Use and comparison of Automatic Weather Observing System (AWOS) to study the incidence of Wind in the air pollution

By Saúl Canjura Jiménez and P.Ayala

Ministerio del Medio Ambiente y Recursos Naturales (MARN) Instalaciones ISTA
Servicio Nacional de estudios territoriales (SNET) San Salvador El Salvador
Phone (503) 22679563 cel phone (503) 77794232 fax (503) 22679520
Email saulcanjura@yahoo.com.mx scanjura@marn.gob.sv

ABSTRACT

Pollution is a worldwide problem in all climate weather conditions, San Salvador capital of El Salvador is not the exception in this problem. High grade of pollution has been detected by using mobile and stationary pollution stations in the city. The Government is doing a study trying to prevent bigger problem on pollution . The plan consist of the implementation of an Air Quality Monitoring Network with Automatic Weather Observing Systems (AWOS) of Meteorology and Pollution sharing the same monitoring site. The main objective is to study the pollutant levels and the tendency of Wind Speed and Wind Direction and make statistic, graphics and correlation with the pollution and compare this information with old studies about Air quality and Wind tendency in San Salvador.
San Salvador has mountains to South and west (green zone) and a relative flat zone to North and East (industrial zone) lately converted in a densely populated city air pollution is often identified with major stationary sources , but the greatest source of emissions is mobile sources, mainly automobiles.
In order to control the quantity and where the pollution accumulate or disperse the Enviroment and Natural Resources (MARN) has installed three air quality monitoring stations of continuous method measure (automatic analyzer) with meteorological sensors and is planning to install two stations more of discontinuous method measure (accumulative). This network has been designed to meet the basic monitoring objectives and must be capable of informing managers about many things including the peak air pollution levels, typical levels in determined areas, air pollution transported into and outside of the city , and air pollution levels near specific sources

INTRODUCTION

There is little data on air quality control in El Salvador. Between 1970 and 1982, air quality was monitored by the Red PANAIRE, parameters monitored: Material suspended particulate and SO2. From 1996 to 2002, Swisscontact and FUSADES, under the Clean Air Program, worked in the Air Monitoring Network in El Gran San Salvador. Parameters monitored: NO2, O3, PTS and PM10.
Since 2004, the Ministry of Environment and Natural Resources (MARN) works in conjunction with FUSADES to continue operating the monitoring network in San Salvador, In the same four monitoring points which are located in Santa Elena, Cologne Escalon, Hospital Maternity and Soyapango.

In the period 2004-2007 Fusades continuing with the collection of data, while the programme of decontamination of critical areas (DAC-MARN) air component (2002-2008) started working on studies of components weather (wind) based to historical data in the area of San Salvador, while preparing the groundwork for establishing air quality standards in El Salvador.In 2006 the company Eurolatina drew up an inventory of emissions and designs network Monitoring Air Quality.
The DAC project promotes the creation of a unit to monitor air quality in the country

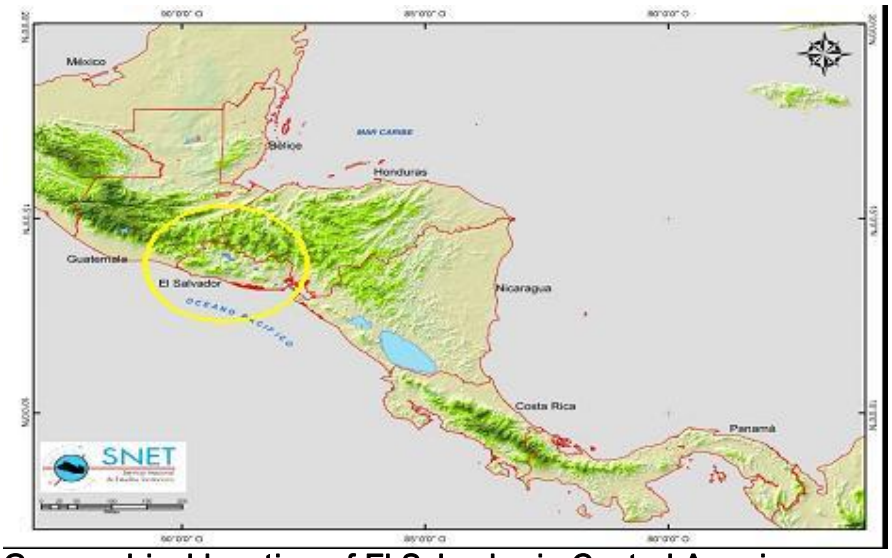
starting in San Salvador by acquiring the necessary equipment for this purpose which began operations in May 2008.
San Salvador is a small city and according to this is classified in an Urban Scale (4 to 50 Kilometers) this is the spatial scale most appropiate for the monitoring site type of air pollution.
These are some of primary pollutants that in general are being measured in differents places, SO_2, Nox, TPS, PM10, PM2.5, NO2, CO and secondary pollutant O3.
There are several pollution control technologies we are using the continuos methods (automatic analyzer) for measuring PM10, PM2.5, SO2, NO2,and CO But we will concentrate on monitoring the influence of meteorological parameters in particles PM10 and PM2.5 because they are the most common pollutants in the monitoring sites and we should mention that the PM10 is the highest concentrations presented in previous studies exceeding international standards.

Objectives of the new monitoring network

• Provide the public about air quality data (maps, Internet, weather forecasts)
• Give support to the development of air quality standards and emission reduction strategy
• Give support to research (atmospheric processes, impacts, measurement methods).

Geographic Location of El Salvador

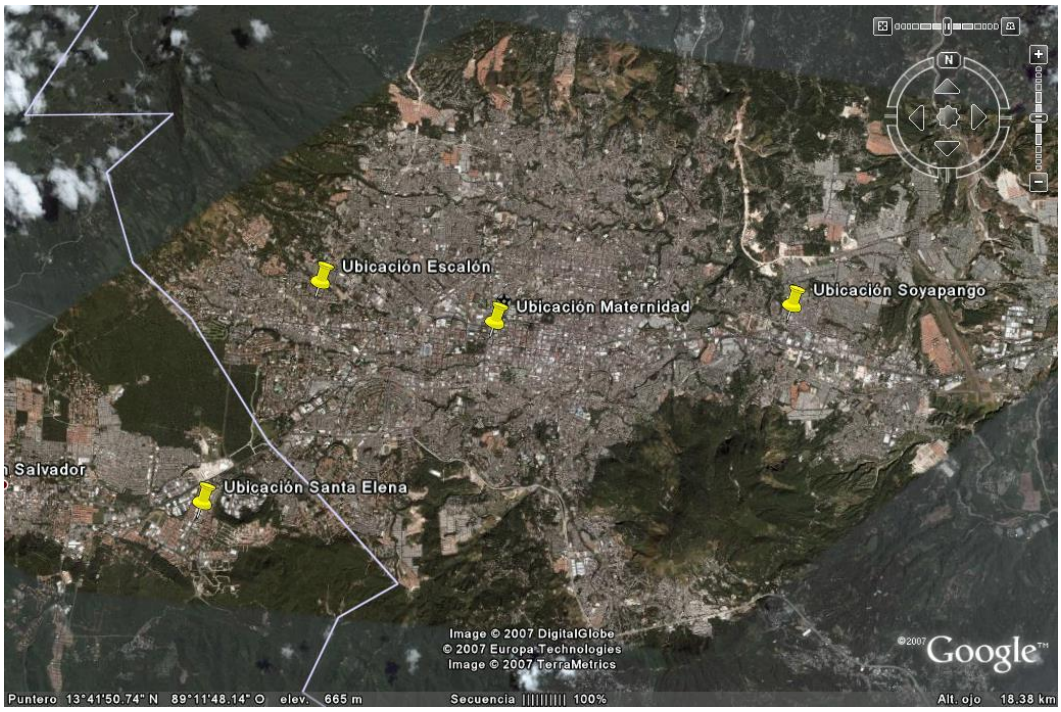
El Salvador is at a latitude between 13 º and 14 º North, or within the tropical belt that is between the Tropic of Cancer (23 º north of Ecuador) and the Tropic of Capricorn (23 º south of Ecuador). And a longitude between 89^0 and 90^0



Geographical location of El Salvador in Central America

Coordinates and places of sampling points of old network of pollutants monitoring installed in 1996.

