ABSTRACT

LEWITSKY, JEFFREY RYAN. A Southeastern United States Site Characterization Involving Black Carbon Aerosol Concentrations and Meteorological Variables. (Under the direction of Dev Dutta S. Niyogi and Fred H. M. Semazzi).

Aerosols present in the Earth's atmosphere play a crucial role in global meteorological conditions. If there is a larger concentration of aerosols then there may be a resulting variance in the weather and climate. One particular aerosol, which was measured and observed for this study, is black carbon. The presence of black carbon concentrations could result in a variance of certain weather variables at any given location. Black carbon aerosols absorb incoming solar radiation, which can impact the vertical temperature profile. A comparison of results can be made between weather and climate conditions in which a significant amount of black carbon is present, and other conditions with minimal amounts of black carbon in the troposphere. The observed data analyzed is from the Lake Wheeler site, a semi-urban location near the threshold of the piedmont and coastal plain zones of central North Carolina. The period for evaluation is June 2003 through May 2004. The weather variables that were closely examined include air temperature, dewpoint temperature, relative humidity, wind speed, and wind direction. In addition, radiation data was collected and analyzed including solar radiation, photosynthetically active radiation (PAR), net irradiance, diffuse radiation and direct radiation. Aerosol optical depths (AOD), which are the measurement of light attenuation at specified wavelengths, were also collected and evaluated in both the ultraviolet and visible light spectrums. This was done in order to determine any relationships between black carbon concentrations and AODs at certain wavelengths. After examining the

year's worth of data a site characterization involving the black carbon concentrations and meteorological variables for the Raleigh, NC location was devised.

A Southeastern United States Site Characterization Involving Black Carbon Aerosol Concentrations and Meteorological Variables

By

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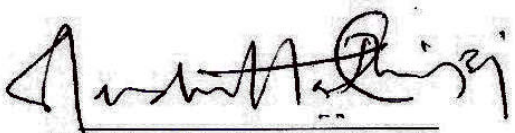
A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Master of Science

MARINE, EARTH, AND ATMOSPHERIC SCIENCES

Raleigh, North Carolina

2006

APPROVED BY:



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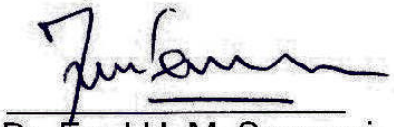

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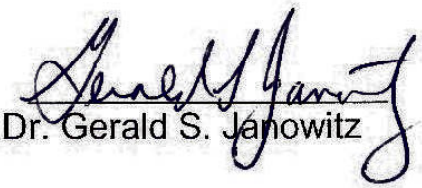

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DEDICATION

Dedicated to Lorenzo Piczon Agustin

BIOGRAPHY

Jeffrey Lewitsky was born in the city of Welland, Ontario, Canada on 2nd November 1980. He moved to Raleigh, North Carolina in August 1990, where he attended Ravenscroft School for his early education. Jeffrey graduated from high school in June 1998. In August 1998 he went on to study at the University of North Carolina at Asheville, where he would eventually receive his Bachelor's of Science degree in Atmospheric Science with a concentration in Weather Forecasting in May 2002. He went on to pursue his Masters of Science degree in Atmospheric Sciences at North Carolina State University in August 2003. He currently works for the National Weather Service in Eureka, CA.

ACKNOWLEDGEMENTS

The author is truly grateful for all of the advice and inspiration that the members of his advisory committee have given over the past 3 years. Dr. Niyogi helped to develop the original idea of a study involving black carbon aerosols and meteorological variables by utilizing data from a site near Raleigh, North Carolina. The author would also like to thank the department of Marine, Earth and Atmospheric Sciences for providing financial assistance from 2004-2005, which ultimately allowed this project to continue. Additionally the author would like to thank the National Weather Service weather forecast office in Eureka, California for supporting him in his pursuit of this degree.

The author would especially like to thank his parents, Jerry and Mary Lewitsky of Raleigh, North Carolina, his sister Miranda Lewitsky of Austin, Texas, all of his family in Canada and abroad. In addition, Jeffrey is extremely thankful and appreciative of the support and kindness of his lifelong friends Lorenzo Agustin and Angela DePoy. Each of the above has provided continuing encouragement and strength throughout the author's time at North Carolina State University and beyond.

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1. INTRODUCTION

1.1 Introduction and Background

Currently there is a great deal of debate and discussion in the scientific and public communities as to whether or not our population is altering the earth's atmosphere and environment due to anthropogenic causes, or if these alterations are occurring naturally. Black Carbon, BC, is an aerosol that is created both through natural and anthropogenic processes. BC is an aerosol that may alter surface meteorological and radiation variables by absorbing incoming solar radiation. Increases in BC are mainly due to anthropogenic causes such as from diesel engines, as well as from trash and other unnatural burning. There are natural sources of BC such as biomass burning and volcanic eruptions, but such natural causes are not common and are isolated. Black carbon has both indirect and direct effects on the earth's climate. Indirect and semi-direct effects result from BC aerosols acting as cloud condensation nuclei in the atmosphere, which affect the properties of clouds as well as cloud coverage. Direct effects resulting from BC occur when BC absorbs solar radiation. BC aerosols absorb more solar radiation than other aerosols. Black carbon aerosols have a direct effect on the earth's climate, thus it is extremely important to continue to examine and study the BC origins and effects.

