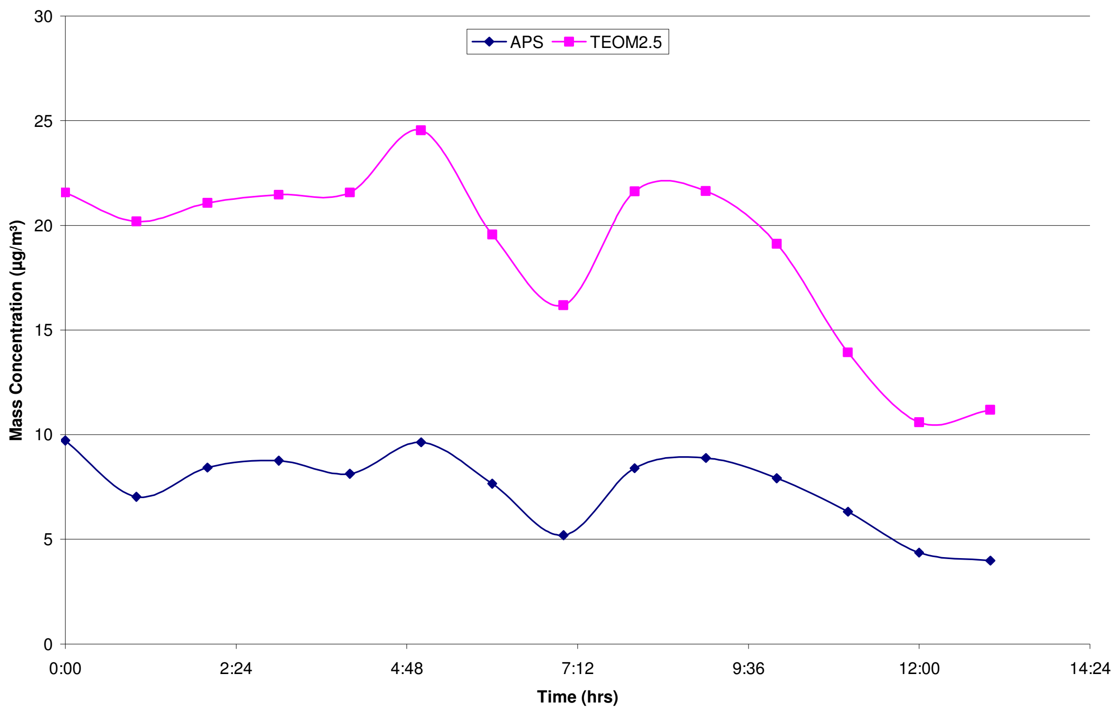


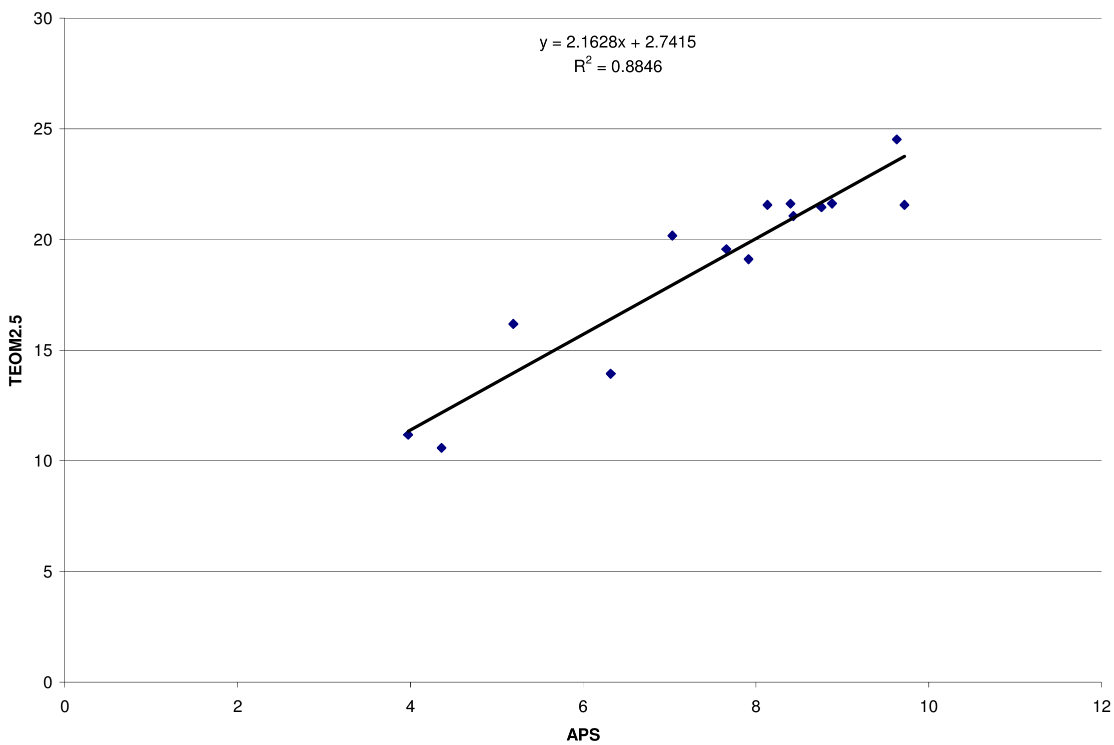
November 8, 2008





November 9, 2008

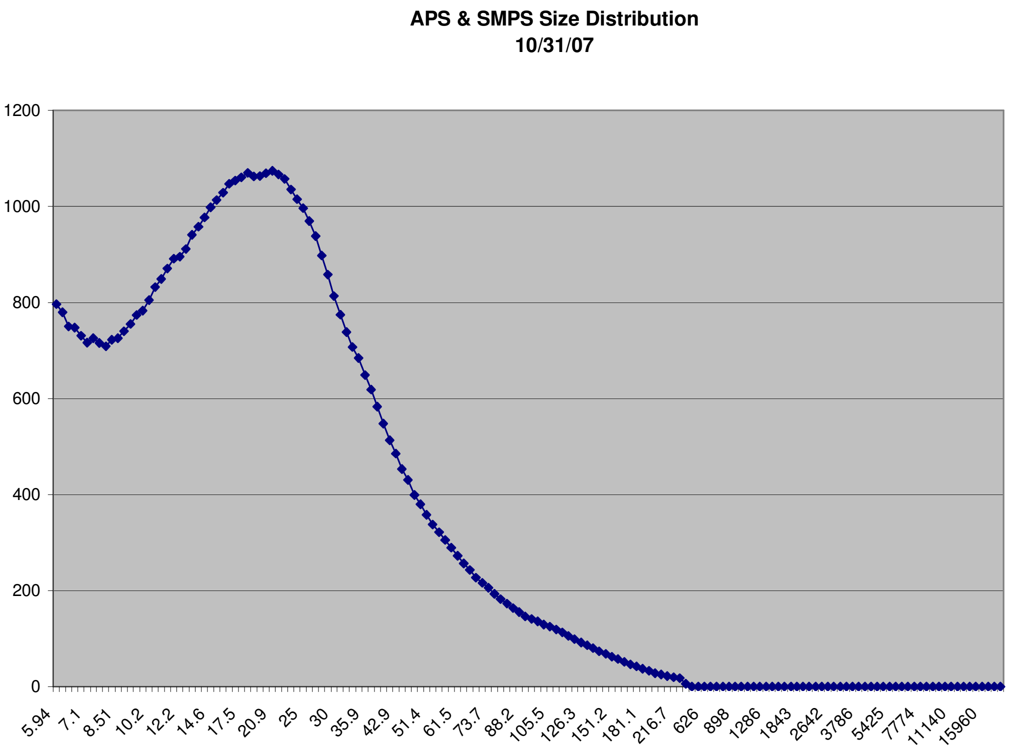


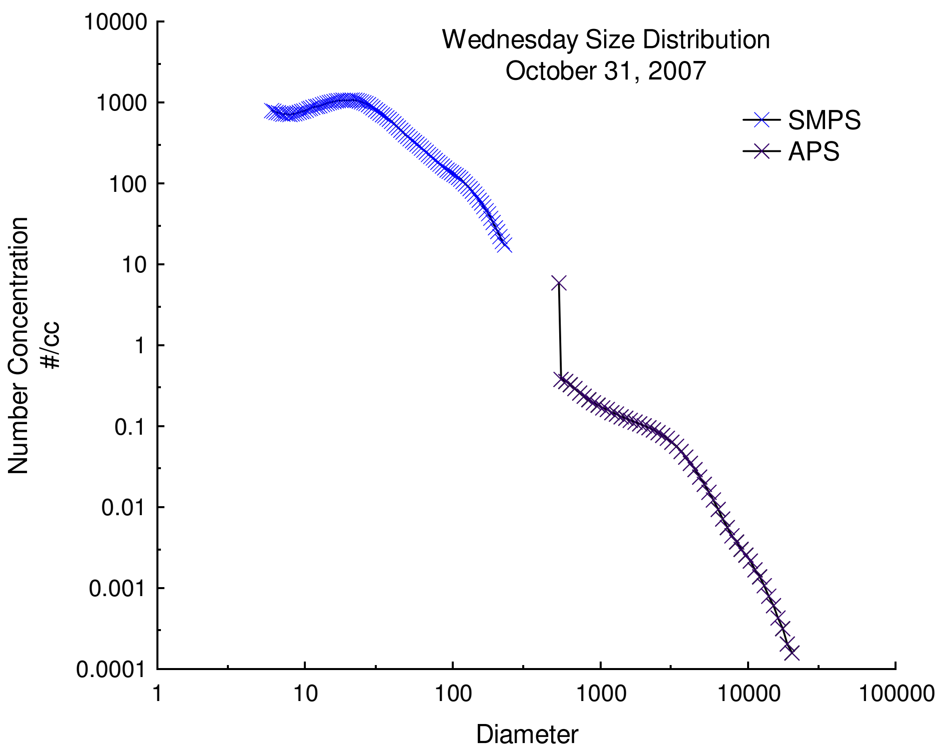


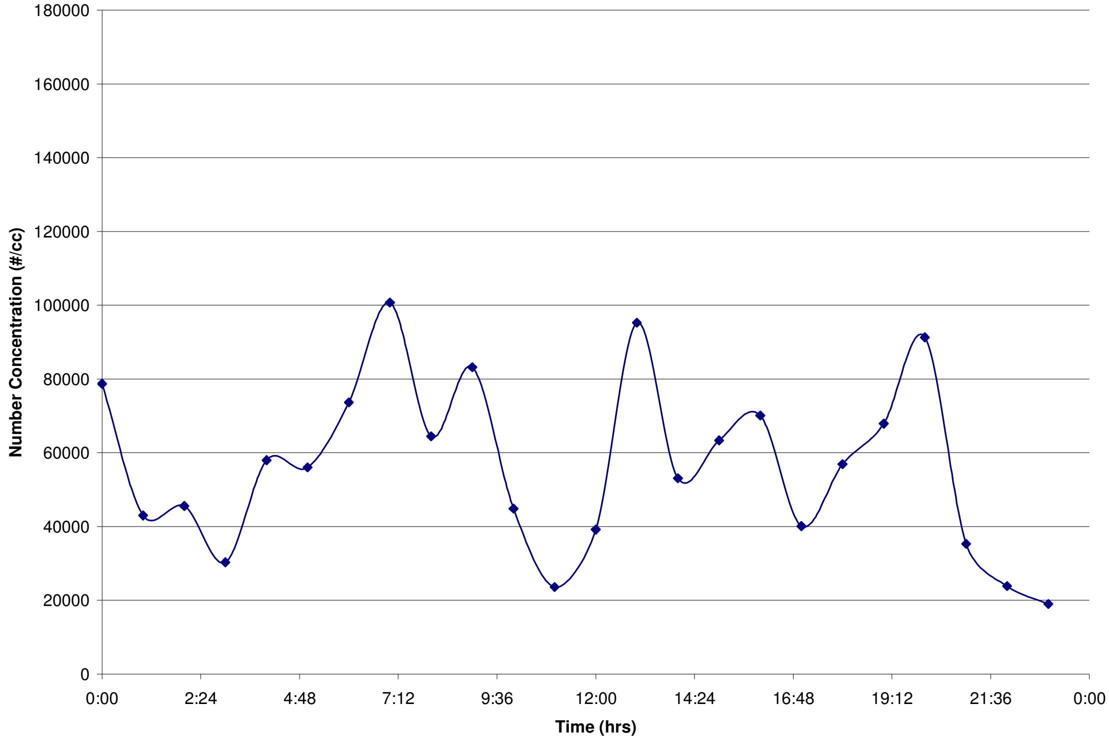
Appendix C

Daily Size Distribution Transition and Number Concentration Comparison for SMPS & APS for October 31 to November 9, 2008

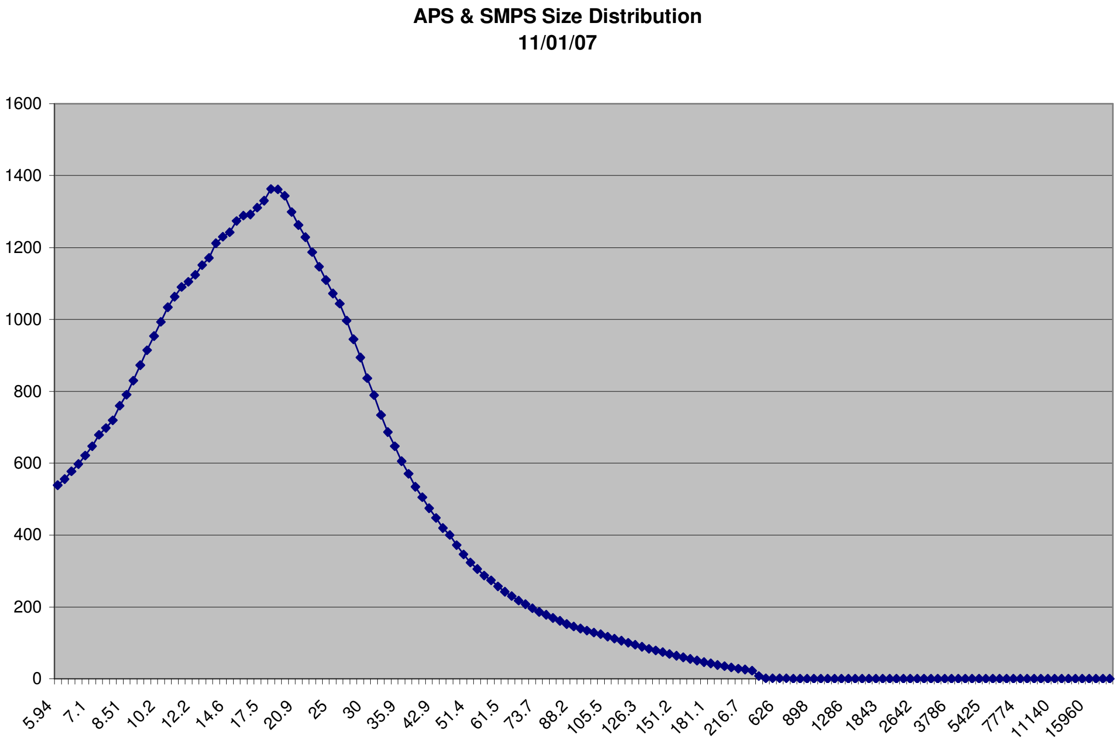
October 31, 2008

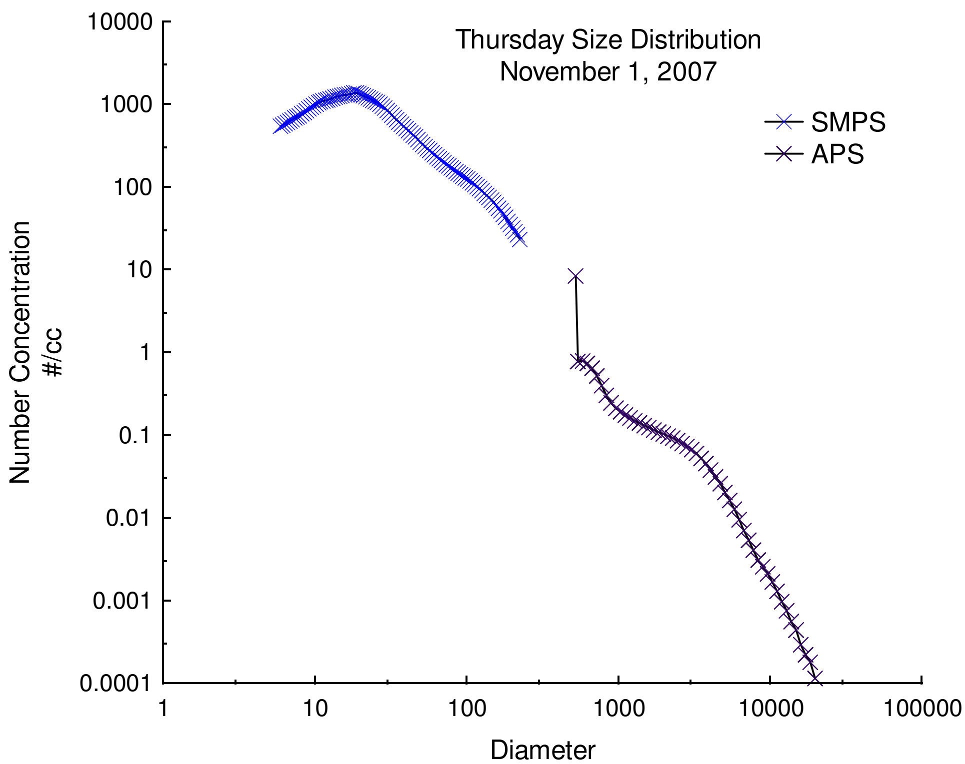


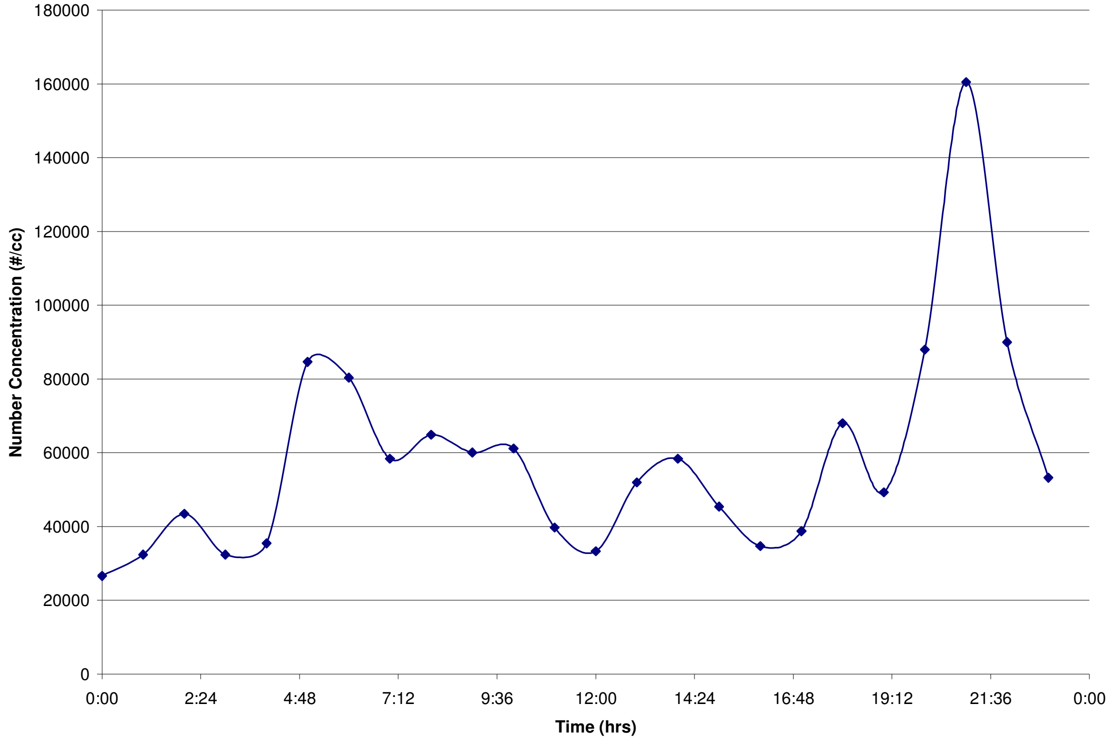



180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Number Concentration (#/cc)
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time (hrs)