Place	COORD_N (Latitude N)	COORD_W (Longitude W)
Santa Elena	13´40´10.28”	89´15´19.11”
Maternidad	13´42´07.86”	89´12´16.99”
Soyapango	13´42´14.54”	89´09´09.61”
Colonia Escalón	13´42´23.39”	89´14´01.15”



Location of monitoring points in San Salvador in 1996.

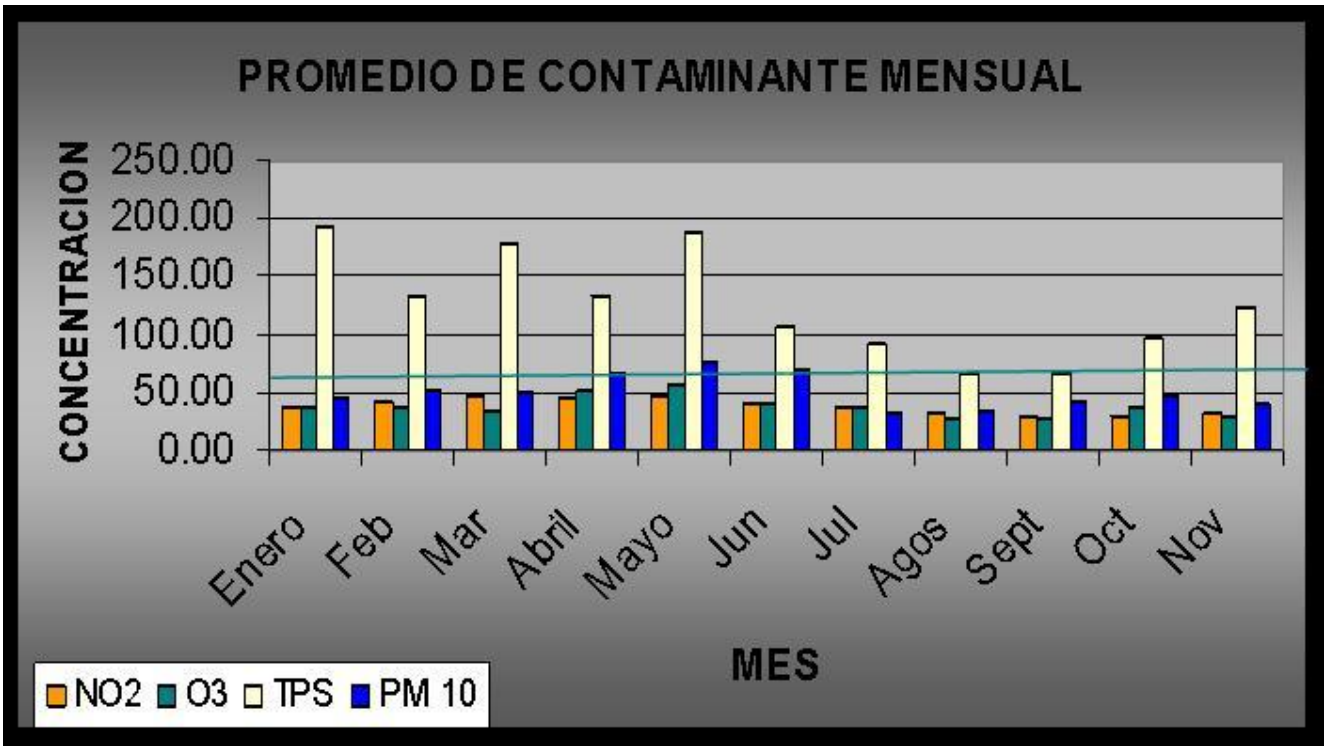
RESULTS OF THE MONITORING NETWORK INSTALLED IN 1996

Contaminante	Enero	Feb	Mar	Abril	Mayo	Jun	Jul	Agos	Sept	Oct	Nov
NO2	38.28	42.28	46.71	44.37	46.24	39.69	35.91	31.52	30.92	28.53	32.57
O3	37.99	36.32	34.32	52.37	57.46	38.38	38.28	26.87	26.96	36.77	29.92
TPS	192.52	134.39	178.02	133.85	189.29	107.35	91.49	65.71	65.83	95.48	123.12
PM 10	45.54	51.73	49.51	65.69	75.61	68.43	31.93	34.30	42.02	47.84	39.51

Monthly averages of contaminants in San Salvador in 2007 in ug/m3, measured in the network installed in 1996.

SITIO	Dióxido de Nitrógeno	Ozono	TPS	PM 10
Santa Elena	32.74	36.16	127.85	37.90
Cercanias Hospital de Maternidad	50.98			68.70
Soyapango	39.00			56.13
Colonia Escalón	28.92	39.46	122.52	38.04

Geometric Average Annual pollutants by sampling site
in ug/m3 2007 year, measured with network installed in 1996.

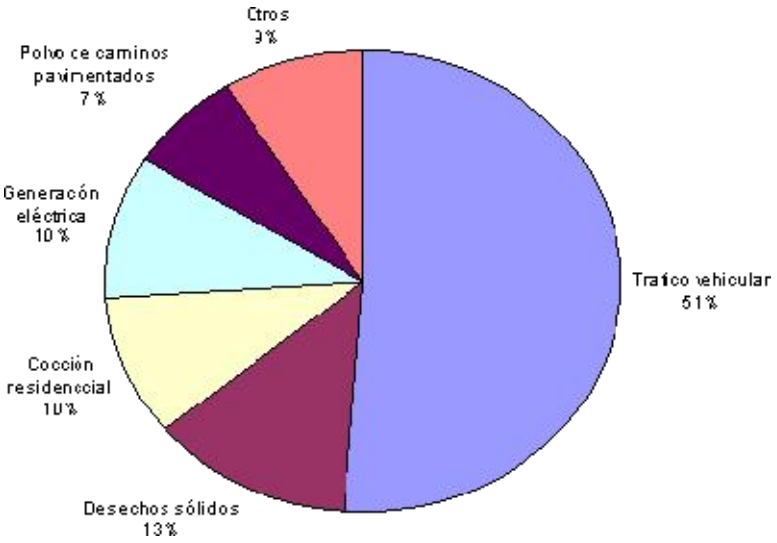


Average Pollutant per month in 2007.

Based on the data and graphs provided; it can be observed that the point located at Maternity Hospital has the largest pollution presents,in the parameters of nitrogen dioxide and particulate matter PM 10, these are very dangerous to human health.
The results of contaminants evaluated, total suspended particulates showed an increase of 67% compared to the standard of 50ug/m3 per year (Green Line) established by world health organization .
Based in this results: El Salvador has decided to follow the studies with continuous methods and using automatic equipment for monitoring pollutants and meteorological parameters at different points to corroborate the results specifically for particulate matter PM10 and PM2.5.

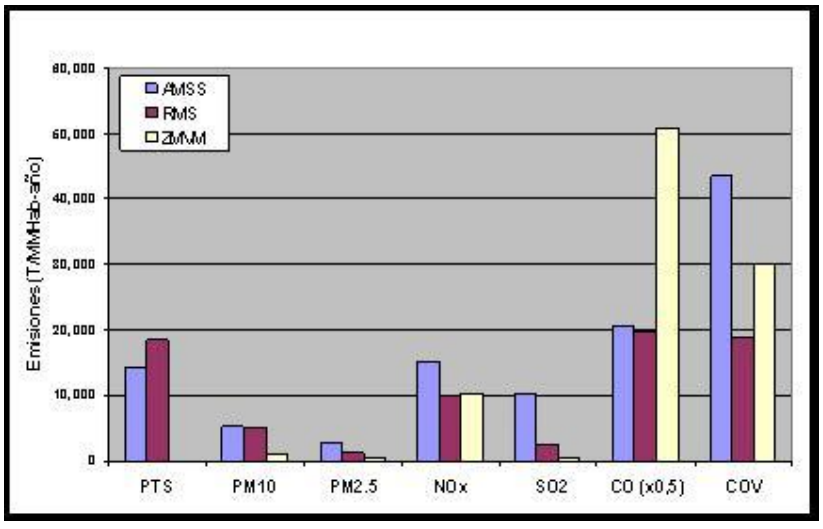
DESIGN OF THE NEW MONITORING NETWORK SPONSORED BY MARN

The company Eurolatina, prepared this study in 2006 based on data for the year 2003 They (Eurolatina) made an inventory of emissions on the basis of which they designed the new air pollution monitoring network. It can be seen in the graphic results of this study.