November 1, 2008

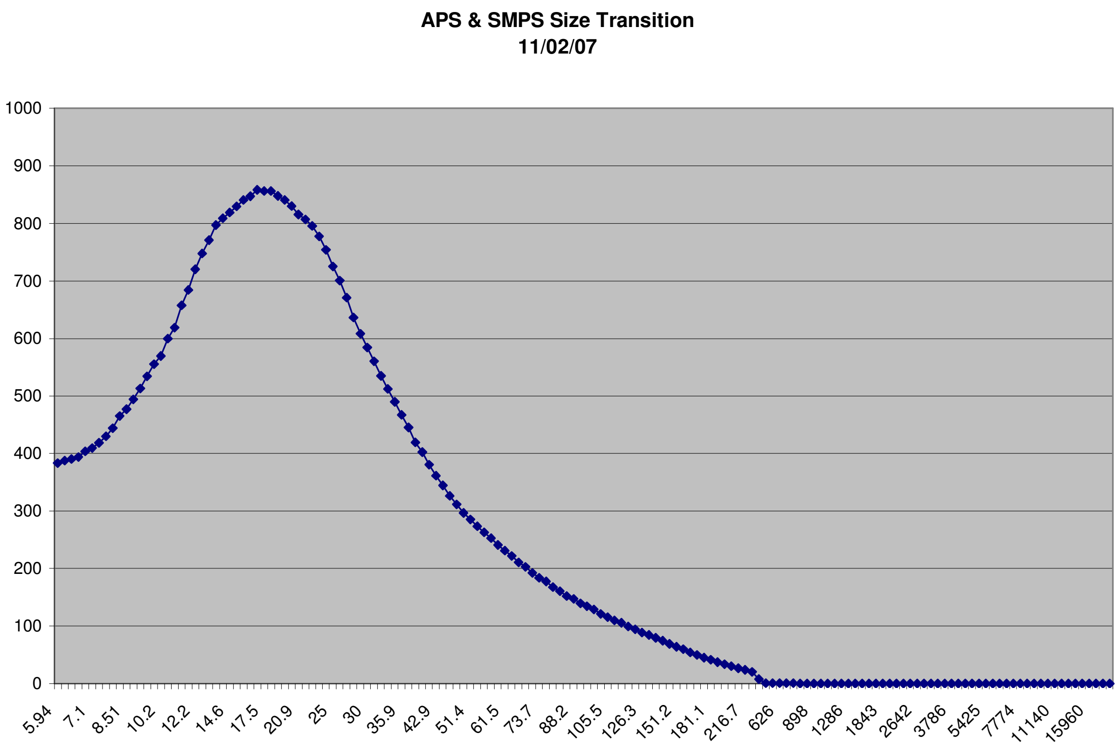


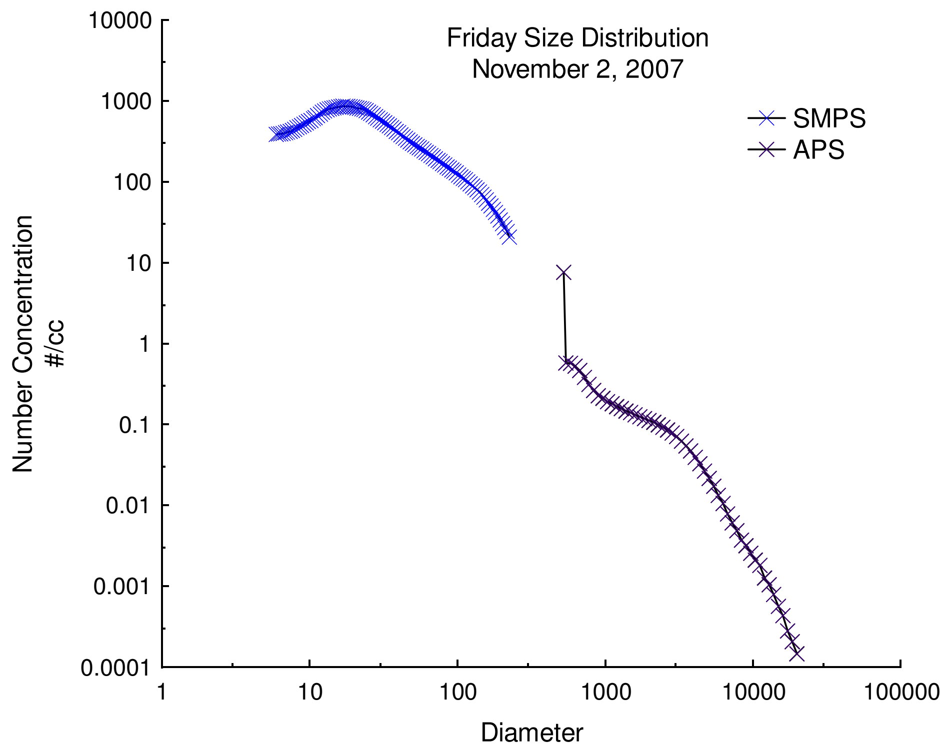


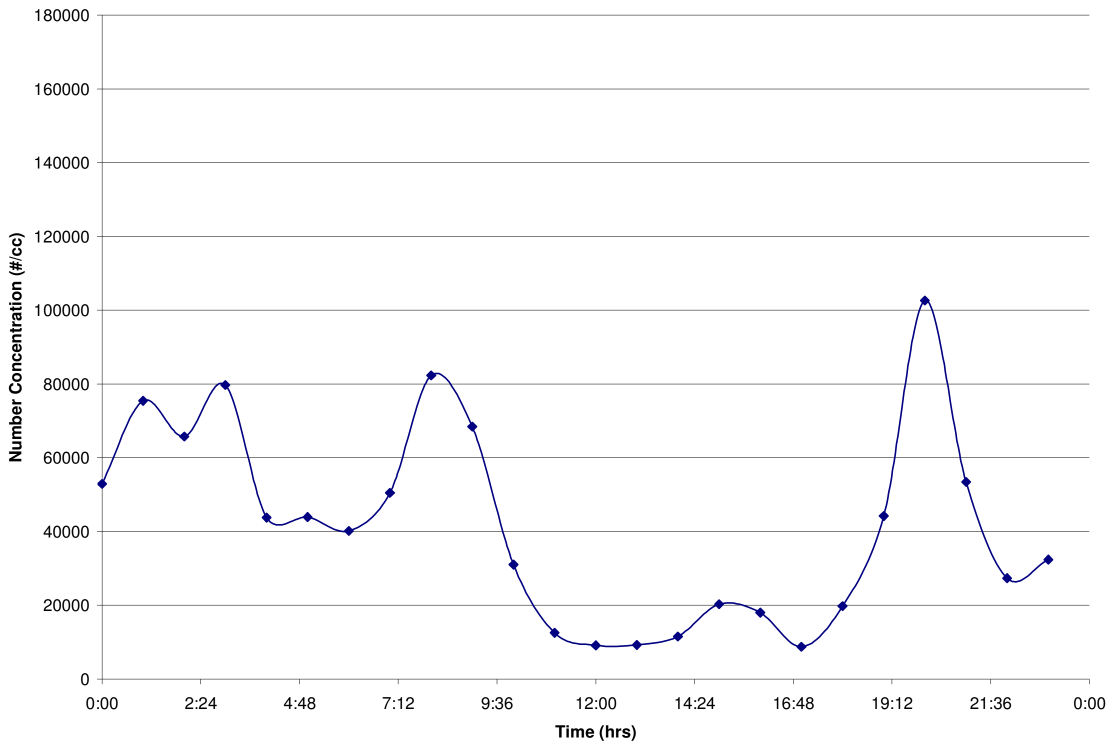


180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Number Concentration (#/cc)
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time (hrs)

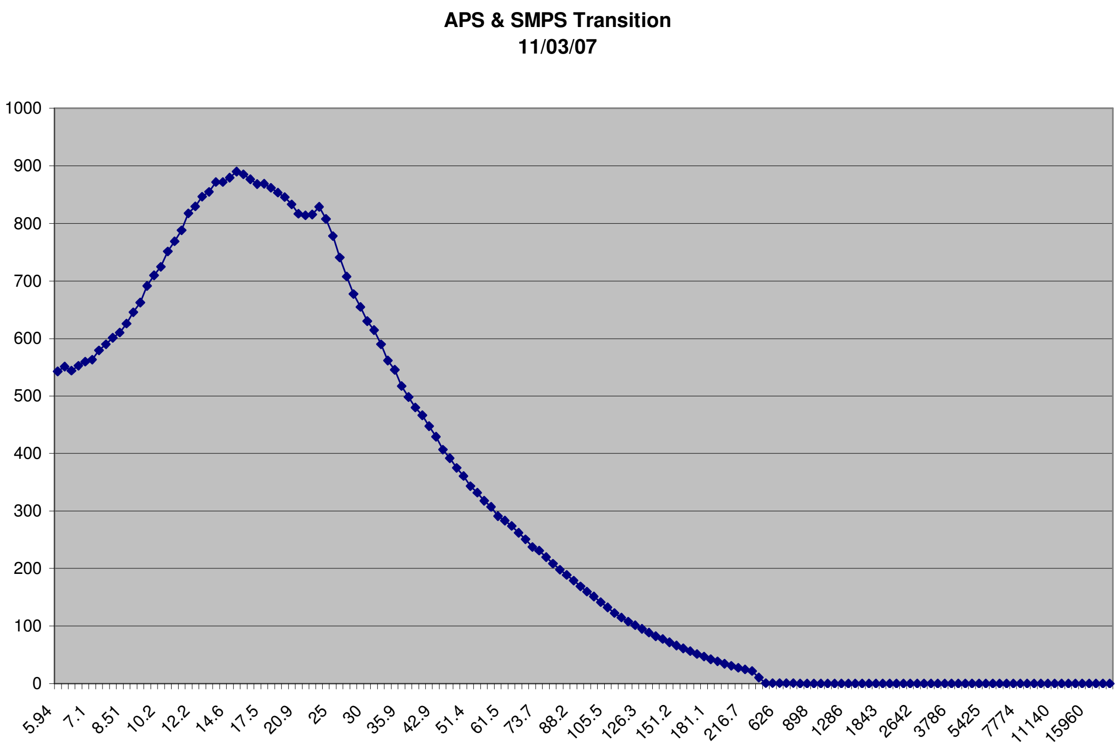
November 2, 2008

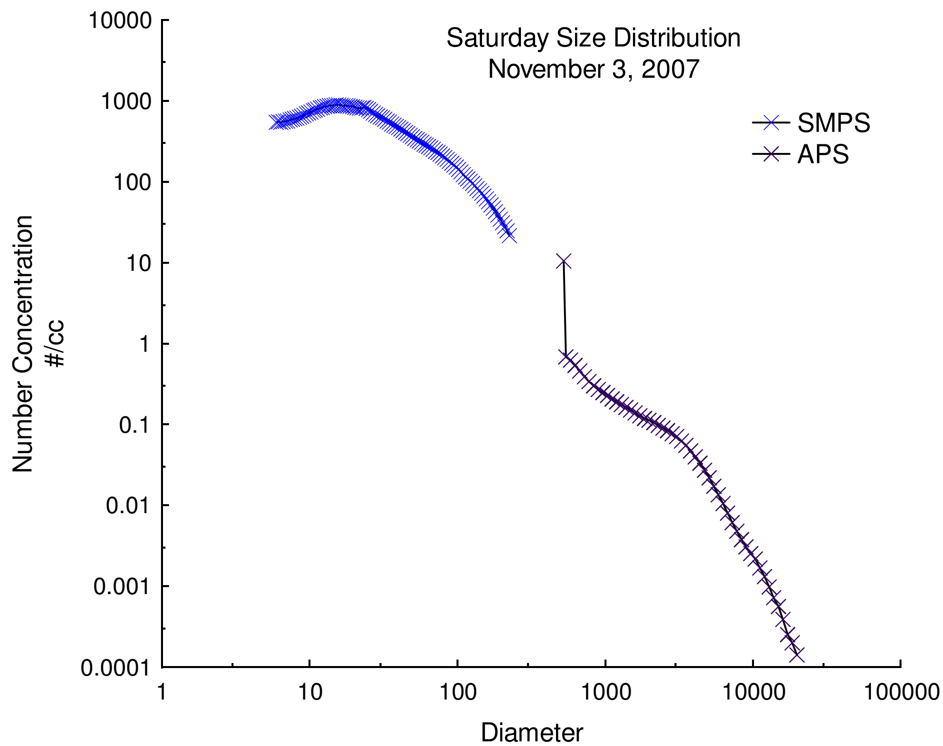


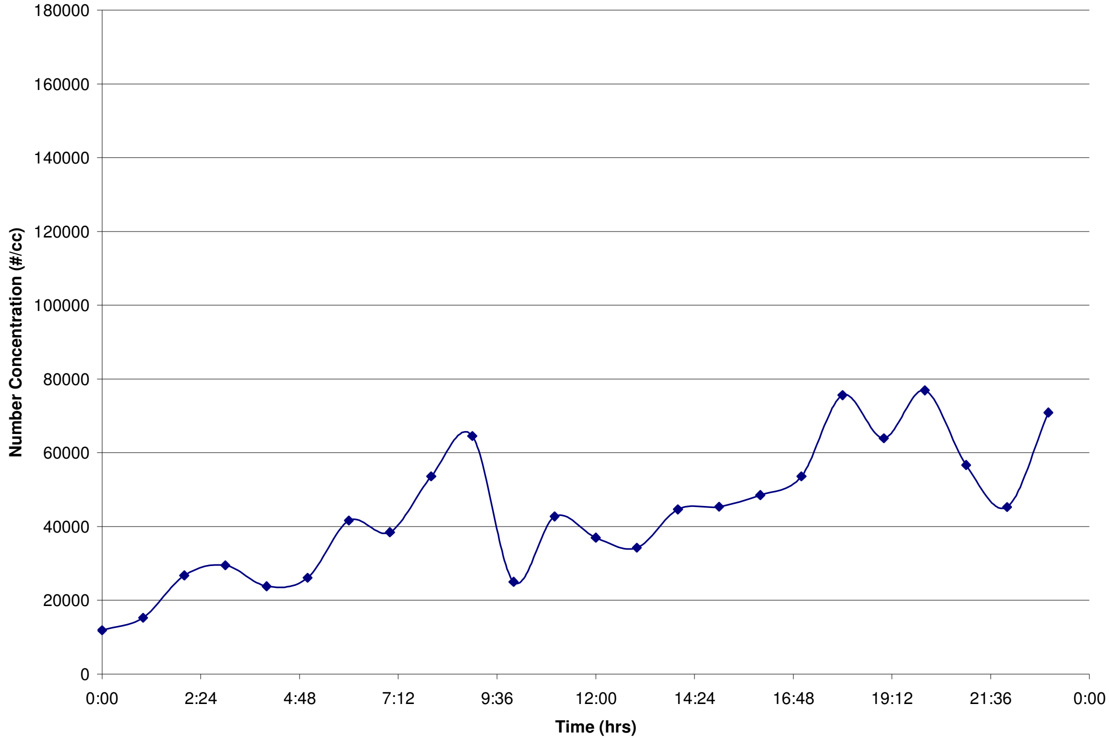



180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Number Concentration (#/cc)
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time (hrs)