Distribution of atmospheric emissions in the metropolitan area of San Salvador (AMSS)

We can see that vehicular traffic contributes over 50% of atmospheric emissions in the AMSS.



Graph showing a comparison of emissions of pollutants from metropolitan areas in different countries.

In the graphic are the abbreviations that identify: (AMSS) Metropolitan Area Great San Salvador, (RMS) Santiago Metropolitan Region of Chile, (MCMA) metropolitan area of the Valley of Mexico.

According to what was observed in the graphs; it could be seen that the problem of pollution in San Salvador is serious, since, relatively few people have higher concentrations than larger cities.

Based on the inventory of emissions in the city of San Salvador the company used a model of dispersal of air pollutants (Model ISC3) to estimate concentrations of pollutants in the AMSS comparing them with national standards in approval process and so choose points more adequate for monitoring.

Aerial Photography of AMSS showing a map of Isolina model pollutant dispersion ISC3 with the annual average PM-10 in ug/m3 for comparing with the Standard Reference 50 ug/m3 per year.

In the same way the model ran for pollutants PM-2.5, SO2, NO2 presenting the same behavior in concentrations; higher in the center of AMSS and decreasing around the city. Therefore, the installation sites were chosen (see photo below).

Aerial photograph of AMSS we can see the installation sites and the pollutants monitored in the new network installed in 2008

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Geographic Location of AIR Pollution Stations (Automatic)
For recent Study.

Location	Pollution Station	North latitude	West Longitud	Elevation m.s.n.m.
Soyapango	Universidad Don Bosco	13° 42.913	89° 09.289	632
San Salvador	Asamblea Legislativa	13° 42.400	89° 12.110	633
San Salvador	CODEM	13° 6873	89°2315	766

Taking into account that we need a continuous recording to study the variation of the contaminant, has been installed sensors of rain and wind speed and direction in the three sites that have automatic stations to observe if the dispersion of pollutant concentrations are influenced by wind .
In two months the project is going to install two more equipment (discontinuo) around the city, in order to improve the monitoring of PM10 and PM2.5

In addition to the factors described to define the number of equipments to install (according to international standards) the factor of the topography characteristic of the metropolitan area of San Salvador (irregular) increases the number of monitoring units. When observing the monitoring sites, they (sites) show little difference in elevation and the distances that separate them are similar (5 km) which is in the area of coverage established for a weather station.

EQUIPMENT INSTALLED FOR MONITORING AIR QUALITY WIND AND RAIN

Esc Model 8832 Data System Controler
Model BAM 1020 PM10 Analyzer (2)
Model 700 MASS Flow
Model 300E/EM Carbon Monoxide Analyzer
Model 100E UV Fluorescent SO_2 Analyzer
Model 701 Zero Air Module
Model 200E Nitrogen Oxides Analyzer
Model 05103-11 Anemometer Young
Model 5600-0425-2 Rain Gauge Sutron
Model 8210 Data Collection Platform Sutron

PM10 analyser model PAM1020

Its operating principle is beta attenuation, wich measure the density of particles trapped in a filter through a small source of beta rays coupled to a detector that counts the beta particles emitted.When high-energy electrons emitted from a source radioactive ^{14}C interact with the matter these lose their energy and in some cases is absorbed by the matter. These high-energy electrons are called beta rays, and the process Beta rays attenuation.

There are two PAM1020 one is measuring PM10 and the other one measures PM2.5 the difference is a second filter added to PAM1020 of PM2.5

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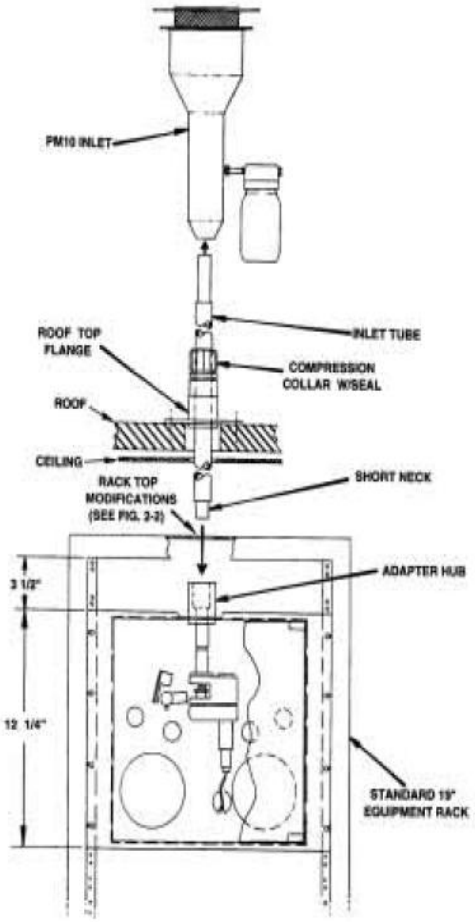


Rain Gauge

Stainless Steel Rain Gauge Tipping Bucket, 5600-0425, is a precision instrument with a sensitivity of 0.2 mm. Per trip. The gauge should be located on the prevailing wind side of any obstruction so not to disrupt rainfall measurement.

Rain entering through a funnel assembly with an 7.87-inch (200 mm) orifice passes through a debris filtering screen and is funneled into one side of the tipping bucket assembly inside the gage. The bucket tips when a given amount of water, determined by gage calibration, has been collected. As the bucket tips it caused a magnet to pass by a ruggedized mercury switch, momentarily closing the switch,. The tipping of the bucket brings a second bucket into position under the funnel, ready for filling. After the rainwater is measured, it is directed into drain tubes that allow it to exit out in the base or the gage, screens to prevent insect entry cover these.

Wind Sensor

The wind monitor measures horizontal wind speed and direction. Propeller rotation produces an AC sine wave signal with frequency proportional to Wind Speed. This AC signal is induced in a stationary coil by a six pole magnet mounted on the propeller shaft. Three complete sine wave cycles are produced for each propeller revolution.

Vane position is transmitted by a 10K ohm precision conductive plastic potentiometer wich requires a regulated excitation voltage. With a constant voltage applied to the potentiometer, the output signal is an analog voltage directly proportional to wind direction angle

The wind speed input uses a slope of 0.1904 and offset of 0.0 for units of knots. If units of meters per second were desired, a slope of 0.098 and offset of 0.0 would be used. If kilometers per hour were desired as the units of measure, a slope of 0.3528 and offset of 0.0 would be used. For the wind direction input, a slope of 72.0 and offset of 0.0 are used for degree (°) unit of measure.

These averages are calculated by the operating system according to the Sample Time, Sample Interval, and Sample to Average in the Measurement Schedule Setup. Upon receipt unit, is configured to sample the input every second and produces the average every two minutes. The average wind speed (WSA) AND DIRECTION (WDA) are also logged.

Monitoring Station with Air Pollution and Meteorological Sensors

Sampling, Analysis Techniques, and Data Collection.

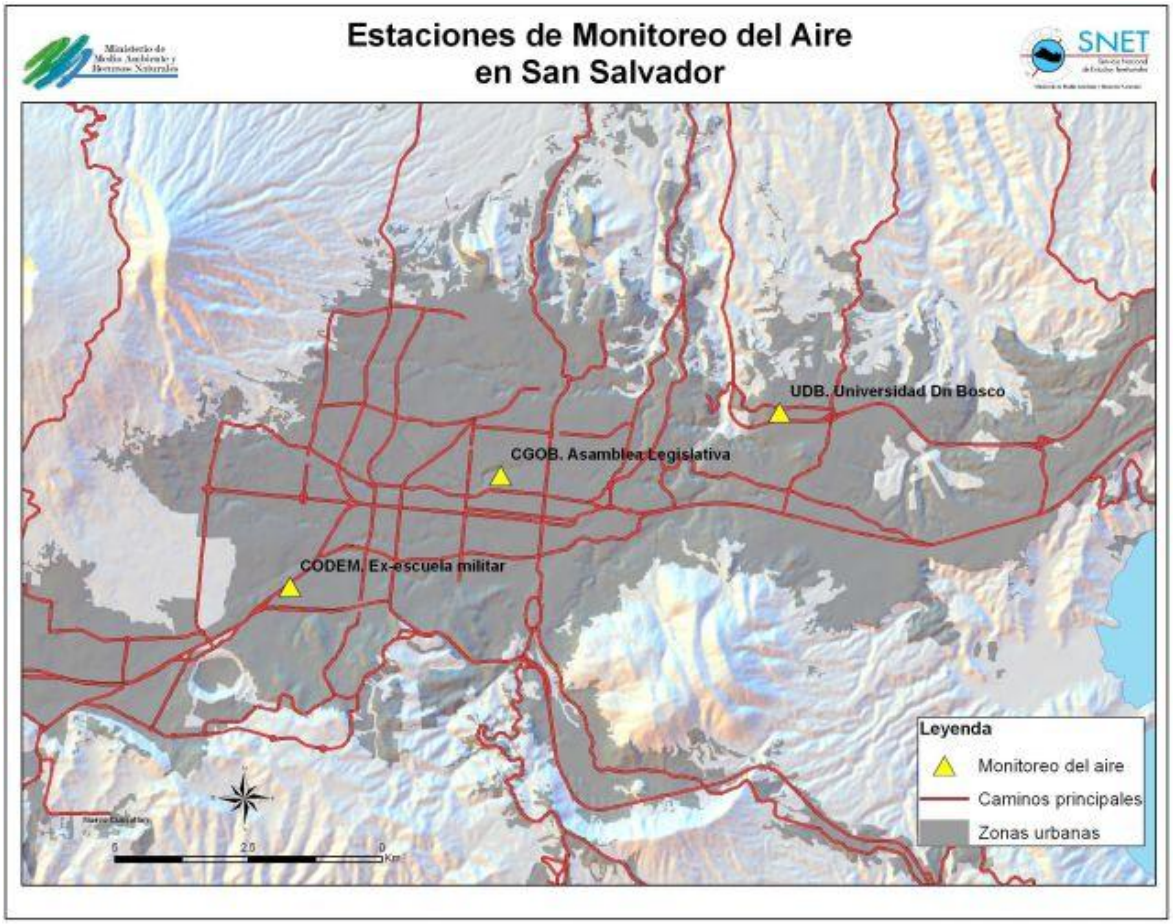
Besides the sensors were installed two dataloggers performing the task of recording and processing data from meteorological sensors and air quality, to process data from air quality is available a software with a datalogger as follows:
The E-DAS Ambient for Window software provides powerful data acquisition, processing and reporting capabilities within an easy-to use operating environment. The E-DAS Ambient for Windows software is a 32-bit application and can fully utilize the multitasking and memory management capabilities of Windows. The data system consists of two primary components:ESC, data logger sensor interface to which sensors are connected And E-DAS Ambient software.
The first component is the ESC Logger sensor interface to which sensors are connected. The data logger scan the inputs approximately once a second, digitize the analog signal, and scale the values to engineering units. The data loggers then calculate hourly averages and other (minute, fifteen-minute) averages as needed. These averages are delivered to the other primary component, the E-DAS Ambient software package.
The E-DAS Ambient software is a menu-driven package that runs under Microsoft Windows 98, NT, 2000, or XP on PC-Compatible computers. The central PC connects via dial-up, cellular, or radio modem to one or more data loggers or the PC can be connected directly to the data logger via a serial port.
In the E-DAS Ambient software, an operator enters configuration about the instruments connected to the data loggers. The software stores and downloads configuration information to the data loggers, then polls for (requests) data averages and other information from the data loggers automatically, at regular intervals, or when manually initiated by the operator, in our case we got data of air pollution by laptop, connecting this one via a standards RS-232 cable every seven days.
Graphs or tables of information, such as average data and calibration data, can be generated to the display screen, a printer, or a file.

The Sutron Data Collection Platform (DCP) 8210 Data recorder is specifically designed to meet a wide variety of data and applications, this time it´s being using to collect and log meteorological data of wind speed and direction and rain ,it runs a software of differents versions and sometimes executes tiny basic routines for special applications These operations may range from simple data recording to transmission via satellite or other telemetry links. The time to poll and log can be programmed by the user we used a measurement interval of 00:02:00 and Sample interval 00:00:01. The units of measure are determined by the slope and offset of the sensor configuration in the 8210.

The 8210 data recorder has been designed to use small RAM Cards to move data from the log memory to other computers for processing.It is possible to store the data from multiple sites on a single card as space permits. The procedure to retrieve data from a station requires a minimum of effort and expertice We retrieved data every seven days by this system.
A card reader is used to read the PCMCIA card used with the 8210.The RAM card readers connects to a serial port on a PC using program that convert data to ASCII form After we convert this information in spreadsheet excel to process the data.

The equipment was installed at the beginning of May 2008, provides a series of data of few months but the sampling frequency of data has led to initial studies of the parameters of interest.
The data was processed in Excel, and a graphic form was used to illustrate the behavior

of the parameters for a period of three days with little rain to avoid disruption in parts of the graphical of particulate.

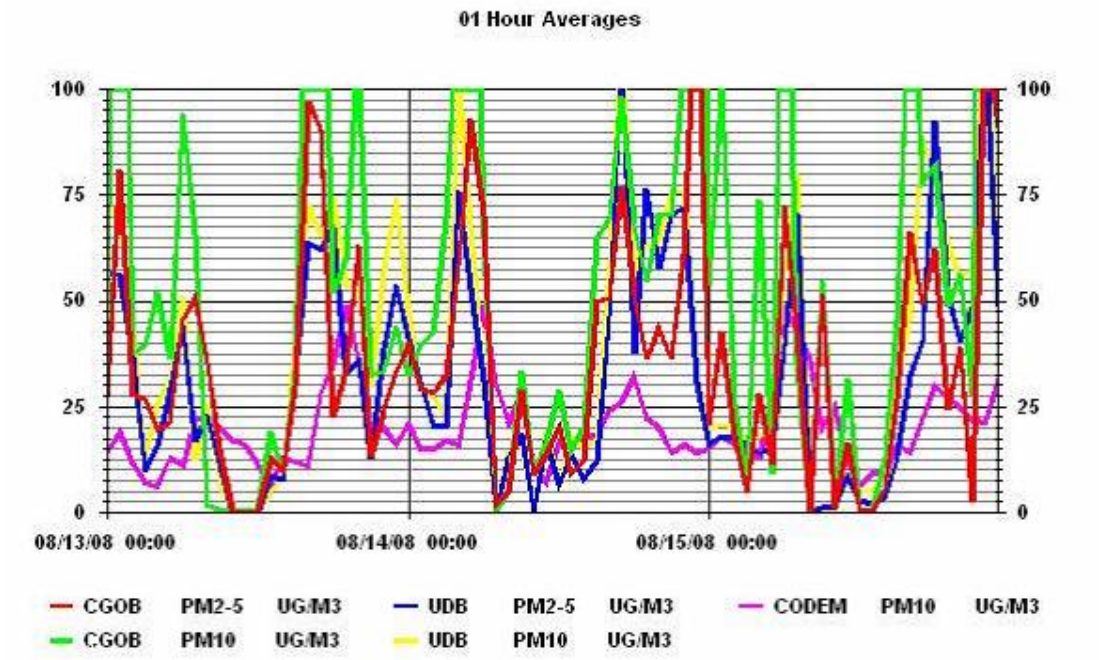


Topography of San Salvador

One important factor in the variation of the wind in the cities is the topography ,this include volcanoes, hills, basin rivers, buildings etc.