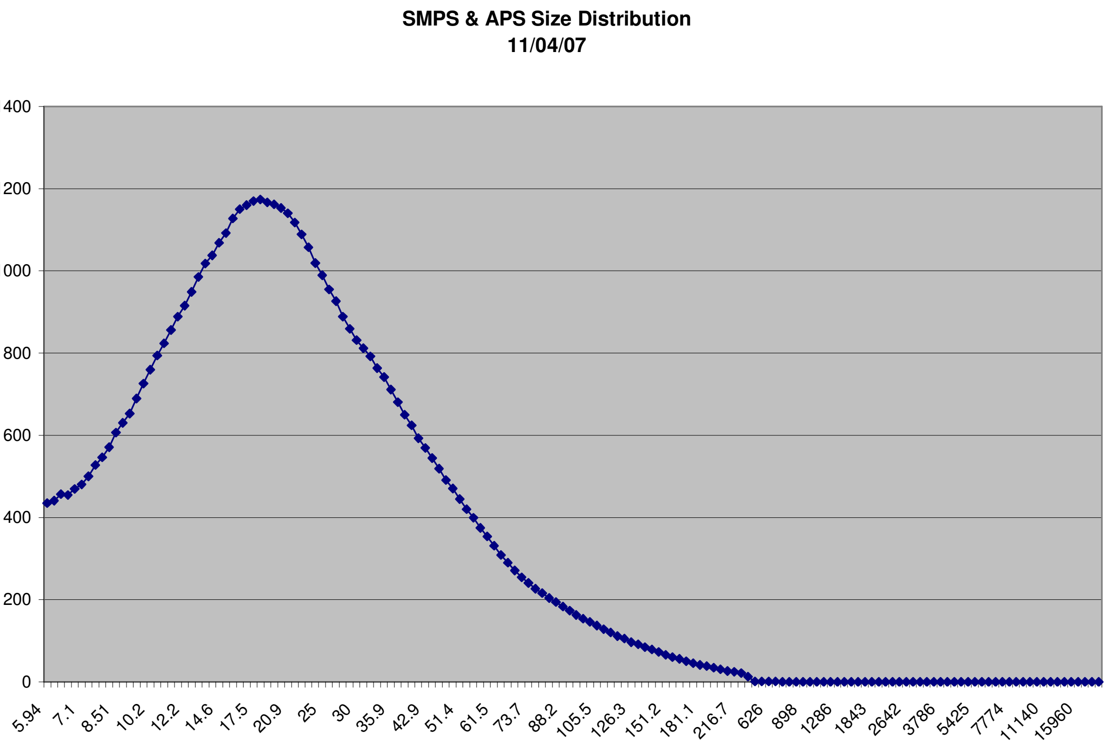
November 3, 2008

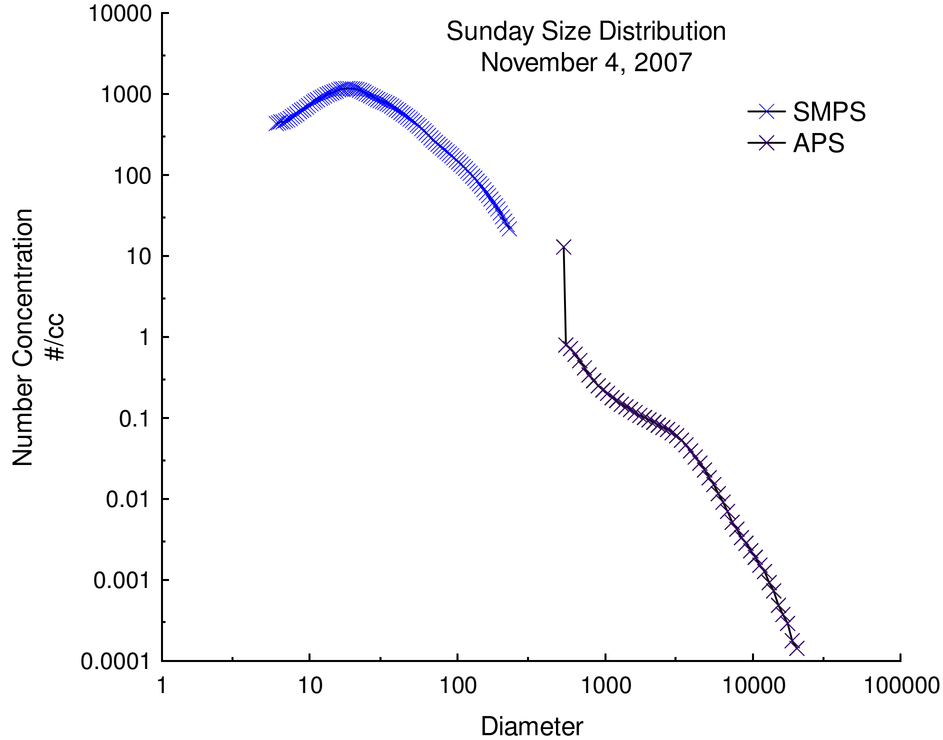


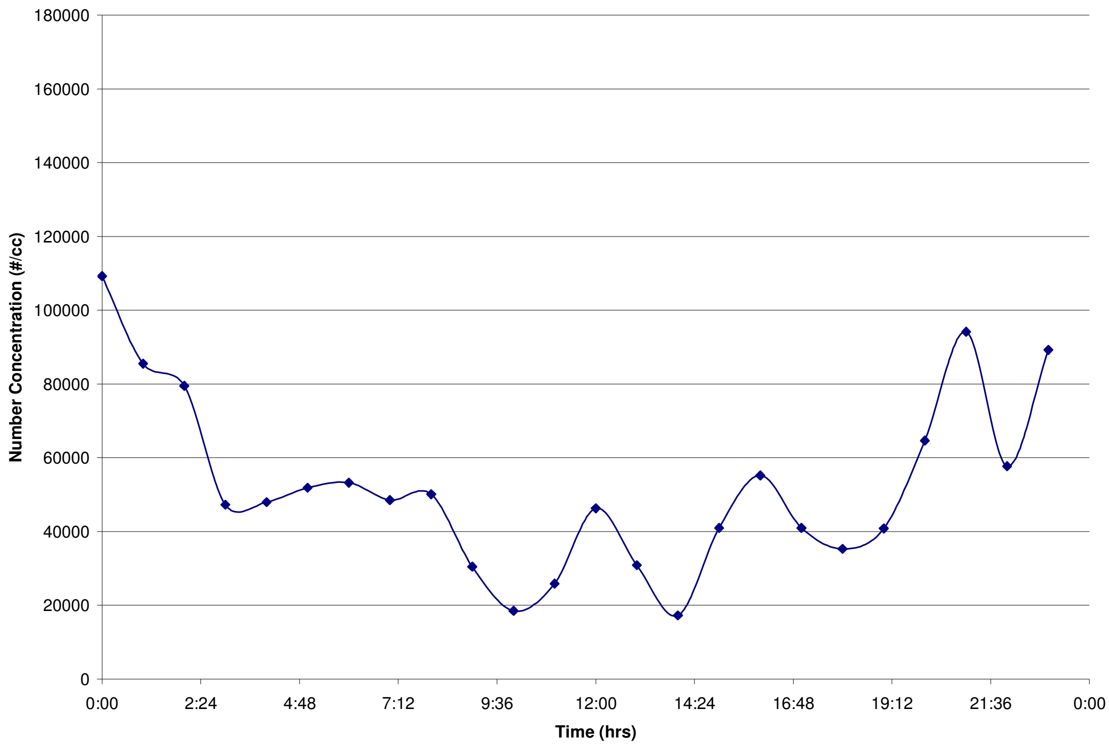



180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Number Concentration (#/cc)
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time (hrs)

November 4, 2008

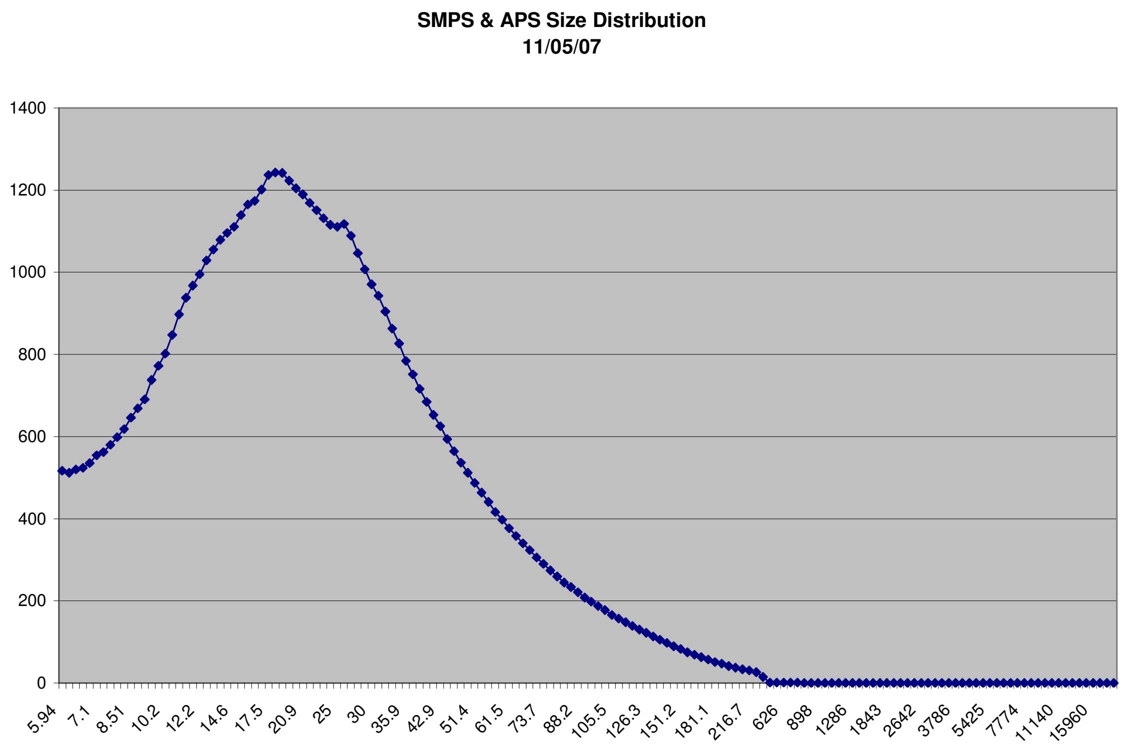


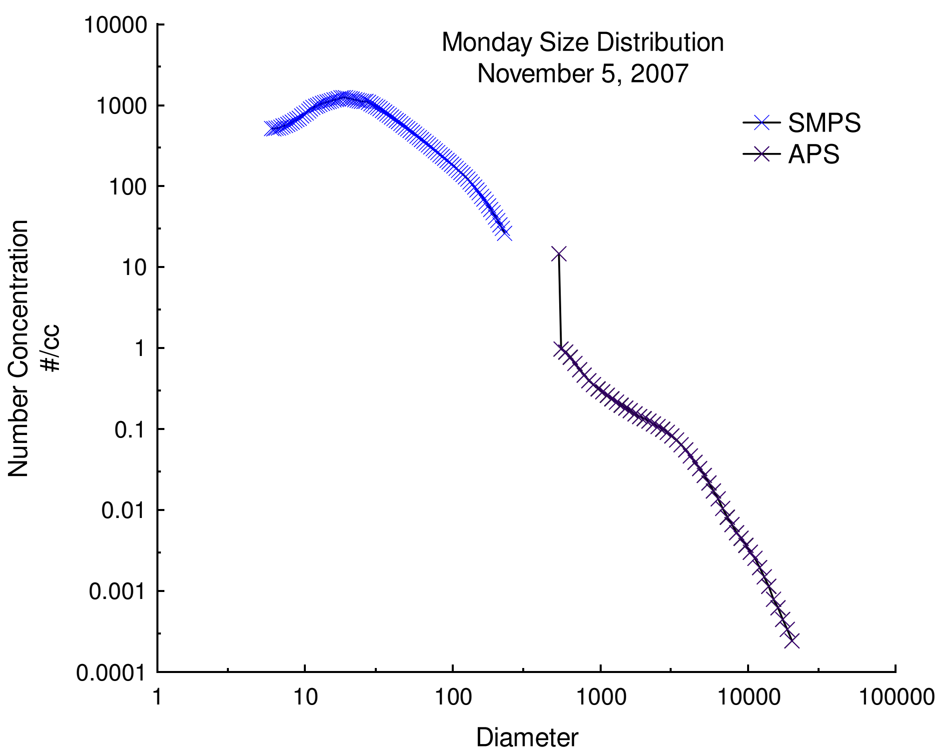


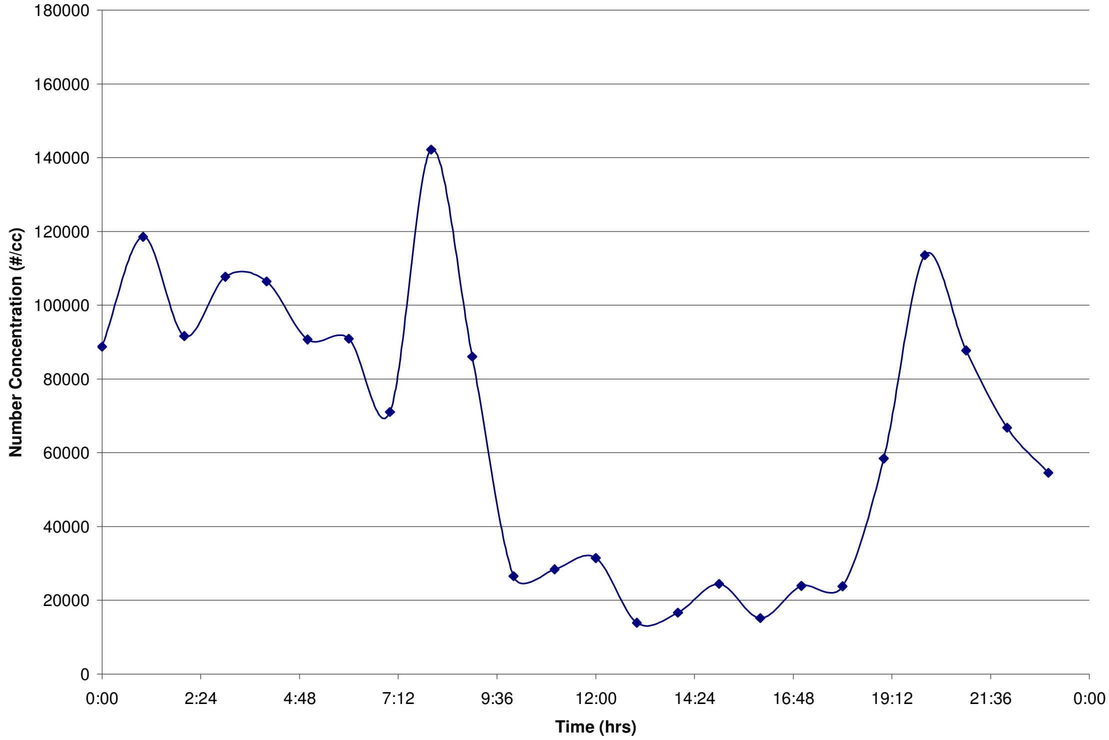


180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Number Concentration (#/cc)
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time (hrs)