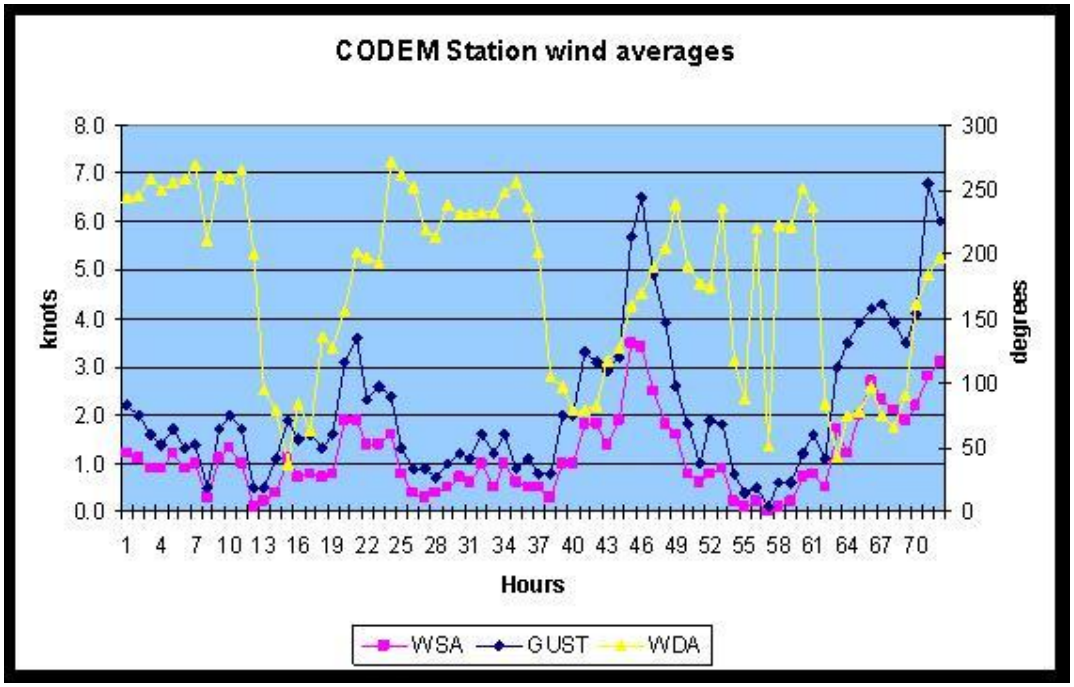
San Salvador and its metropolitan area is situated on a relative flat surface with several basins of small rivers , with a height between 600 and 800 meters above sea level, along which is located one volcano. This plain is bounded to the east by Ilopango Lake (438m) the West by San Salvador Volcano (Boquerón and Picacho with 1967 meters). To the south, this whole area is bounded by the Cordillera del balm with maximum heights of 1100 meters and the Cerro San Jacinto with 1154 meters with a semicircular morphology south of the hill which is interpreted as the remnant of the collapse of an ancient volcanic structure . To the north is an area of low hills with a maximum elevation of 798m in the hills of Mariona.

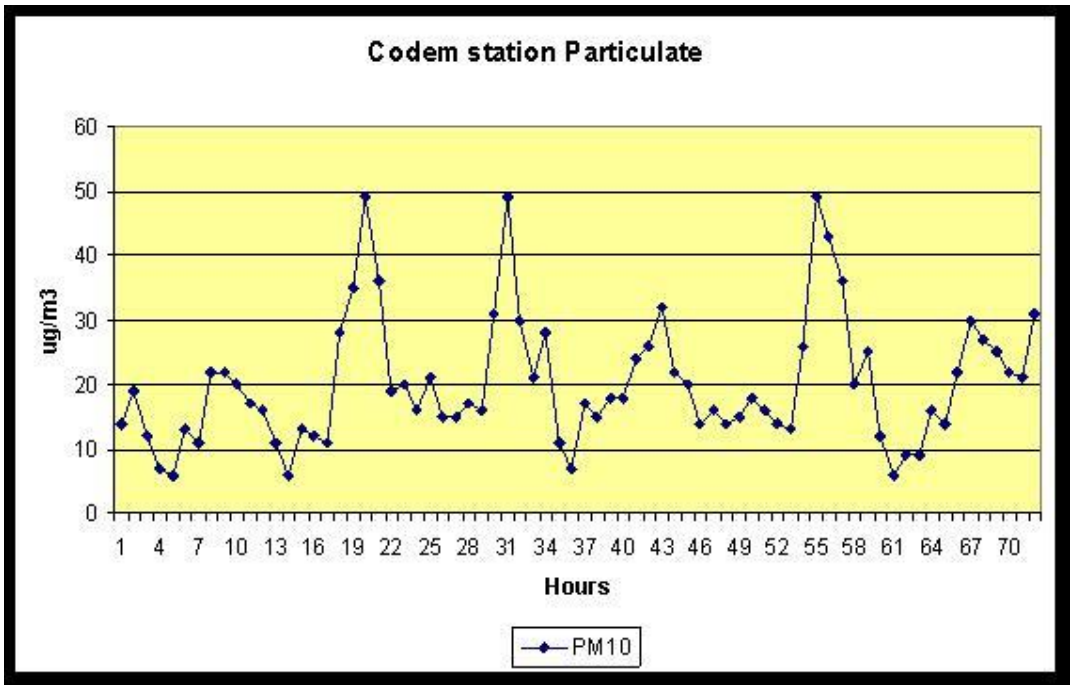
Results

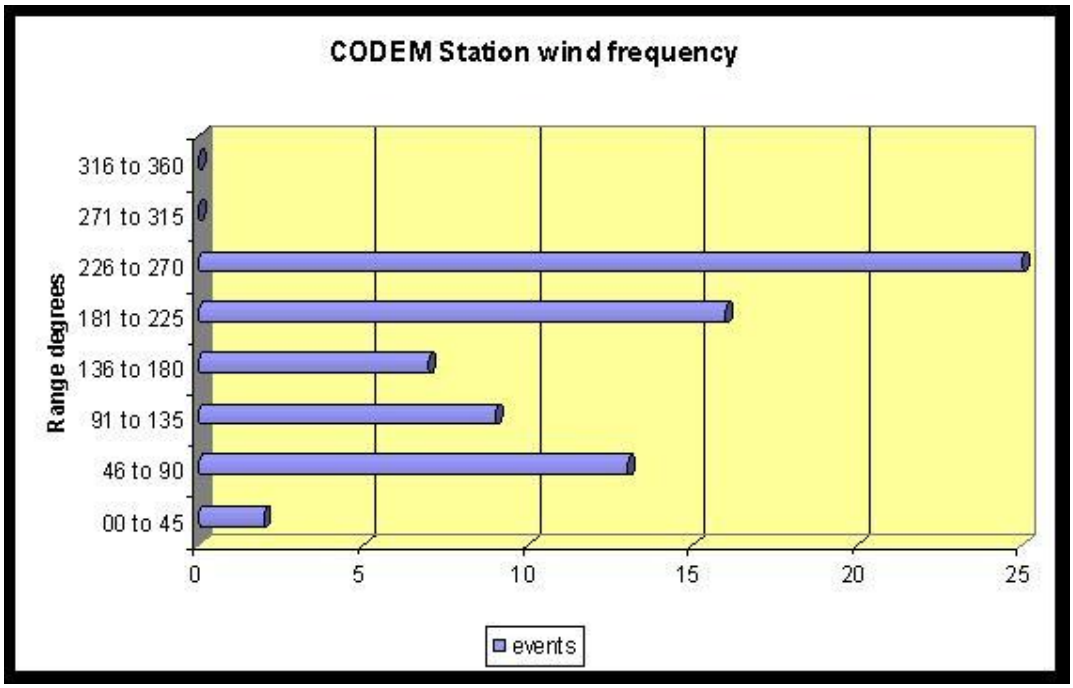


GRAPHICS of PM10-PM2.5 of CGOB, UDB,CODEM from 08/13/08 to 08/15/08

These values were obtained in the three monitoring stations for three days, it can be observed that levels of particulate PM10, PM2.5 have increased compared with the values obtained in 2007 during the first monitoring in the city of San Salvador . CGOB station (Central government) has the highest values recorded 375 ug/m3 PM10 and 140ug/m3 PM2.5 followed by UDB (Don Bosco University) 125 ug/m3 PM10, 115 ug/m3 PM2.5 ug/m3 and CODEM (Control operations staff) with 50ug/m3 of PM10.