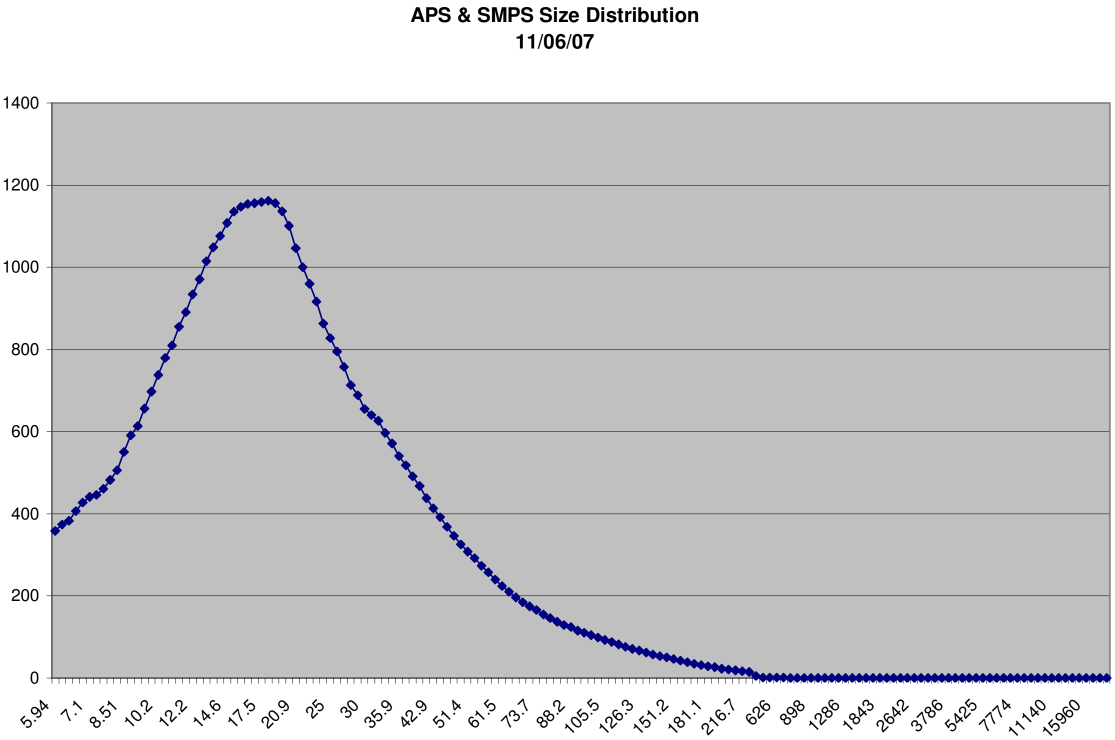
November 5, 2008

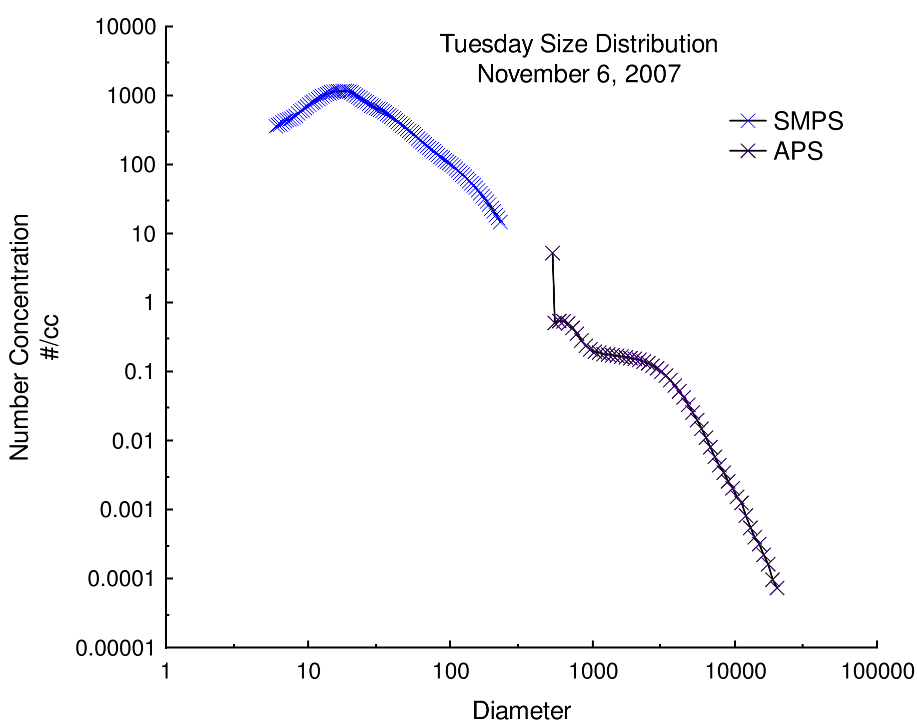


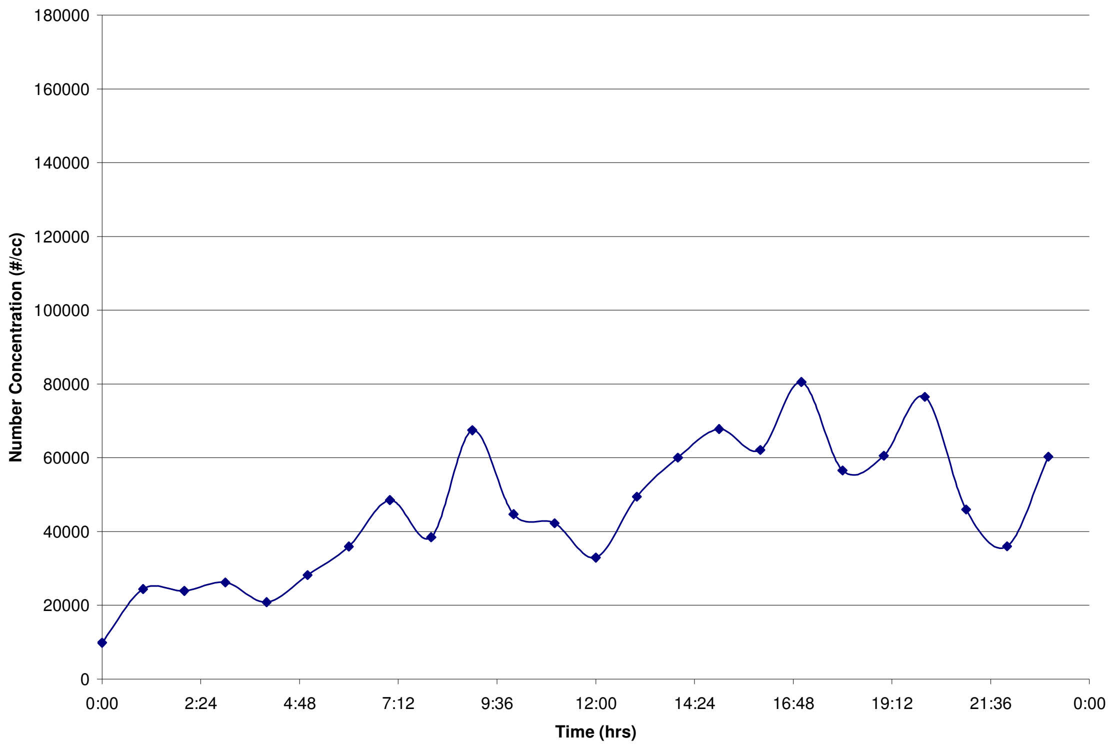



180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Number Concentration (#/cc)
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time (hrs)

November 6, 2008

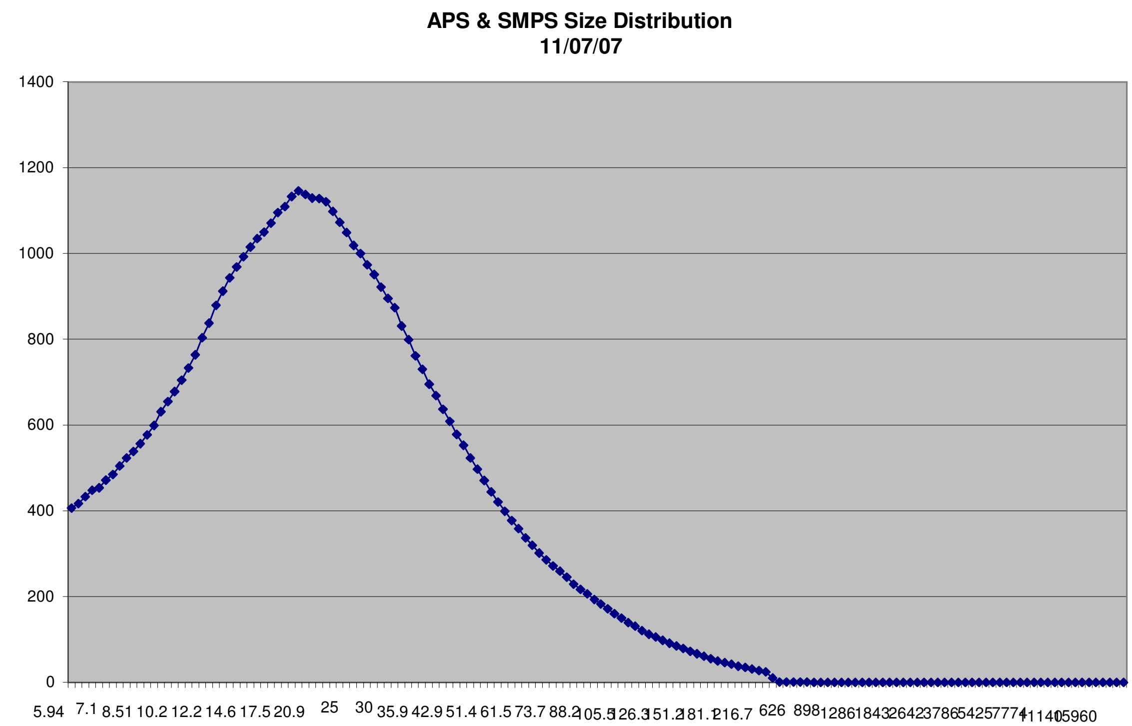


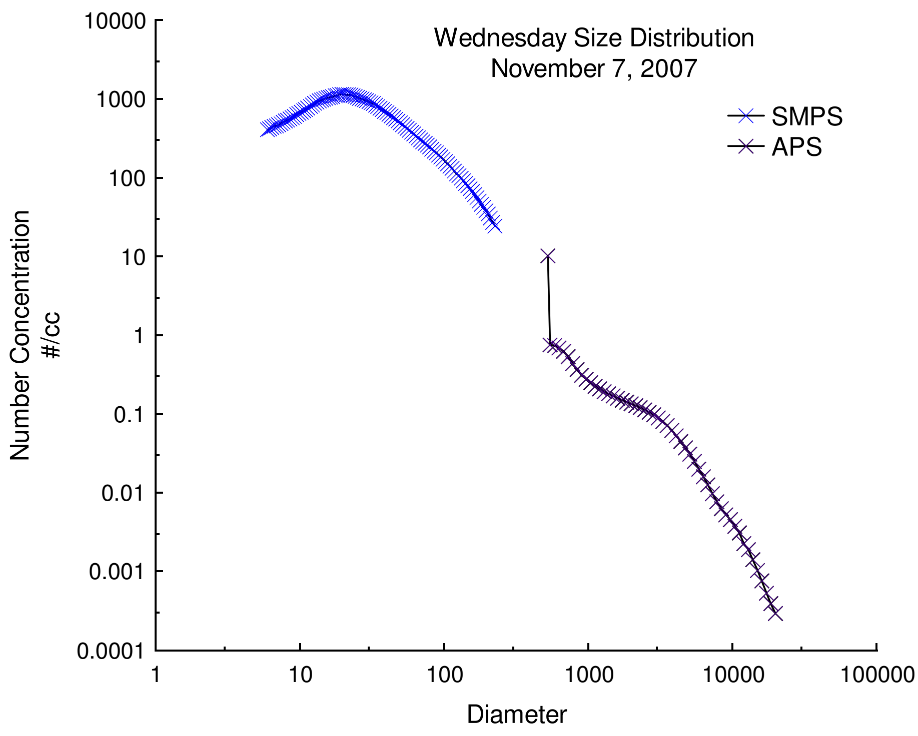


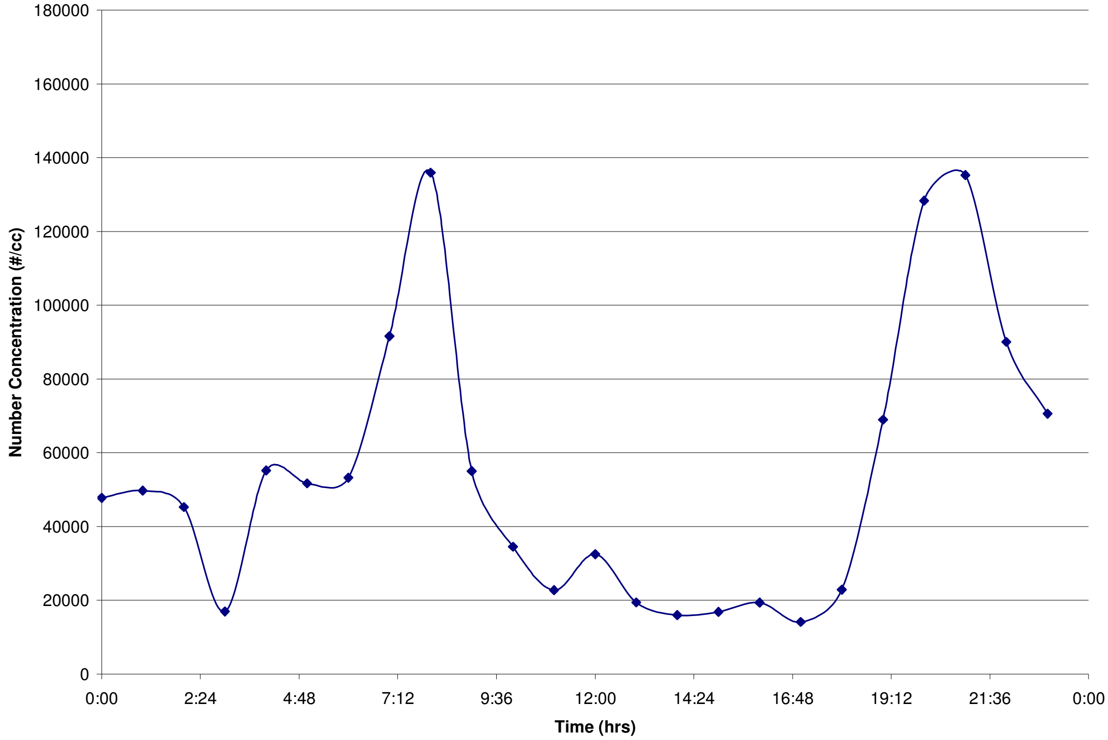


180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Number Concentration (#/cc)
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time (hrs)

November 7, 2008






180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Number Concentration (#/cc)
0:00
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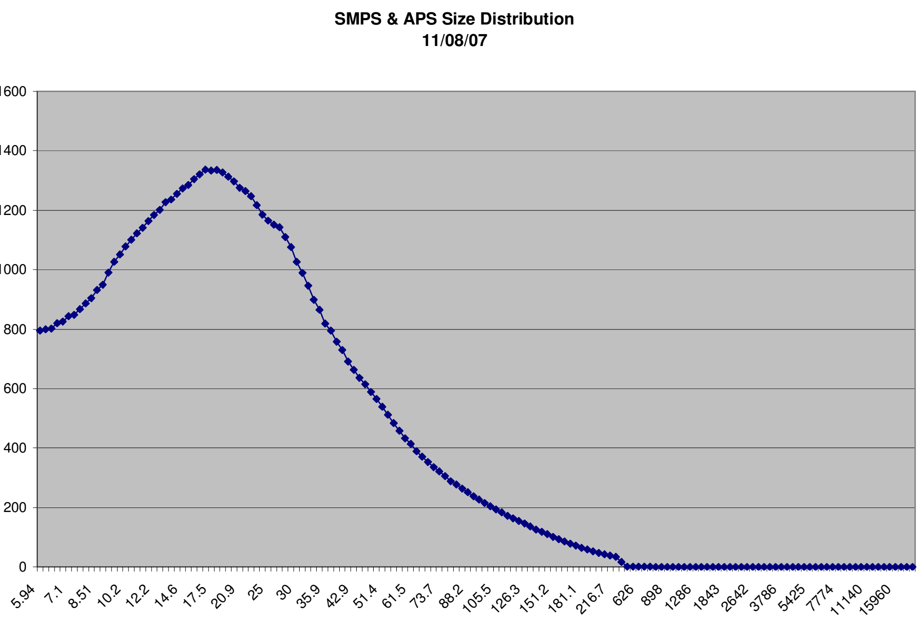
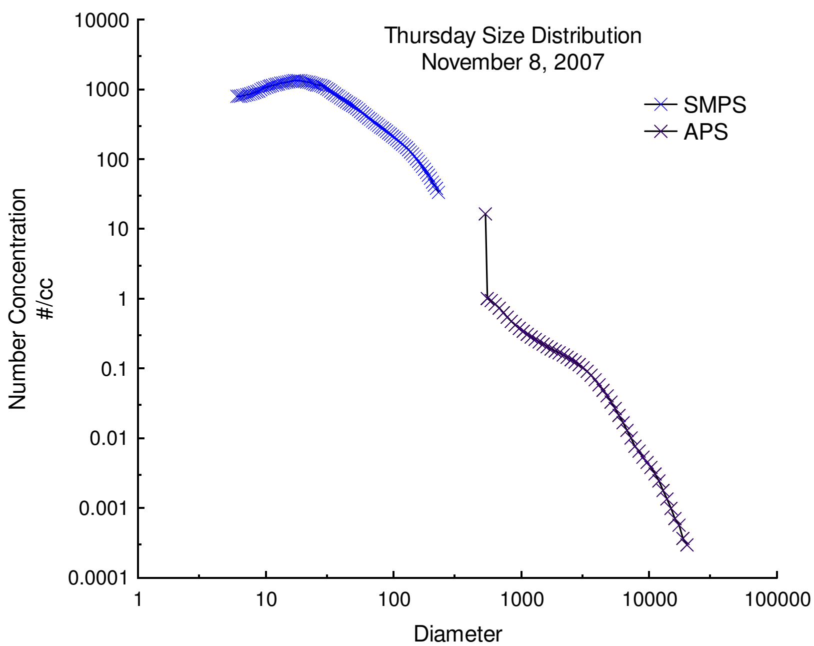
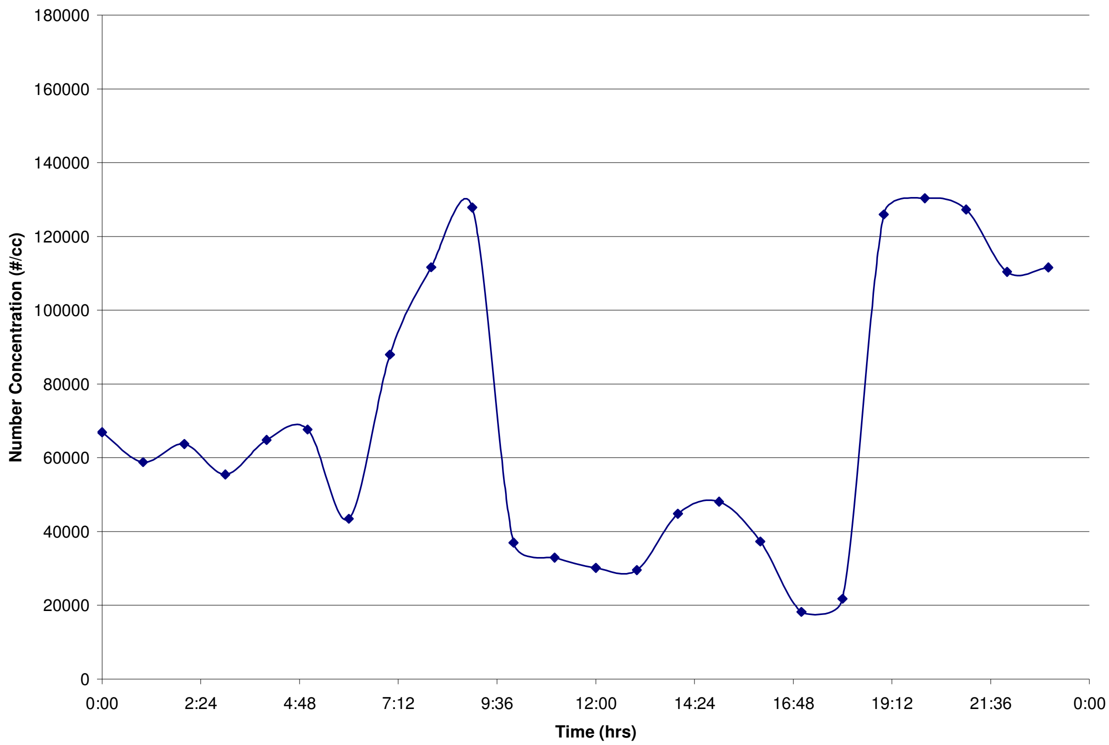
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time (hrs)