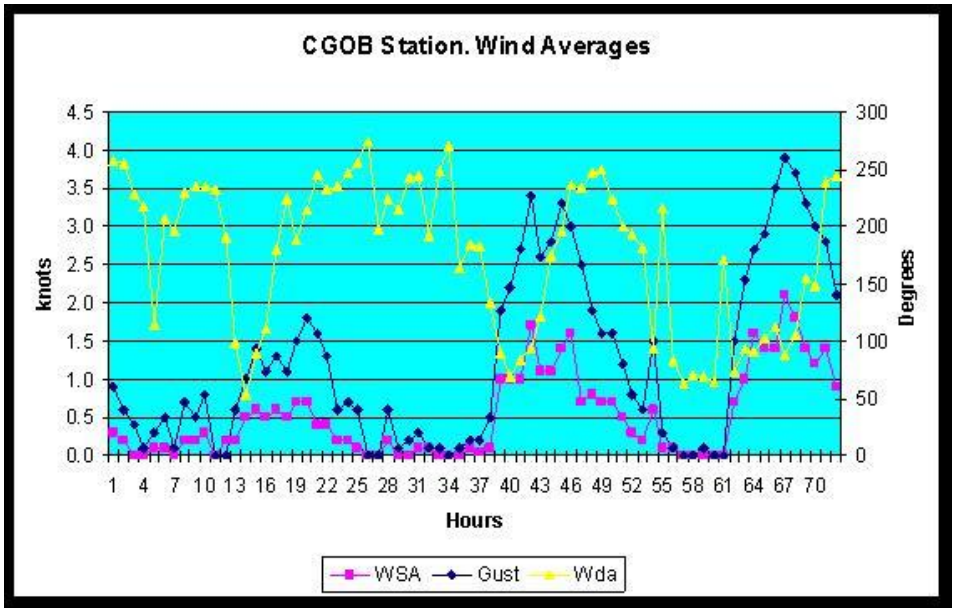
Graphics for Station CODEM

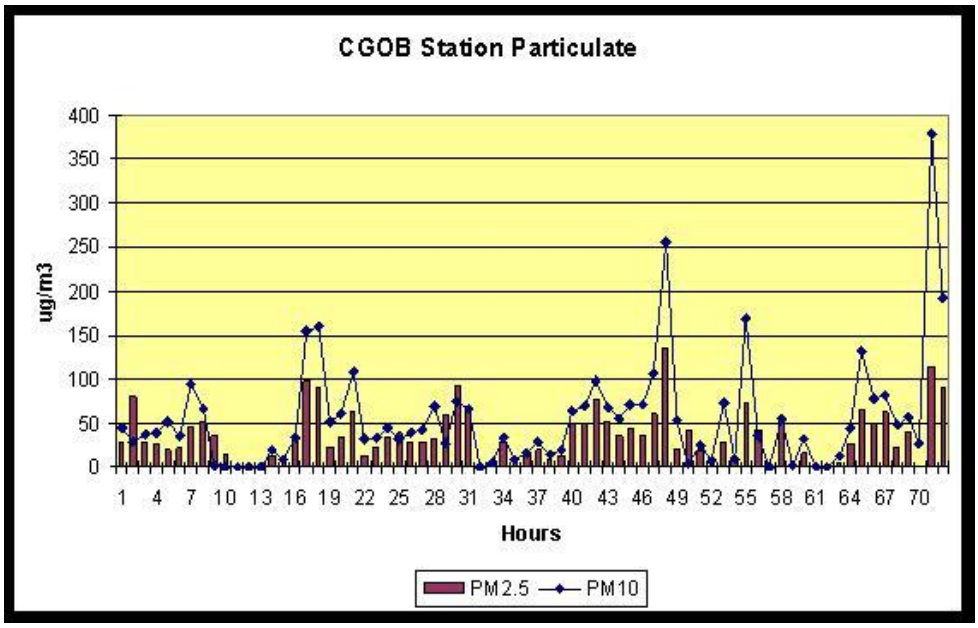
This station was installed in the SW of San Salvador in a residential zone, where there are shopping centers and main roads in the vicinity, but compared with the other two points of monitoring its population; is relatively minor, this station has only recorded levels of PM10 . From the graph of frequency of wind direction it is observed that prevails in this station the wind direction between 270-226 degrees (W, SW) and 225-180 (SW-S) degrees with minimum winds north. The wind speed is proportional to the events of gust, in this site were recorded gusts of greater intensity (6.5 knots), The wind speed has an average in 3 days of 1.8 knots peaking at 3.5 knots This is consistent with previous studies on the wind

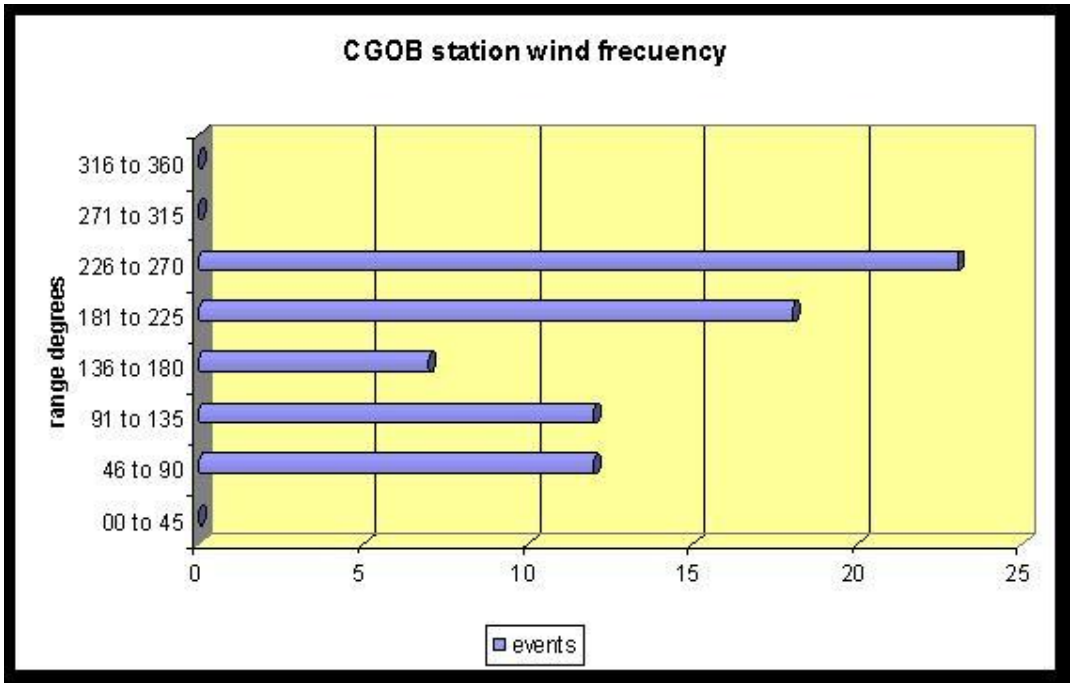
in San Salvador made with data series for several years and registered with anemocinemografos in not too distant points of the current which have achieved average wind speed less than 6 knots. It is important to take into account those same studies that have recorded surface winds in the metropolitan area of San Salvador, wich are more intense in the dry season than in the rainy season.
Also, it is noticeable that in the 3 days the wind increases its intensity in the final hours of the afternoon and had an upward trend in values from the first day to third day.

In the early morning hours the wind decrease speed and is remarkable that when it's from SW stabilizes speed, when the direction changes to the N reduces the speed and when changes to SW increases the speed again keeping the cycle.