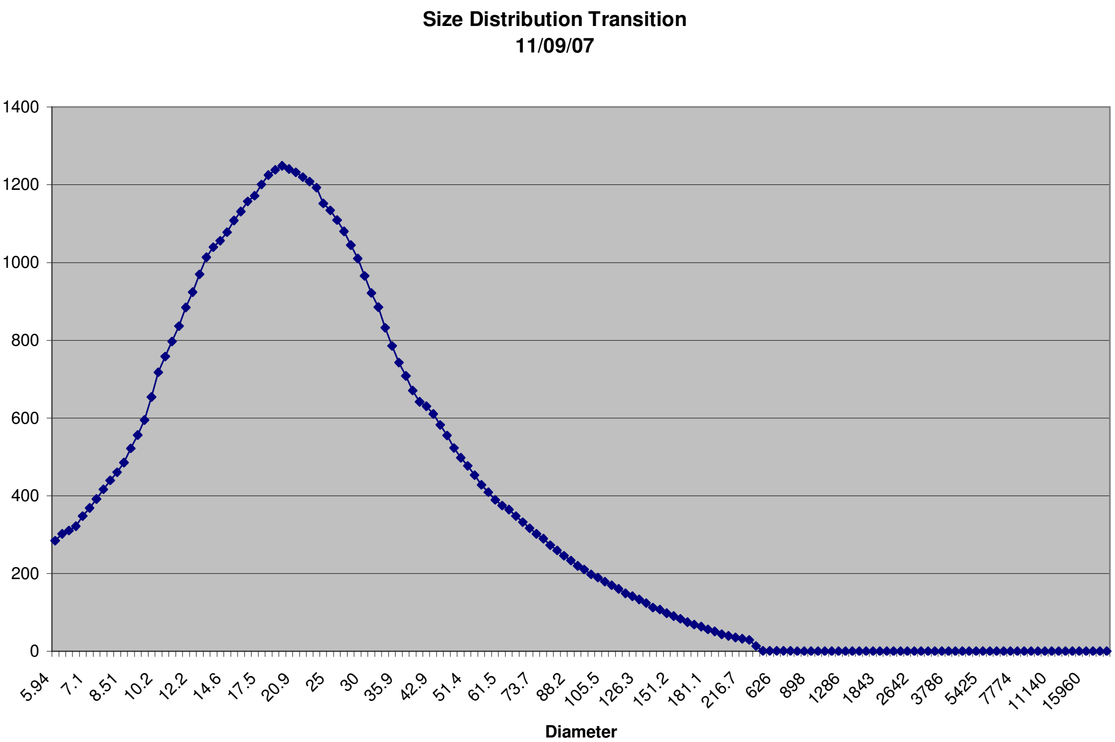
November 8, 2008

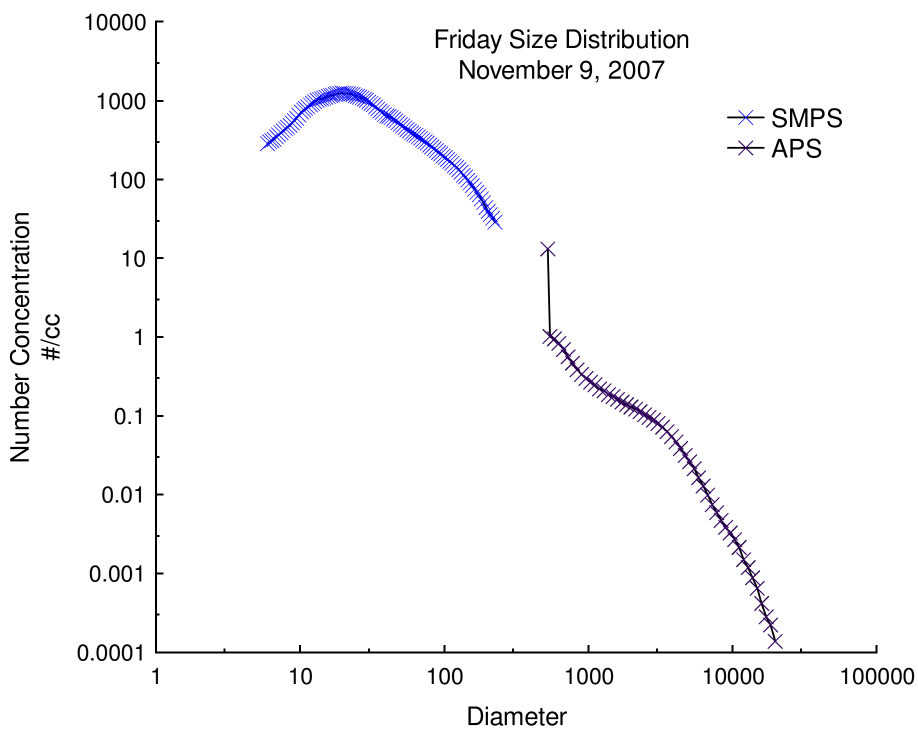


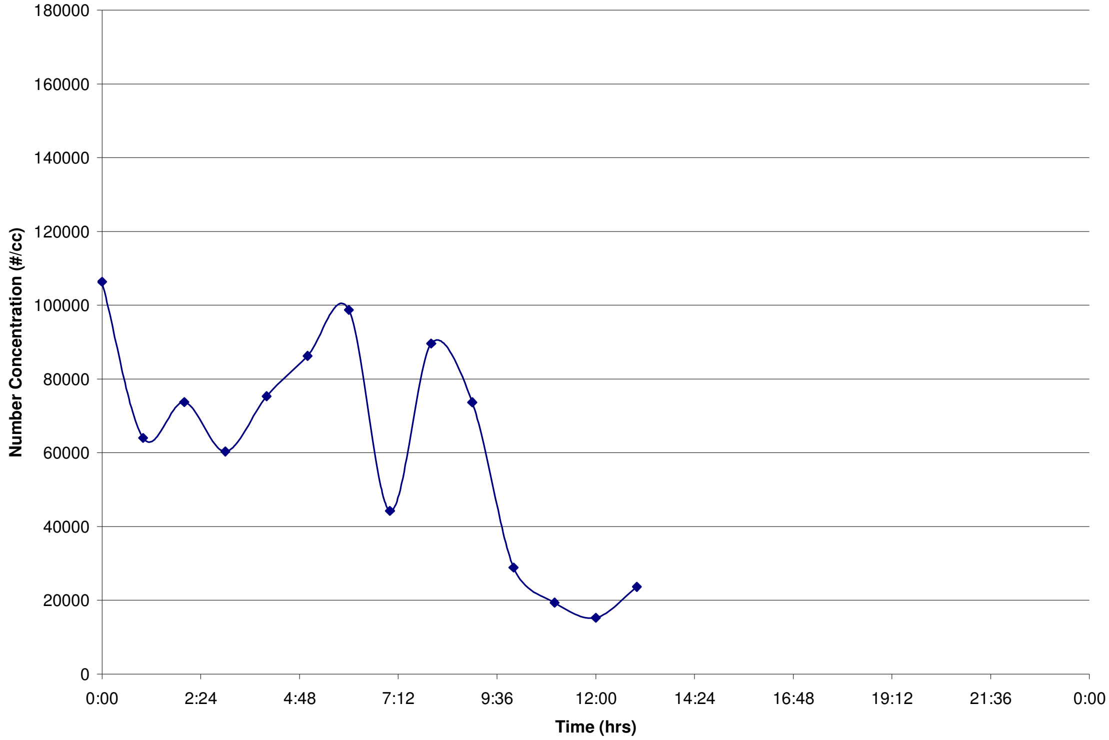



180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Number Concentration (#/cc)
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time (hrs)

November 9, 2008



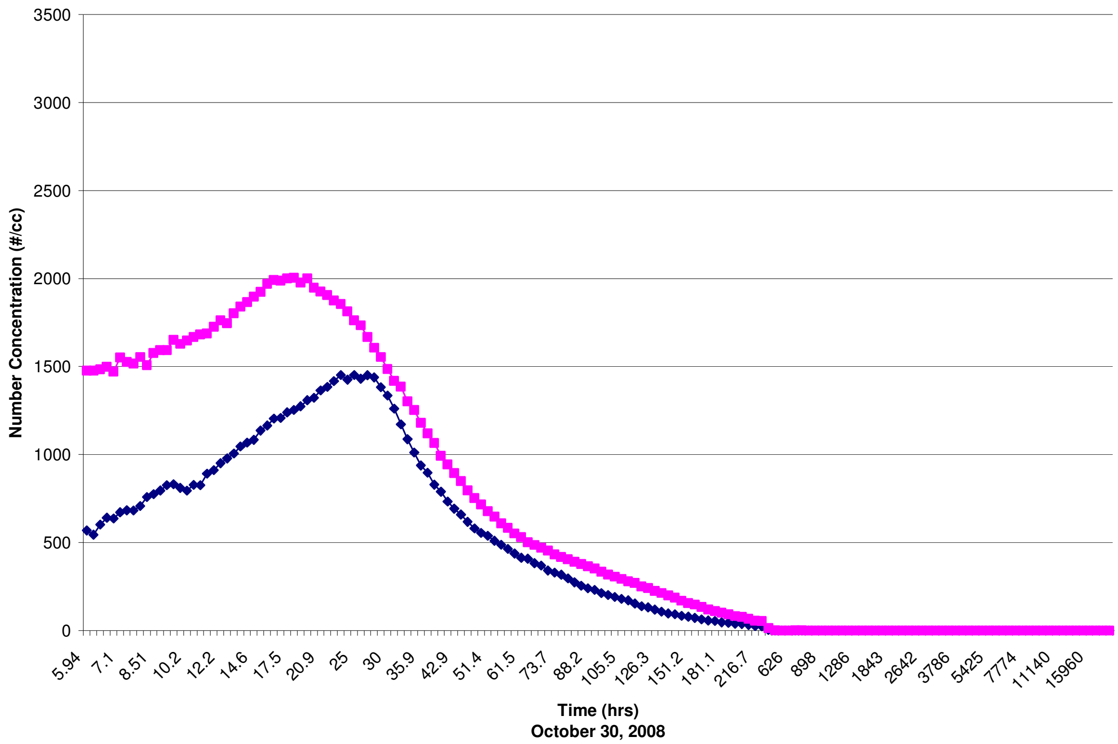


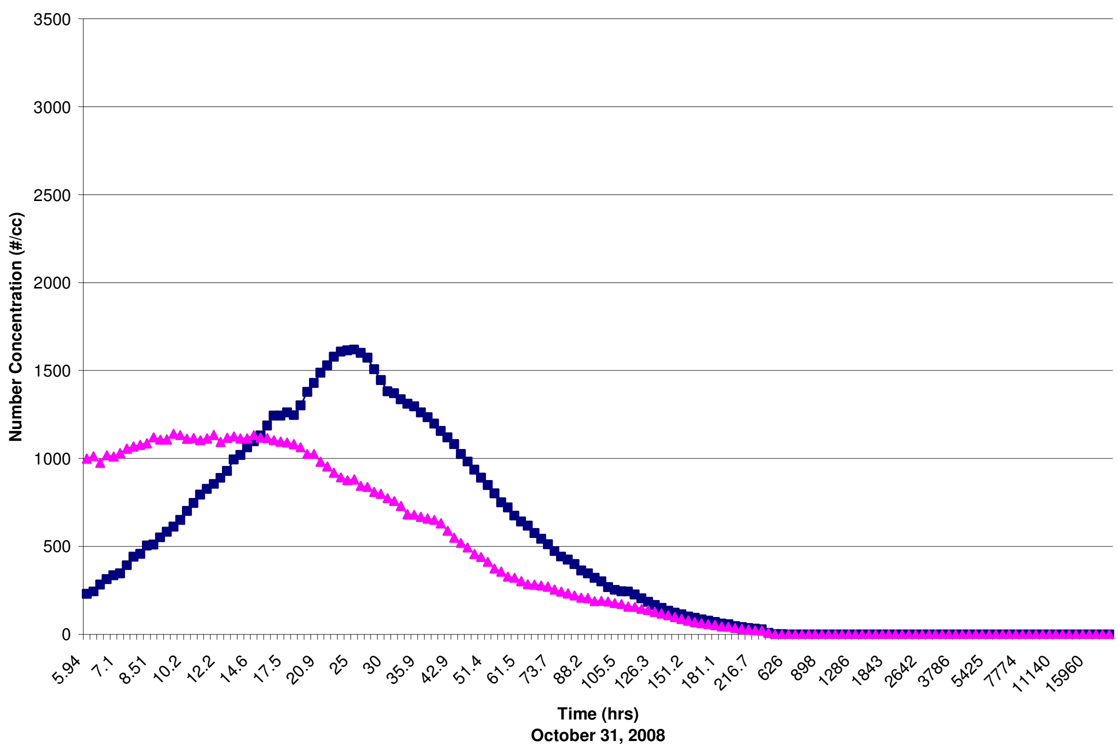


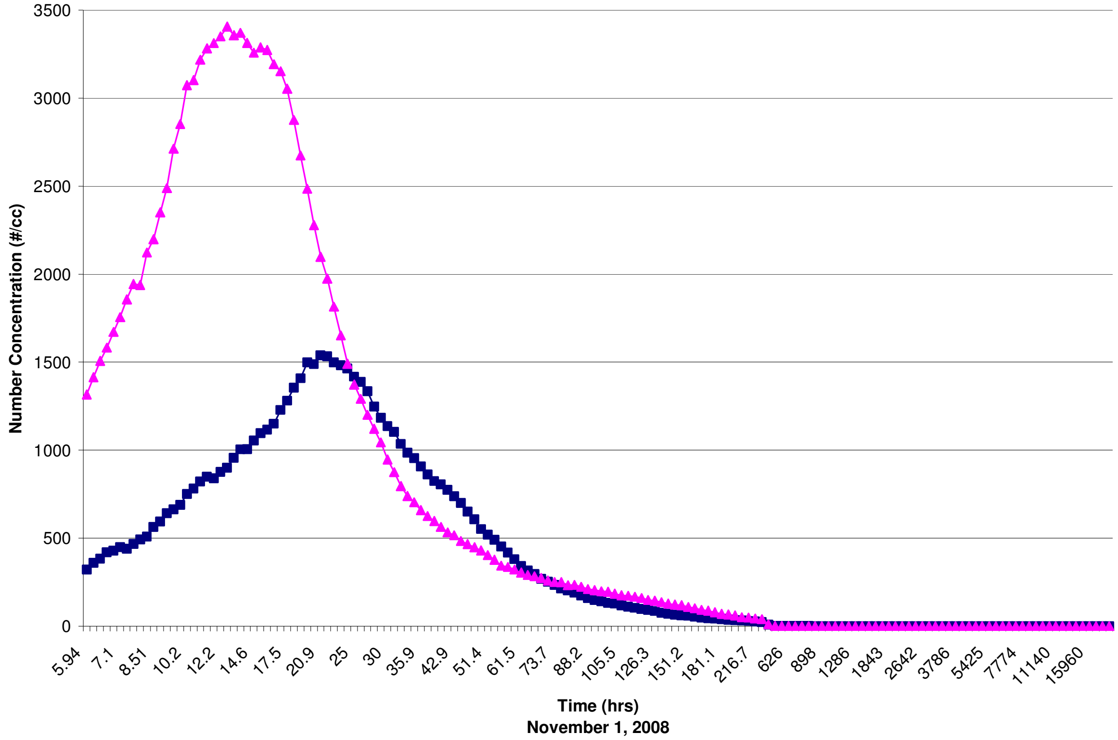
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Number Concentration (#/cc)
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
0:00
Time (hrs)

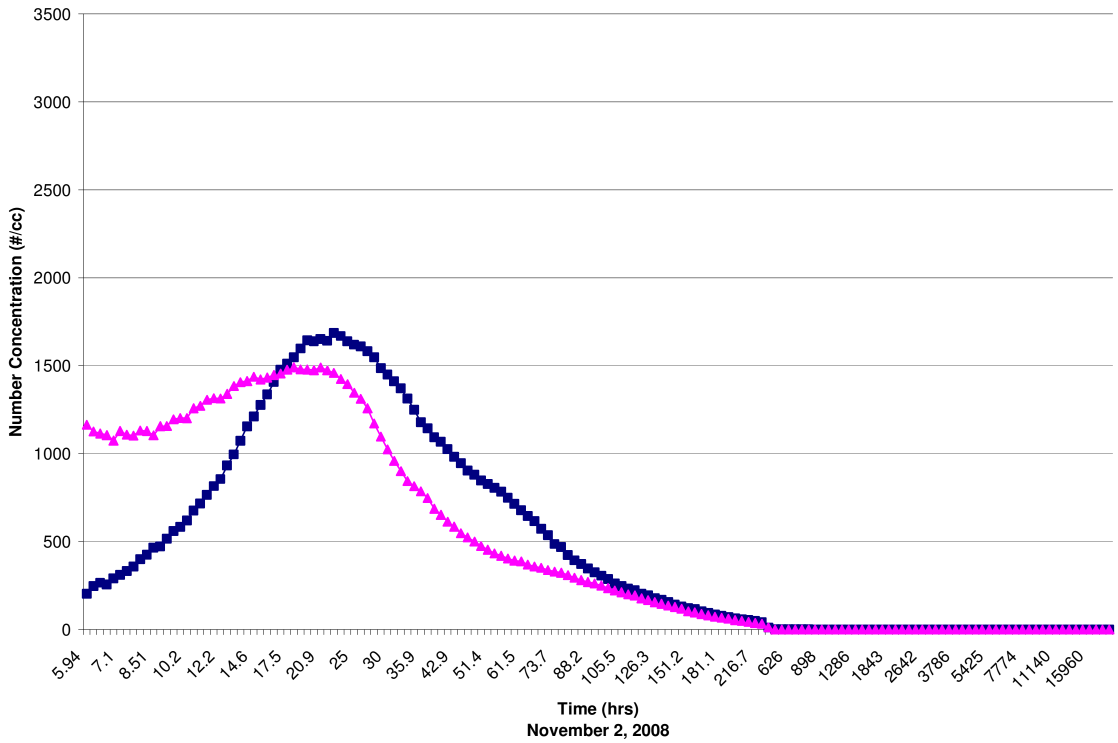
Appendix D

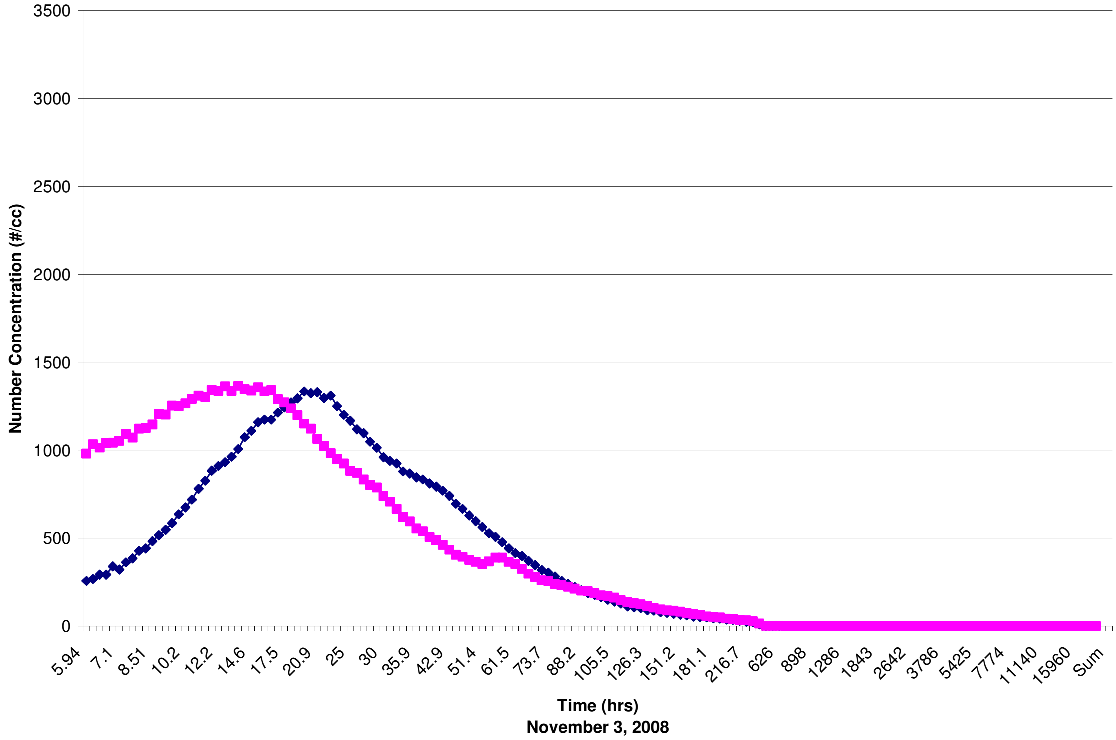
Daily Size Distribution Comparison for Morning and Evening peak Number Concentrations for October 30 to November 9, 2008


Number Concentration (#/cc)
Time (hrs)
October 30, 2008

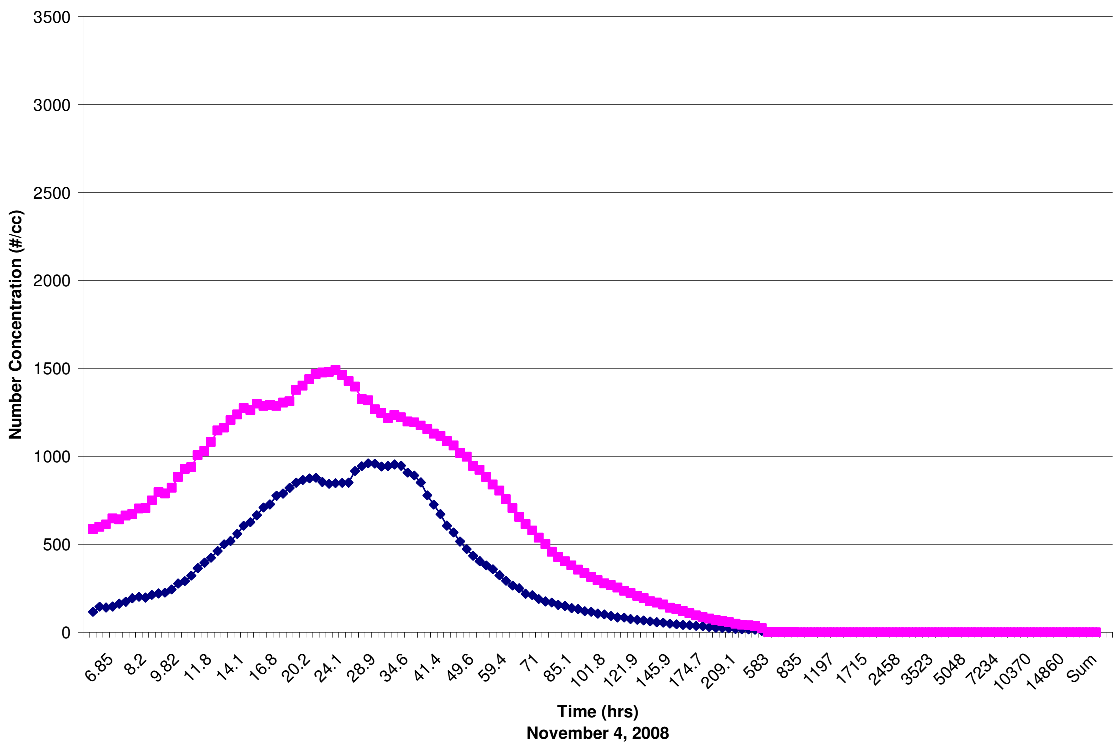

Number Concentration (#/cc)
Time (hrs)
October 31, 2008


3500
3000
2500
2000
1500
1000
500
0
Number Concentration (#/cc)
5.94
7.1
8.51
10.2
12.2
14.6
17.5
20.9
25
30
35.9
42.9
51.4
61.5
73.7
88.2
105.5
126.3
151.2
181.1
216.7
626
898
1286
1843
2642
3786
5425
7774
11140
15960
Time (hrs)
November 1, 2008

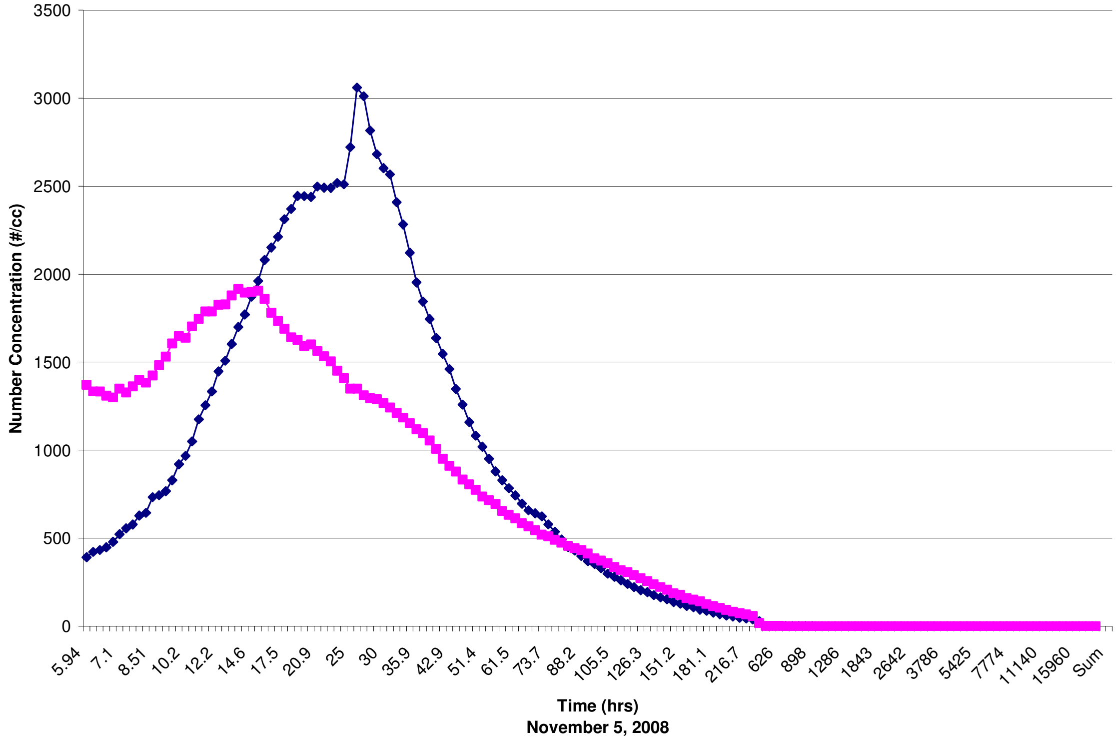

3500
3000
2500
2000
1500
1000
500
0
Number Concentration (#/cc)
5.94
7.1
8.51
10.2
12.2
14.6
17.5
20.9
25
30
35.9
42.9
51.4
61.5
73.7
88.2
105.5
126.3
151.2
181.1
216.7
626
898
1286
1843
2642
3786
5425
7774
11140
15960
Time (hrs)
November 2, 2008

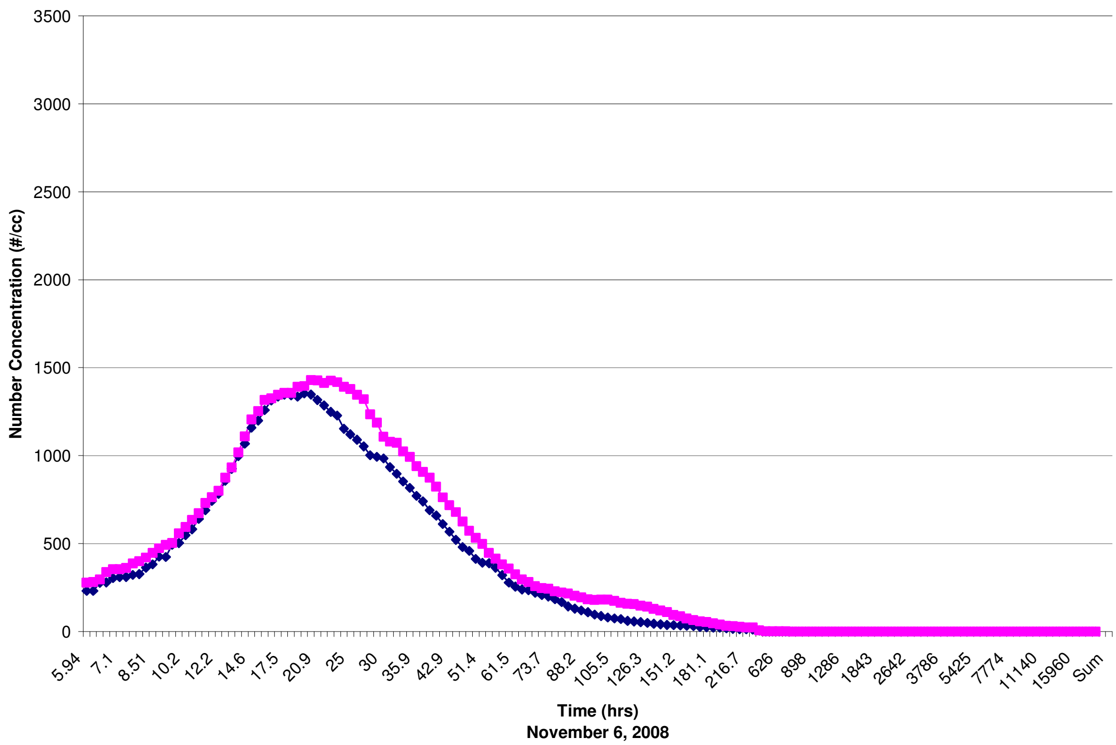


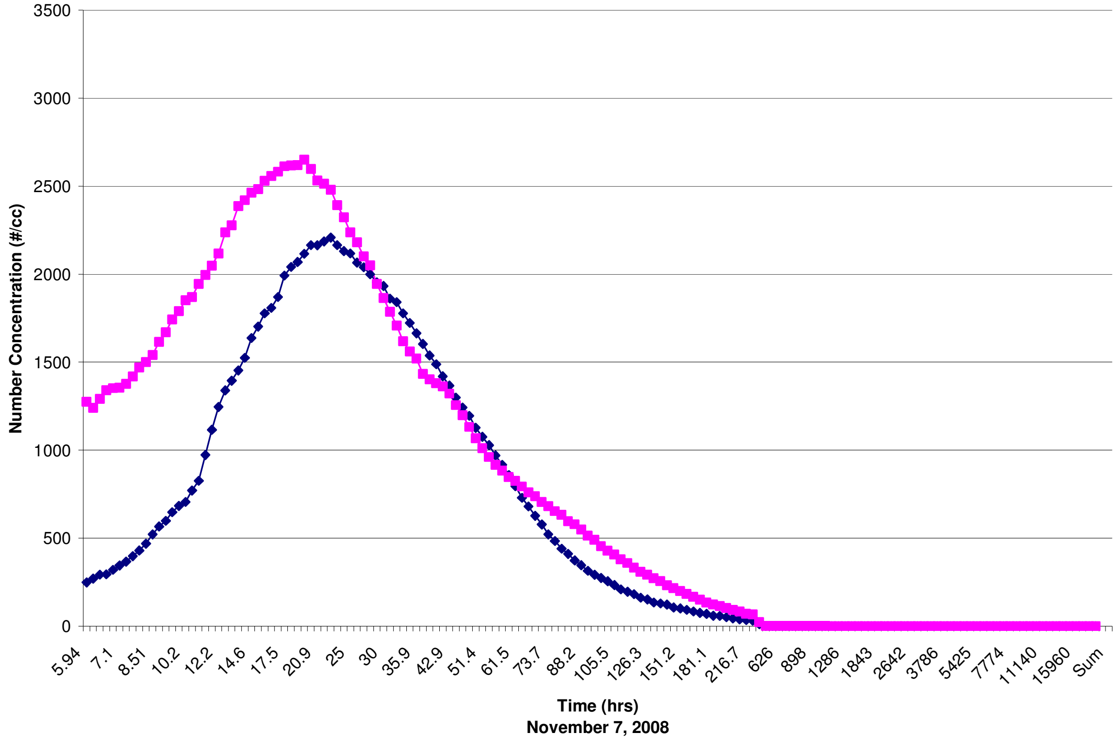
3500
3000
2500
2000
1500
1000
500
0
Number Concentration (#/cc)
5.94
7.1
8.51
10.2
12.2
14.6
17.5
20.9
25
30
35.9
42.9
51.4
61.5
73.7
88.2
105.5
126.3
151.2
181.1
216.7
626
898
1286
1843
2642
3786
5425
7774
11140
15960
Sum
Time (hrs)
November 3, 2008

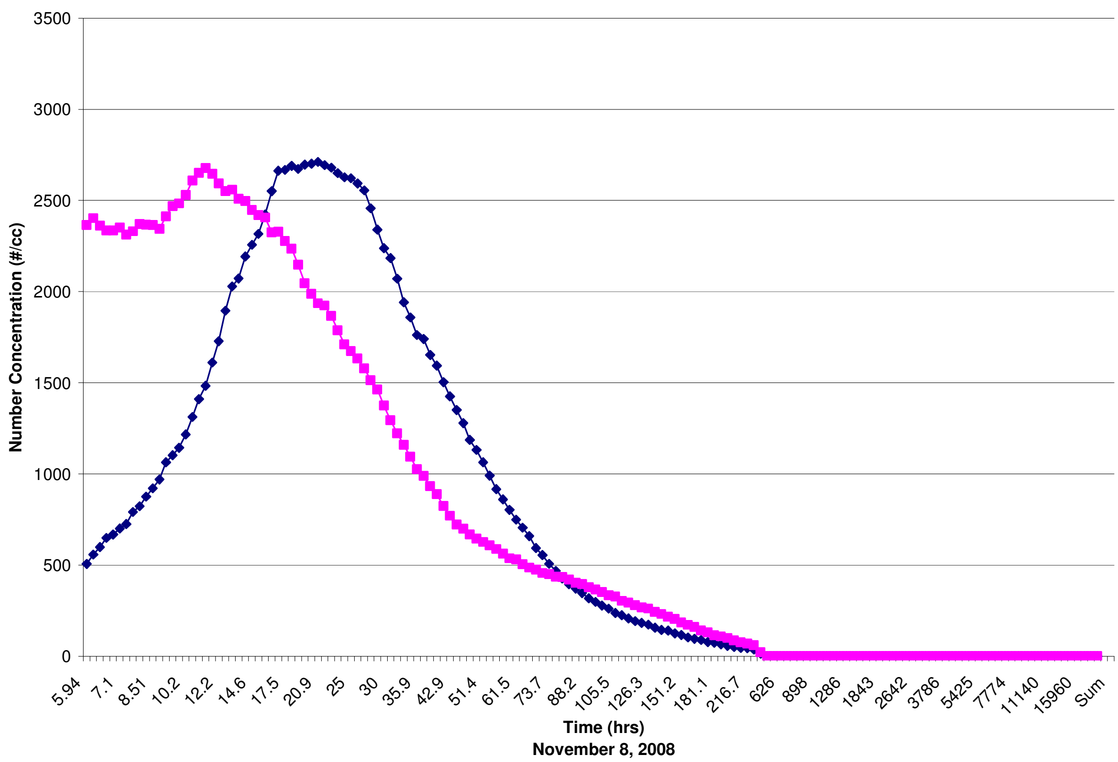


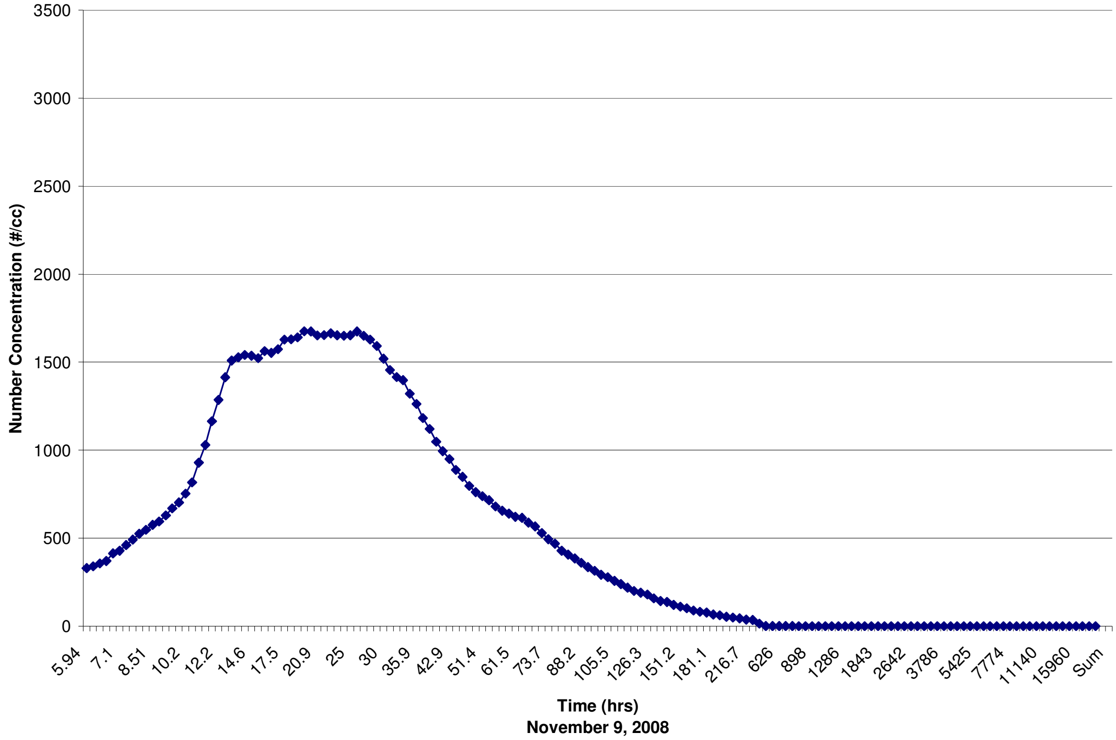
3500
3000
2500
2000
1500
1000
500
0
Number Concentration (#/cc)
6.85
8.2
9.82
11.8
14.1
16.8
20.2
24.1
28.9
34.6
41.4
49.6
59.4
71
85.1
101.8
121.9
145.9
174.7
209.1
583
835
1197
1715
2458
3523
5048
7234
10370
14860
Sum
Time (hrs)
November 4, 2008