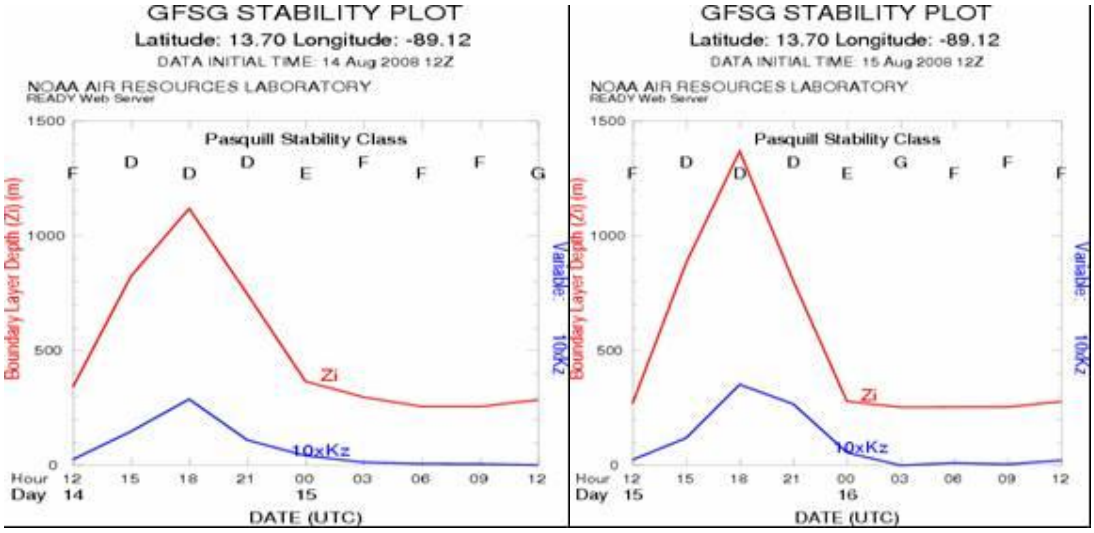
With regard to pollution concentration is high when the wind is low (there is less dispersion)
The maximum value of PM10 reached in this station is of 50ug \ m3 and makes every day in the morning from (6 AM) to (8 AM) and begins to decline, reaching values Lowest at noon, starting to raise again at approximately 18 hours, both peaks are in the greatest vehicular hours activity.
On August 13 rained from 07:16 AM until 12:00 (32.8 mm) which contributed to dissolve the particulate and it was unable to reach their maximum concentration.







GRAPHICS FOR STATION CGOB

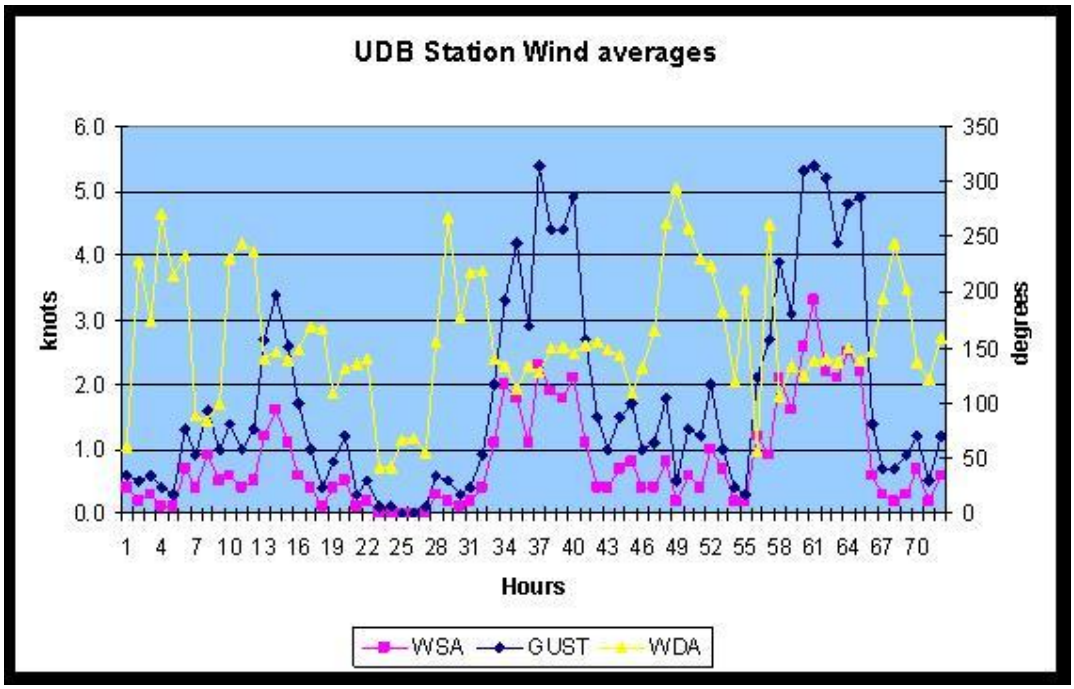


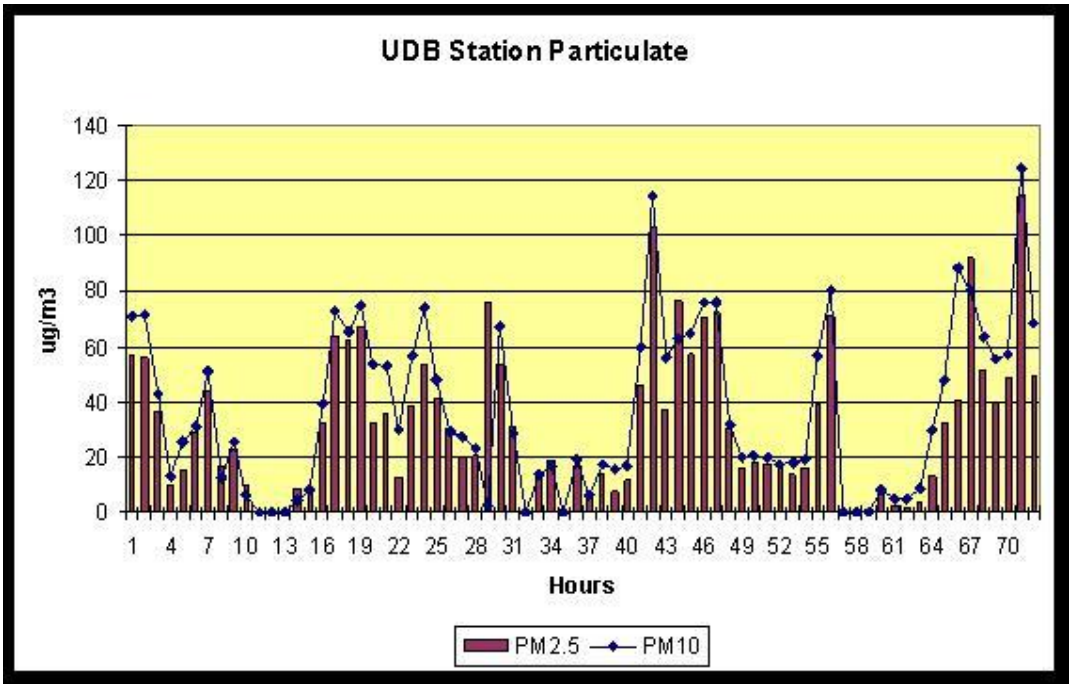
STABILITY PLOT 14 AUGUST 2008 STABILITY PLOT 15 AUGUST 2008

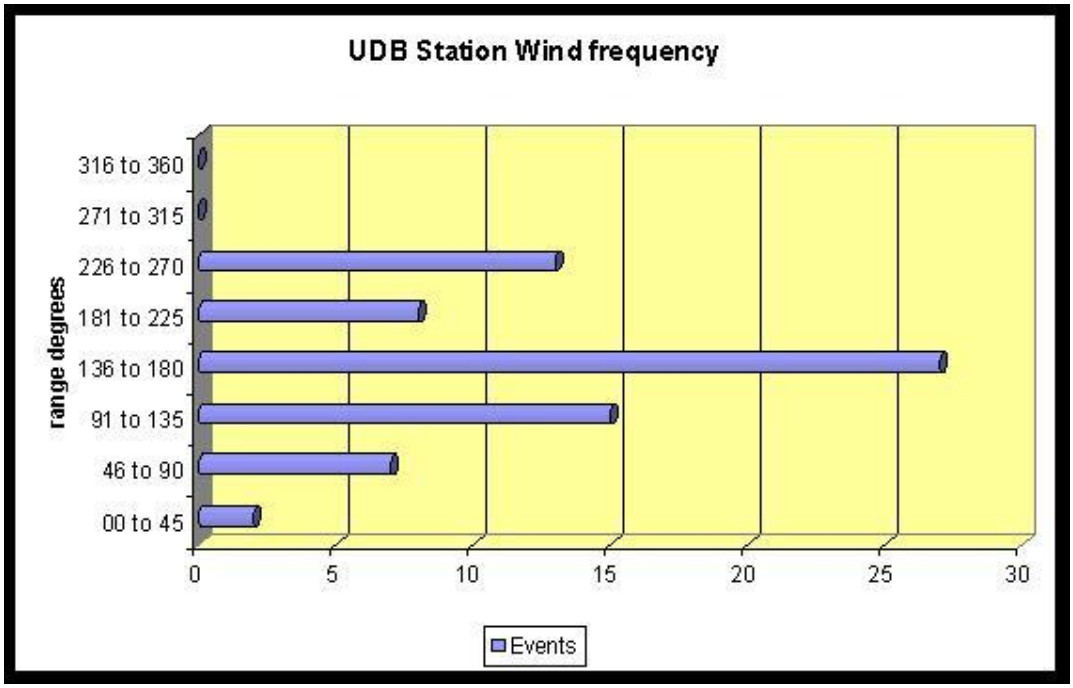
This station CGOB (Government Center) is located in the center of the metropolitan area where we have the greatest concentration of vehicles, in the graphs we have the largest concentrations of PM10 and PM2.5.
Also recorded the lowest wind speeds probably by the influence of the buildings located at SW that is from the prevalent wind comes.
The direction of the winds (SW) is almost identical in the same hours at the CODEM station .Something similar happened with variations in the wind speed there were increases in the last hours of afternoon ascending from first to third day.
The wind is low when the particulate is high; in this station the particulate maintains high values until midnight and starts to go down in the first hours of the morning.
Variations in the concentration of particles are similar to CODEM values rising at 6 A.M. and 6 pm. Keeping the high levels for almost four hours.