3500
3000
2500
2000
1500
1000
500
0
Number Concentration (#/cc)
5.94
7.1
8.51
10.2
12.2
14.6
17.5
20.9
25
30
35.9
42.9
51.4
61.5
73.7
88.2
105.5
126.3
151.2
181.1
216.7
626
898
1286
1843
2642
3786
5425
7774
11140
15960
Sum
Time (hrs)
November 5, 2008


3500
3000
2500
2000
1500
1000
500
0
Number Concentration (#/cc)
5.94
7.1
8.51
10.2
12.2
14.6
17.5
20.9
25
30
35.9
42.9
51.4
61.5
73.7
88.2
105.5
126.3
151.2
181.1
216.7
626
898
1286
1843
2642
3786
5425
7774
11140
15960
Sum
Time (hrs)
November 6, 2008


3500
3000
2500
2000
1500
1000
500
0
Number Concentration (#/cc)
5.94
7.1
8.51
10.2
12.2
14.6
17.5
20.9
25
30
35.9
42.9
51.4
61.5
73.7
88.2
105.5
126.3
151.2
181.1
216.7
626
898
1286
1843
2642
3786
5425
7774
11140
15960
Sum
Time (hrs)
November 7, 2008

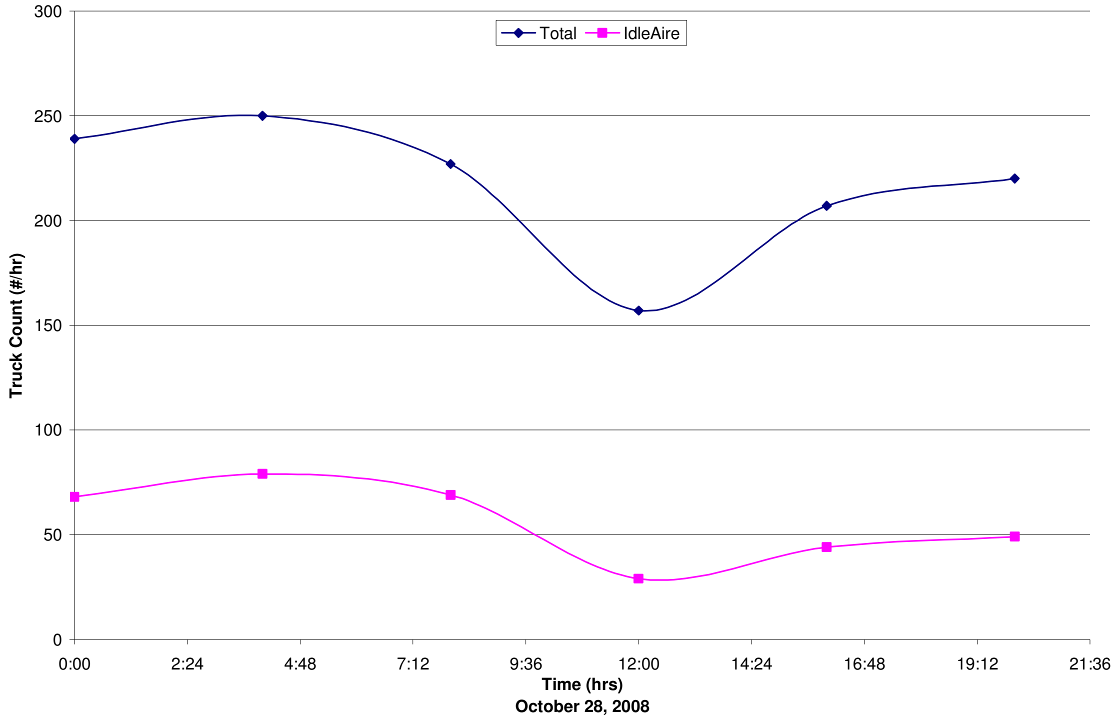

3500
3000
2500
2000
1500
1000
500
0
Number Concentration (#/cc)
5.94
7.1
8.51
10.2
12.2
14.6
17.5
20.9
25
30
35.9
42.9
51.4
61.5
73.7
88.2
105.5
126.3
151.2
181.1
216.7
626
898
1286
1843
2642
3786
5425
7774
11140
15960
Sum
Time (hrs)
November 8, 2008

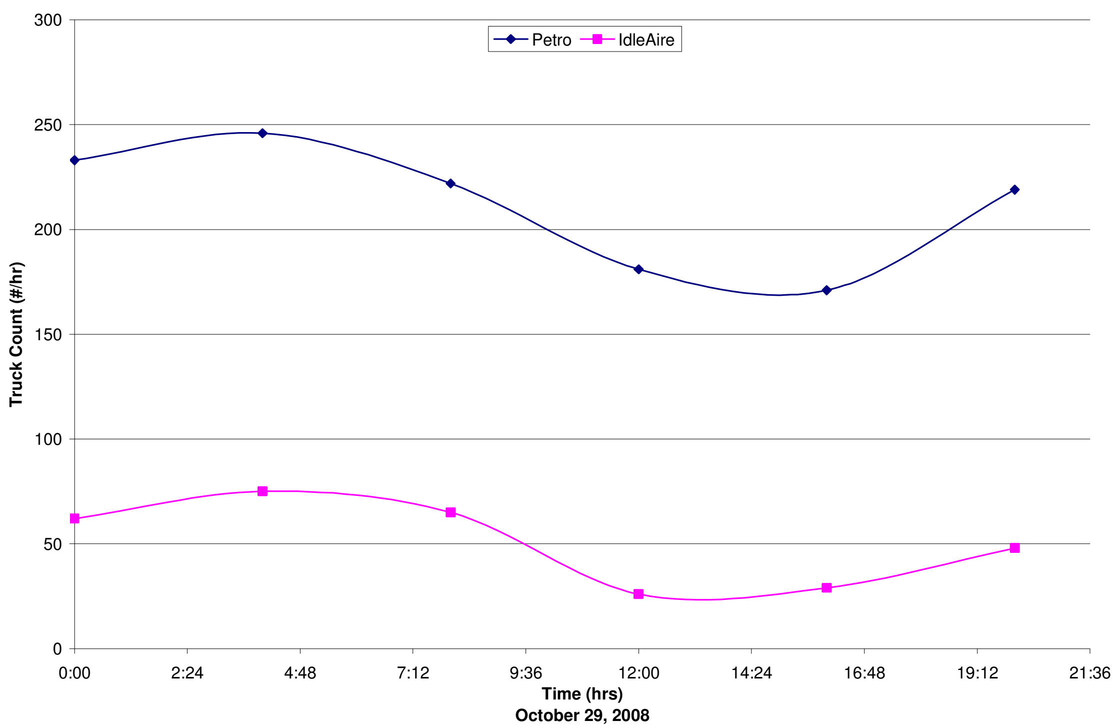


3500
3000
2500
2000
1500
1000
500
0
Number Concentration (#/cc)
5.94
7.1
8.51
10.2
12.2
14.6
17.5
20.9
25
30
35.9
42.9
51.4
61.5
73.7
88.2
105.5
126.3
151.2
181.1
216.7
626
898
1286
1843
2642
3786
5425
7774
11140
15960
Sum
Time (hrs)
November 9, 2008

Appendix E

Daily Petro and IdleAire parking lot concentration from October 28 to November 9, 2008


300
250
200
150
100
50
0
Truck Count (#/hr)
Total
IdleAire
0:00
2:24
4:48
7:12
9:36
12:00
14:24
16:48
19:12
21:36
Time (hrs)
October 28, 2008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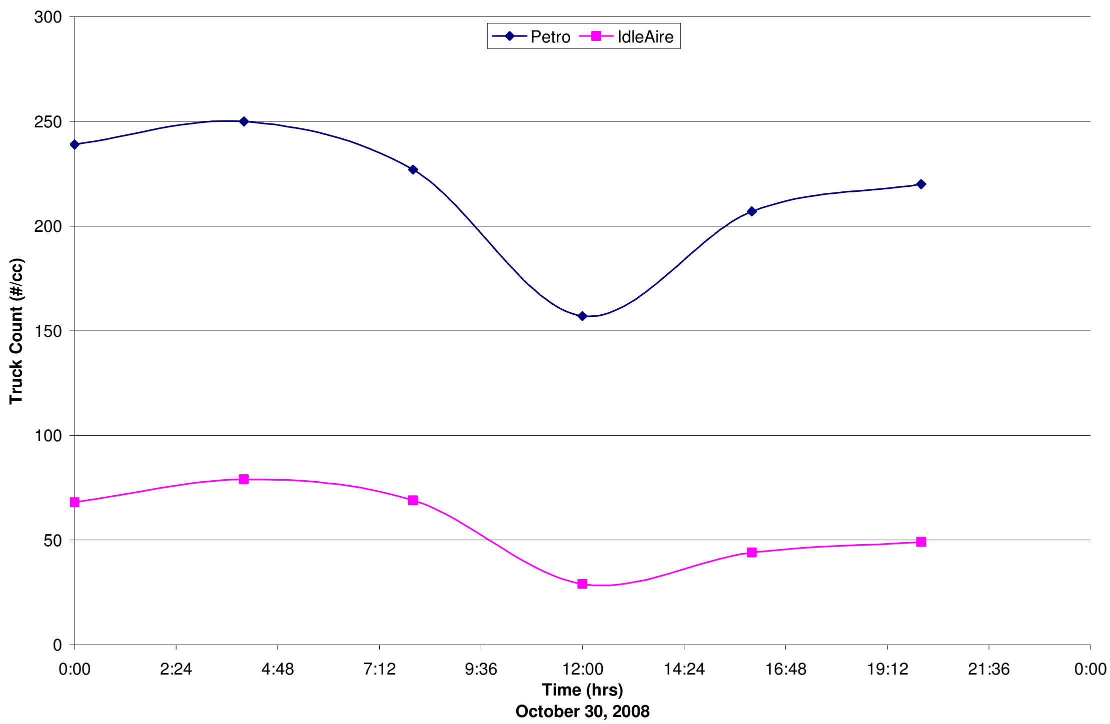
Time (hrs)
October 29, 2008



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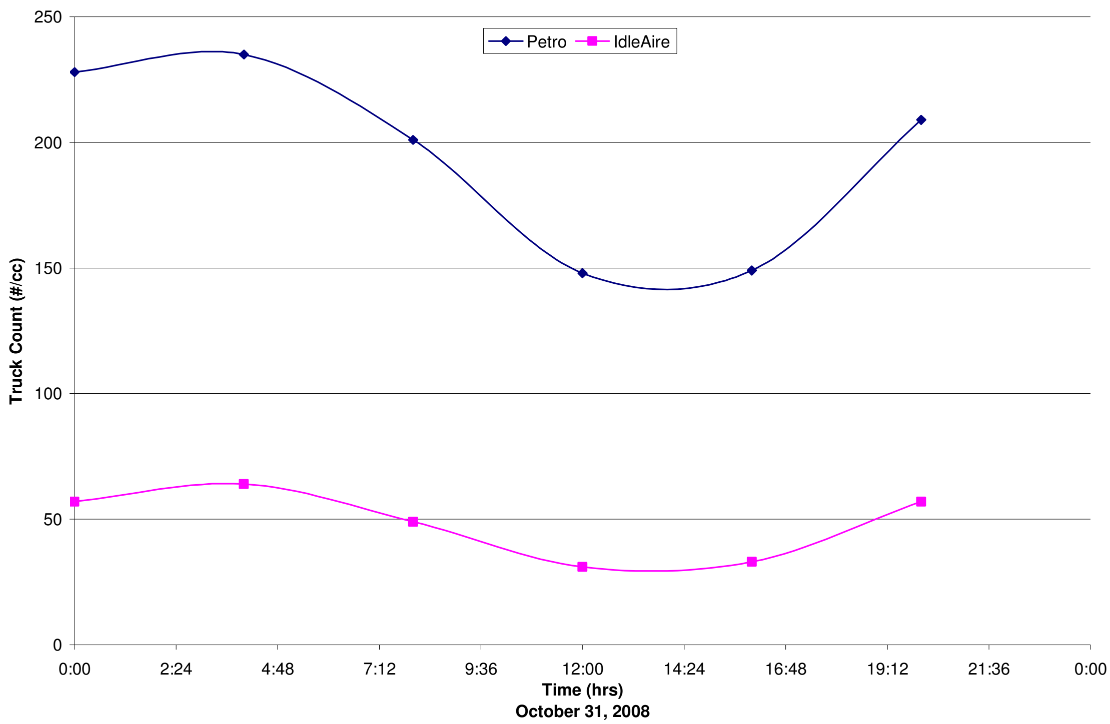
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Time (hrs)
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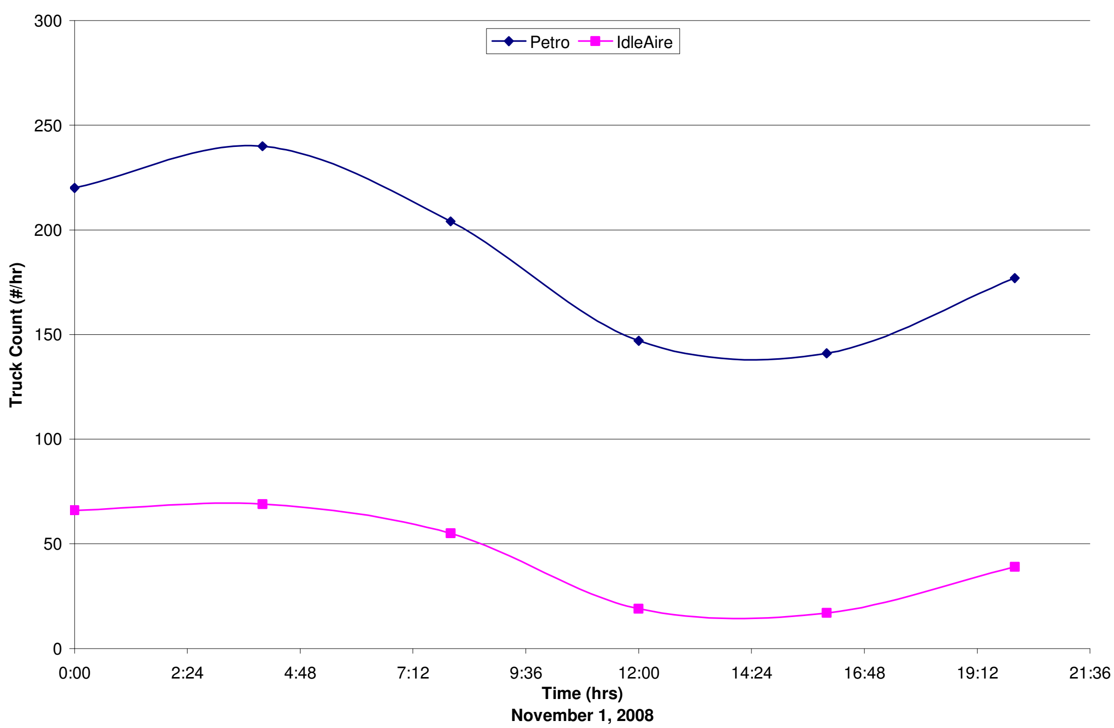
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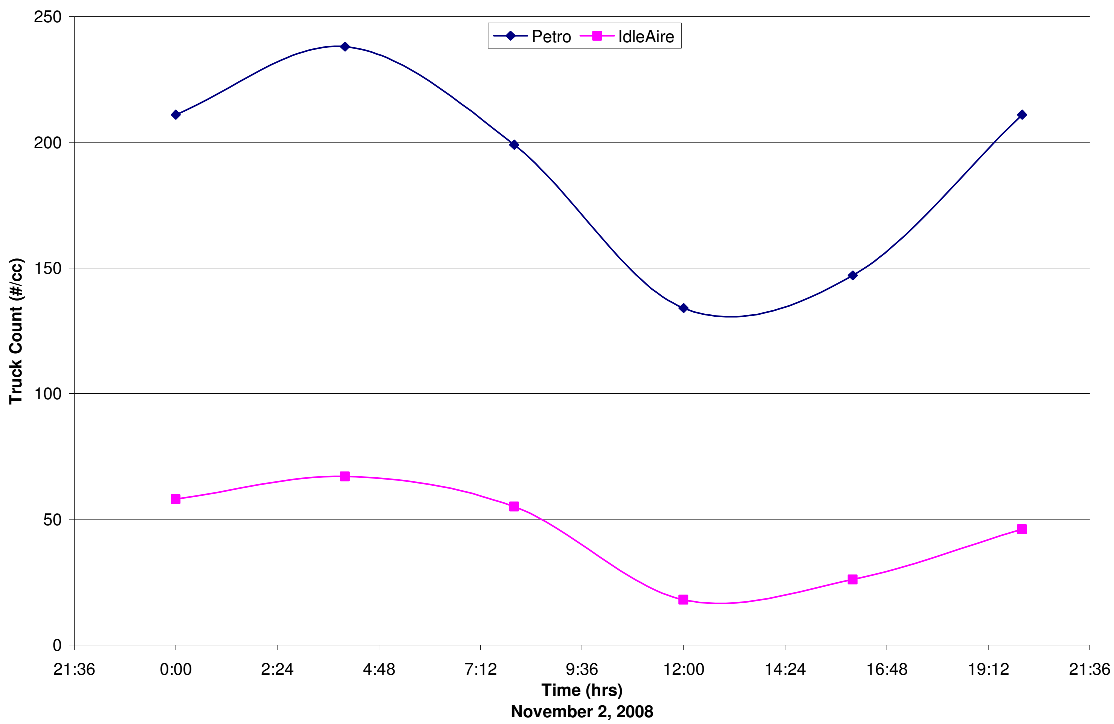
Time (hrs)
November 1, 2008



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Time (hrs)
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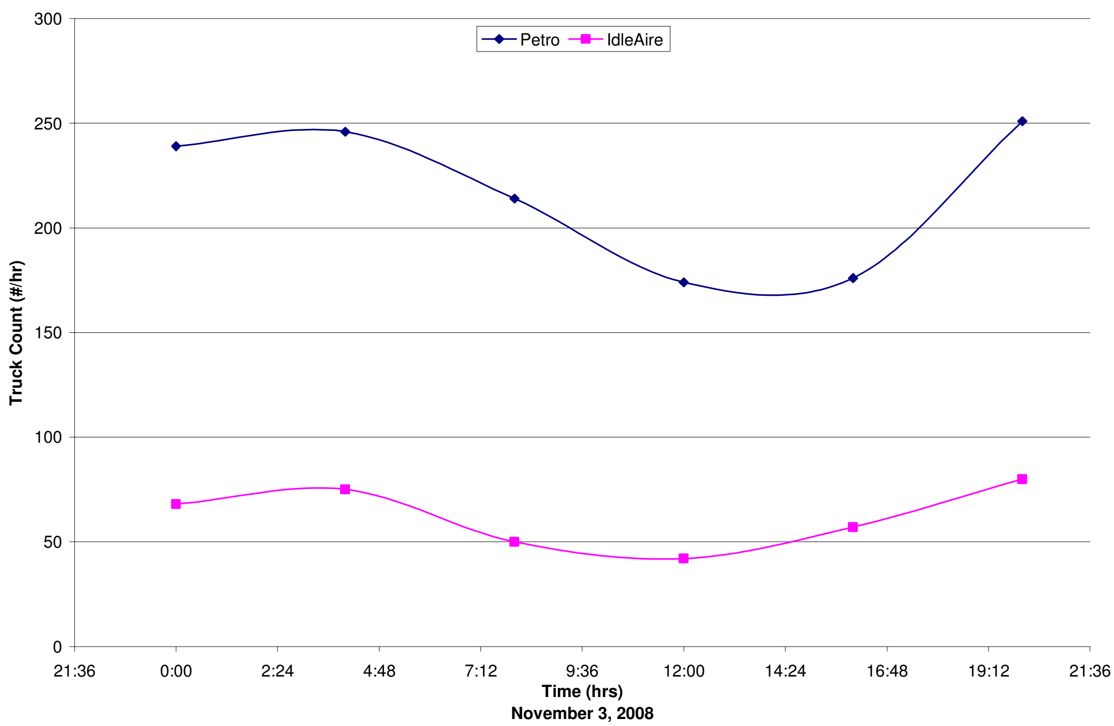

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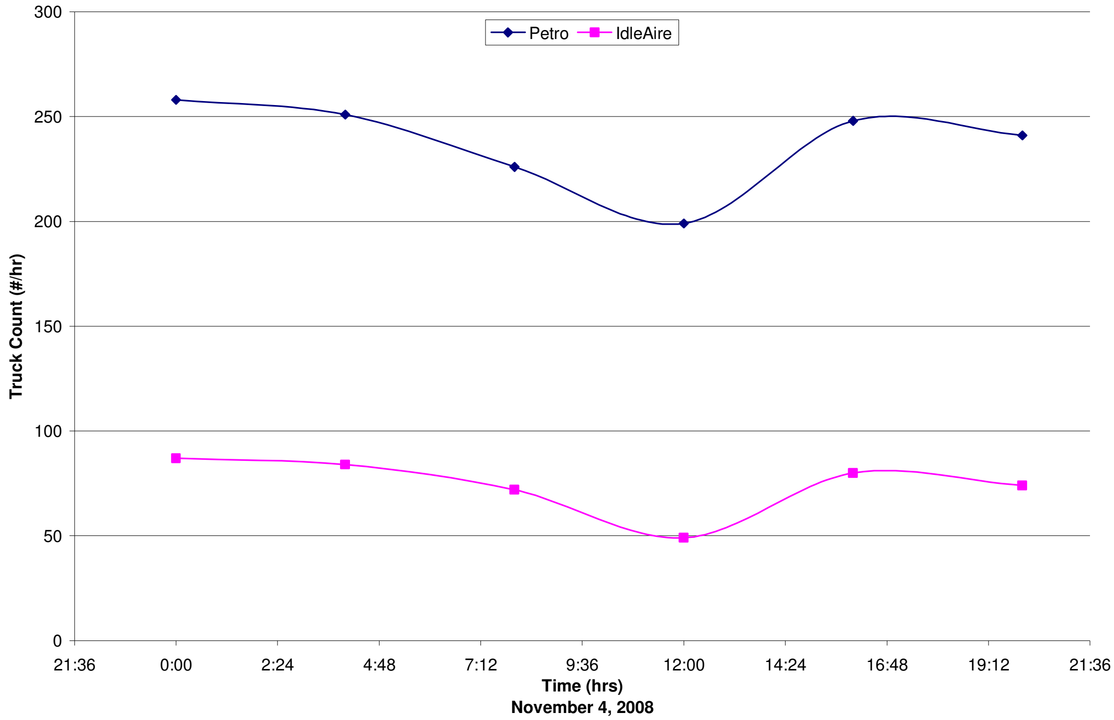
Time (hrs)
November 3, 2008



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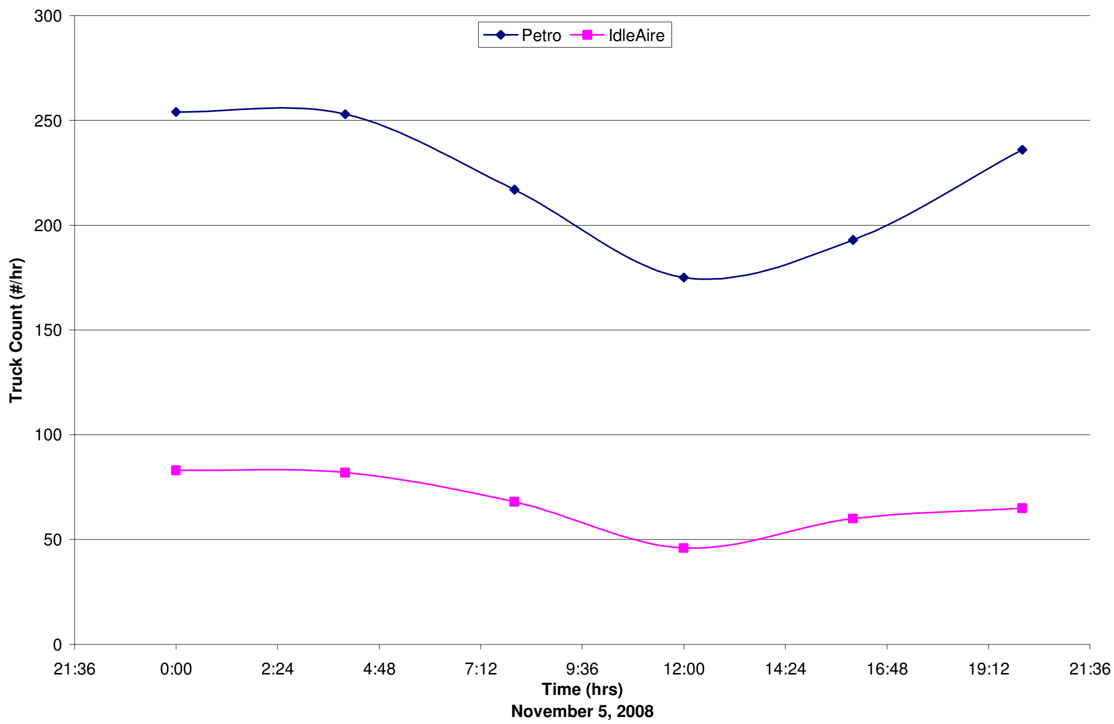
Time (hrs)
November 4, 2008



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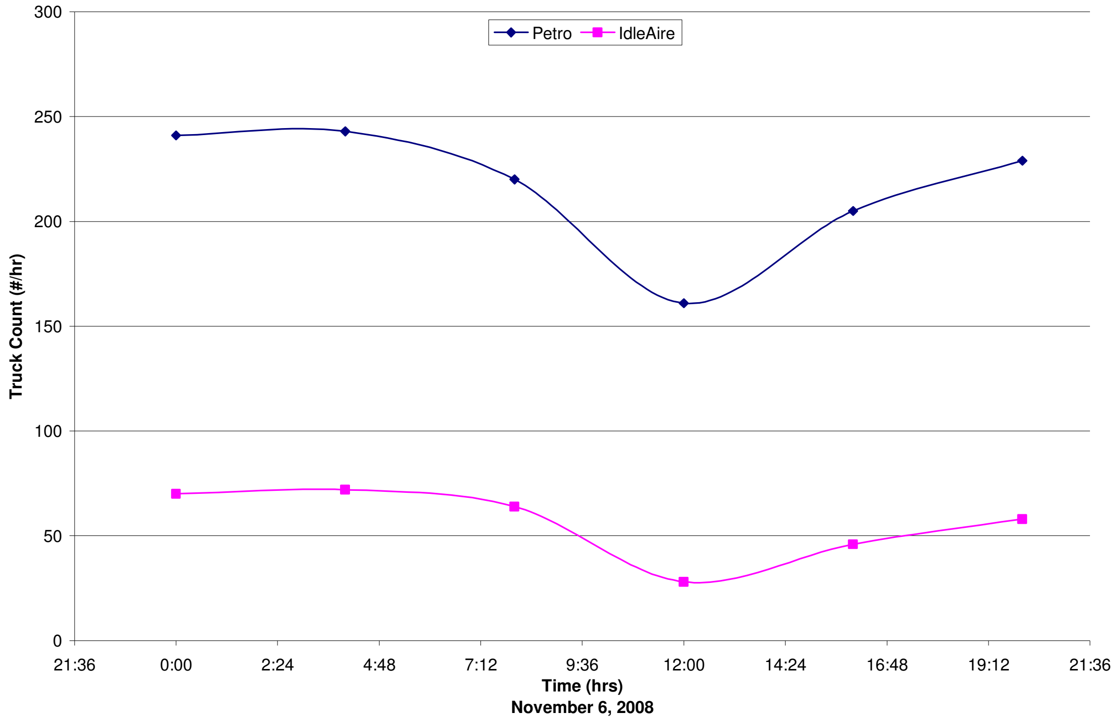
Time (hrs)
November 5, 2008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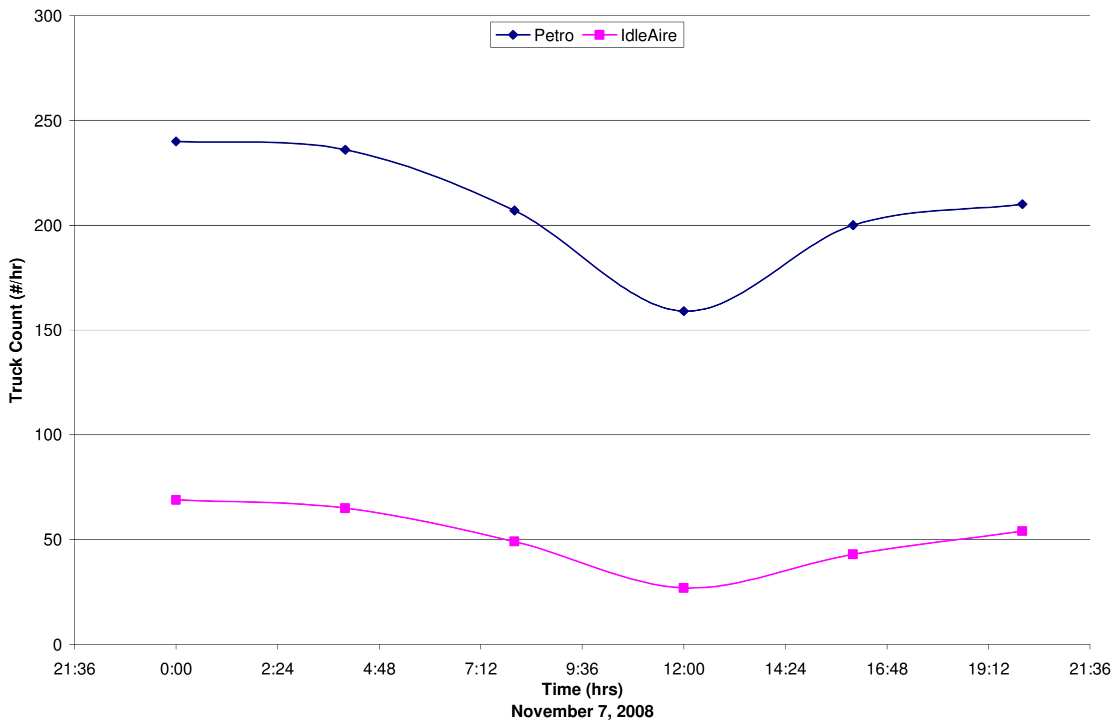
Time (hrs)
November 6, 2008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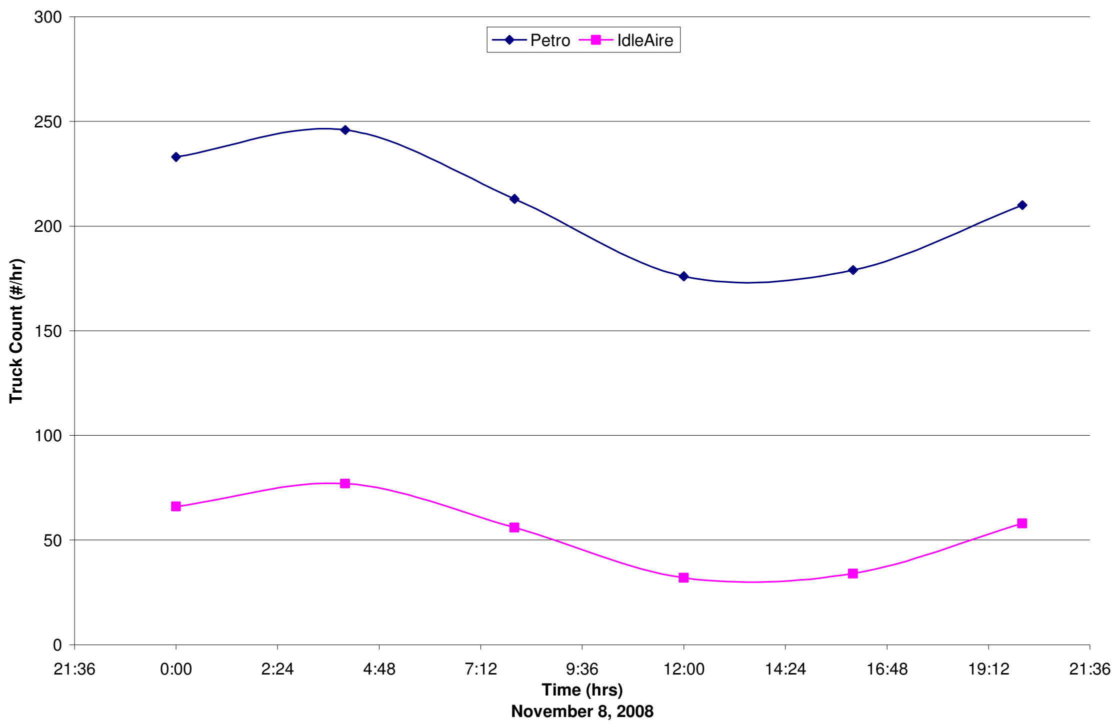
Time (hrs)
November 7, 2008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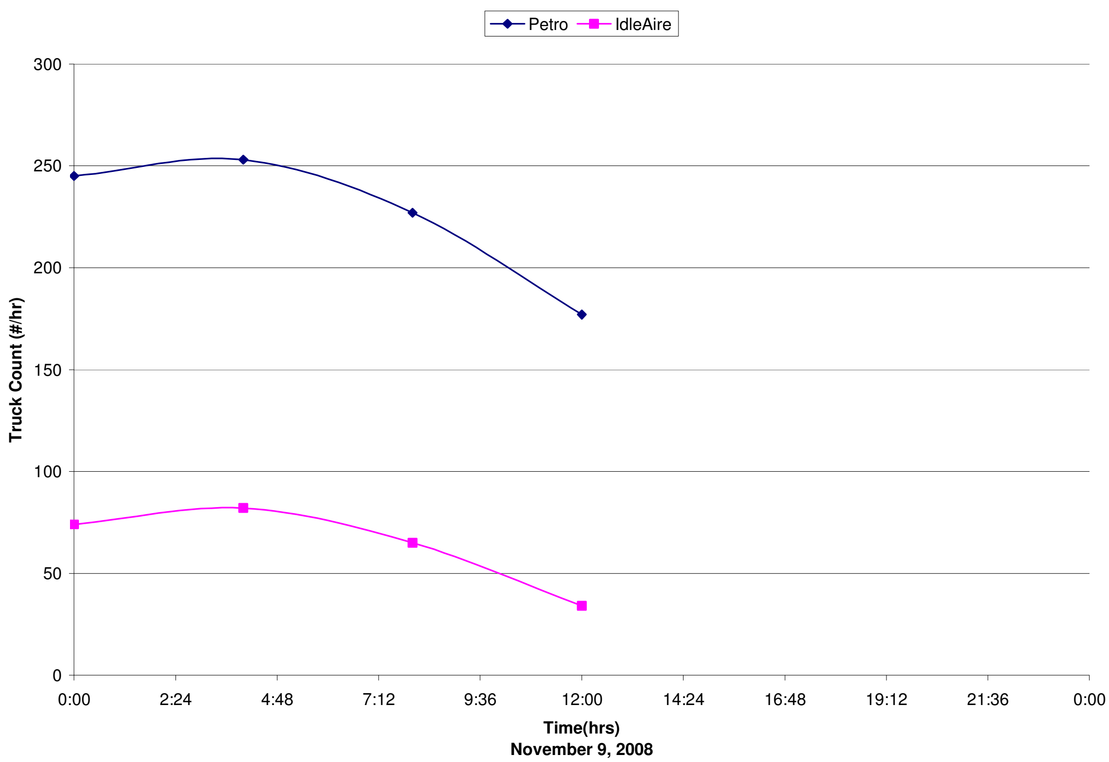
Time (hrs)
November 8, 2008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0:00
Time(hrs)
November 9, 2008

Curriculum Vita

Nancy Garcia was born and raised in Brownsville, Texas. Born the youngest child to Juan Antonio Garcia Sr. and Dora Hernandez Garcia, she was a 3-year graduate at Simon Rivera High School in 1999. Nancy entered The University of Texas at Brownsville in 1999, graduating with her bachelor's degree in Civil Engineering from The University of Texas at El Paso in 2006. While pursuing her bachelor's degree she published and presented "Silt Diversion for Bryan Mound" in the Mickey Leland Energy Fellowship Forum in Houston. Nancy worked for the Department of Energy's Strategic Petroleum Reserve in New Orleans, Louisiana where she assisted in designing for their Raw Water Intake Structure in Bryan Mound, Texas. In the spring of 2005, she entered Graduate School at the University of Texas at El Paso where she was a research assistant to the Civil Engineering Department Chair, Dr. Wen-Whai Li at the Air Quality Research Lab. Nancy earned her Masters of Science in Environmental Engineering in the fall of 2008 from The University of Texas at El Paso.