We can see two charts that contain information of atmospheric stability class of Pasquill for 14 and August 15 predicted by NOAA Air Resources Laboratory for Ilopango Station, these conditions may be valid for the metropolitan area of San Salvador because the station covers a radius of approximately 10 km At AMSS; then the conditions of atmospheric stability applies to the 3 Stations installed in AMSS.

It is notable that in the morning and evening there is a class of stability F (moderately stable) in the category Pasquill, and a class D (Neutral) from 9am to 3pm; with a category E (slightly stable) at 6pm.
With these conditions we can see in graphics that category F has the lowest wind speeds and there is more concentration of pollutants and the boundary layer is lower (between 200 and 350 meters) and has little vertical convective transport (little or no vertical dispersion of pollutants) in these periods are recorded the largest concentrations of the pollutant coinciding in hours with the increased vehicular activity. From 9am to 3 pm there is stability D (neutral) which is characterized by not stimulates nor inhibits the vertical movement of air; in this period the boundary layer rises to values between 700 and 1350 meters and there is decline in the concentration of pollutants and it is effective dispersal.


UDB Station Wind averages
knots
degrees
Hours
WSA
GUST
WDA

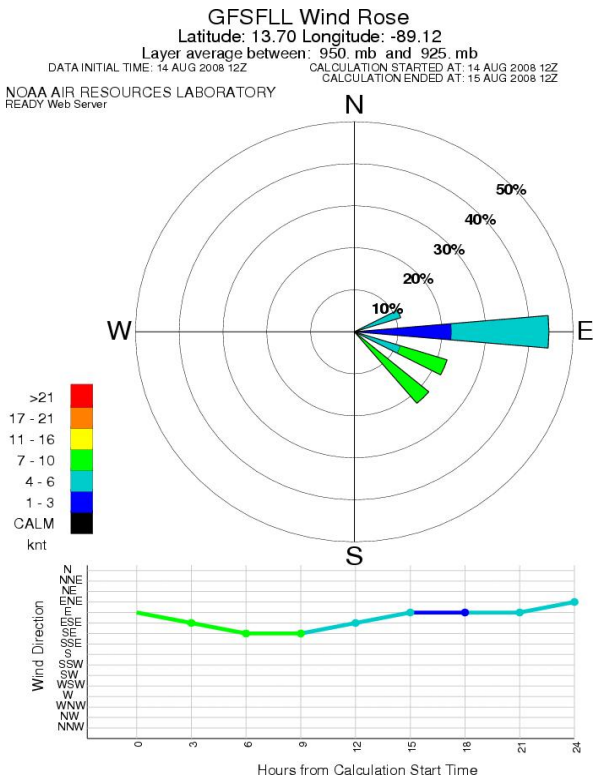

UDB Station Particulate
ug/m3
Hours
PM2.5
PM10

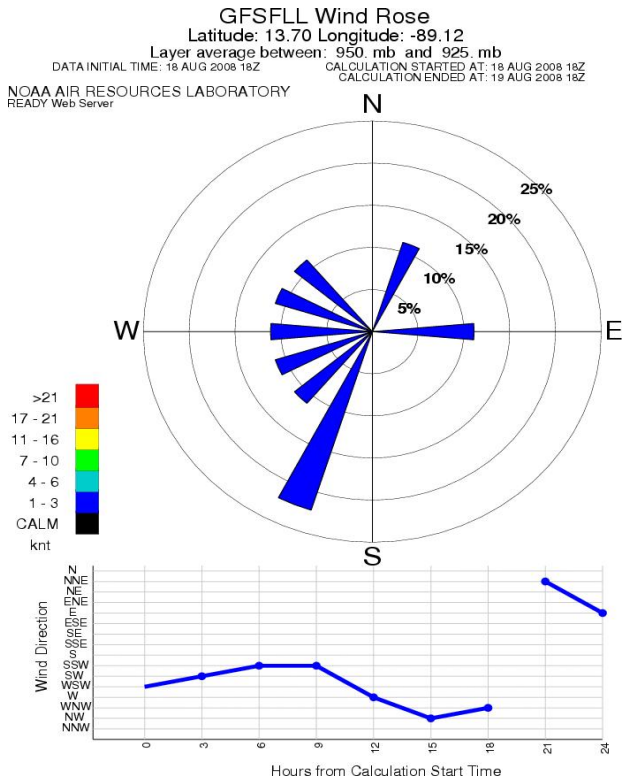


GRAPHS OF UDB STATION

This station is located to the north of metropolitan area with a lot of population around and forest areas and no paved roads to the north.

The PM10 particulate concentrations is similar to PM2.5 this high concentration of PM2.5 is likely caused by combustion process in the next industrial zone to the South.
The diurnal variations of PM10 and PM2.5 are similar to CGOB with lower concentrations in this Station (UDB)..
The wind speed is slightly higher than the speed of CGOB, previous studies with anemocinegrafo in Ilopango station located 4 kms to the NE determined prevailing wind NE in this month of the year, however observing the graphics; has prevalents winds from SE-S and in the order E-SE, SW-W, NE-E winds and by moments coincide with the winds predicted by NOAA Air Resources Laboratory for the station Ilopango on the same days (see chart below).





FORECAST OF WIND FOR ILOPANGO STATIONS (NOAA AIR RESOURCES LABORATORY)

Conclusions

The concentrations of PM10 and PM2.5 exceed the values calculated with the model pollutant dispersion ISC3 based on emissions inventory, if agreed to forecast the largest concentrations in the center of the city.
CODEM and UDB do not exceed the permissible level of concentration of PM10 (150ug/m3) within 24 hours, if exceeded CGOB.
CGOB and UDB exceed permissible levels of particulate PM2.5 in 24 hours according to international standards used in our country 65ug/m3 within 24 hours.
High PH concentration was detected in rain in the 3 stations (3.8,3.2,2.8) if SO2 is low then the NOX are producing this problem.
The winds in the metropolitan area of San Salvador are variable by sector speeds are low in the period measured, confirming previous studies where values are not exceeded 4.5 knots average values and confirming meteorological texts where it is mentioned that in these latitudes generally winds are weak and variable.
These speeds are not high contribution in horizontal convective transport.
There is efectival dispersal when we have Stability D (neutral).

To check that the prevailing wind SW, W does not have an influence of wind from volcano of San Salvador is necessary to install a weather station on top of the mountain (range of balm) to determine whether the trade winds from SW are causing this wind prevalent in stations CODEM and CGOB and to a lesser extent in UDB, with this trend is assumed that part of the particulate of CODEM is transferred to CGOB this could be analyzed when the direction of prevailing winds changes, which according to studies previous with conventional equipment (anemocinemografos) it happens in San Salvador in different months.
It is necessary to record these database in at least one year to determine whether the concentration of pollutants is varying , depending of wind speed and direction.

The series of processed data is relatively short to study all variations of wind and its influence on the dispersal and distribution of the pollutant, but is the beginning of a study showing interesting aspects, this will be strengthened with the use of a dispersion model atmospheric of recent acquisition and the adaptation of MM5 model to forecast winds per hour at 10 meters in San Salvador Area for purposes of comparison. Moreover complement the meteorological stations with additional parameters for further studies.

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