There have been previous studies involving black carbon aerosol concentrations that have been measured at various sites around the globe. Some of these investigations have found that an increase in black carbon concentrations near the surface of the Earth can lead to an increase in temperature with an increase in absorption of incoming solar radiation by black carbon aerosols. Carbon aerosols can be classified into two categories, organic carbon (OC), which is volatile, and as elemental carbon (EC), which is non-volatile, with ambient particulate matter appearing as black carbon (BC) when collected on a filter due to the presence of elemental carbon (Allen et al., 1999). Black carbon can reside in the atmosphere for a period of several days to as long as several weeks depending on the meteorology (Wolff 1981). Black carbon aerosols tend to absorb more incoming radiation in the ultraviolet spectrum than the visible spectrum. BC is the main light-absorbing constituent of soot and it has been considered to be the second largest contributor to global warming (Novakov and Hansen, 2004; Jacobson, 2000). Methane

gas rivals BC for the title of the second largest contributor to global warming, thus it should also be further measured and evaluated in the future.

The main anthropogenic sources of BC are the burning of fossil fuels and biomass burning. BC is thought to be a major player in global warming. About one-half of the global black carbon aerosol emission is estimated to arise from fossil fuel consumption (Cooke and Wilson, 1996). It has been found that in a highway setting in Seattle that 2% of heavy-duty trucks emitted 50 times the amount of light-absorbing particles that were emitted by the average truck (Bond, 2000). BC has an average atmospheric residence time of a few days (Liousse et al., 1996; Cooke and Wilson, 1996) to several weeks (Parungo et al., 1994; Wolff, 1981). It is because of this residence time that BC may be transported and spread over distances of hundreds to thousands of kilometers (Streets et al., 2001). BC consists of stable compounds and does not undergo chemical transformation in the atmosphere (Gatari and Boman, 2003).

The main sink of BC is dry and wet deposition, thus, if there is precipitation occurring then BC concentrations should be lower, with heavy precipitation coinciding with the lowest BC concentrations. BC is efficiently scavenged during rainfall events and its concentration drops dramatically compared to trace gases, such as CO (Derwent et al., 2001). BC versus precipitation amounts at the station was not examined in this particular investigation, but it should be carried out in the future to further illustrate this relationship. The presence of BC also can impact the cloud albedo by altering hygroscopic properties of cloud condensation nuclei (Penner et al., 1991; Liousse et al., 1996). The solar heating caused by the absorption of light by BC can also reduce cloudiness (Ackerman et al., 2000). The Intergovernmental Panel on Climate Change (IPCC), an organization established by the World Meteorological Organization and the United Nations Environment Program to evaluate climate change, has estimated that the global mean clear-sky radiative forcing of BC to be approximately +0.1 W/m^2 (IPCC, 1996), while more recent calculations by Jacobson (2000) have proposed a much higher value of +0.55 W/m^2 (Streets et al., 2001). Hansen and Nazarenko (2003) found a total BC forcing, including its indirect effects on snow and cloud albedos, to be 0.8 +/- 0.4 W/m^2.

Aerosol optical depth and radiation measurements at seven different wavelengths for both the UV and visible spectrum were available for this study. Two wavelengths in the visible spectrum, 500nm and 610nm, and one wavelength in the UV spectrum, 332nm, were selected for comparison and analytical purposes for this particular study. BC has been shown to significantly degrade optical depths (Qui and Yang, 2000). Also, the aerosol optical properties are dependent upon the relative contributions of emissions from inefficient and efficient fuel utilization sectors (Novakov and Hansen, 2004), as well as the properties of natural BC sources.

Other chemically different aerosols such as sulfates can have a different effect on temperature and other meteorological variables if they are present. Sulfates tend to reflect incoming solar radiation versus the absorption effects of black carbon aerosols. Thus, if both aerosols are present at the same time in the same location their respective radiative qualities can counteract one another. Nitrous oxide and ozone concentrations were also measured and available at this station. If BC particles are present, then ozone is affected due to a heterogeneous destruction of ozone molecules on particles (Girgzdiene et al., 1996; Mohler et al., 1997). In another study involving BC and ozone measurements in Slovenia, it was found that a rapid increase of BC concentrations occasionally occurs with a decrease in ozone which is due to the absorption of UV radiation that creates the ozone (Bizjak et al., 1999).

BC aerosols can also impact the health of the human population. There have been recent epidemiological studies which have shown that with the presence of a mass concentration of urban air thoracic particles being associated with mortality and morbidity among cardiorespiratory patients (WHO, 2003). BC has a very small diameter of <1 micrometer. BC's small size makes it easy for it to be inhaled and penetrate deep into the human lungs (Streets and Waldhoff, 2000). When in the lungs, the BC particles may slow clearance mechanisms and provide absorption sites for toxic pollutants (Hamilton and Mansfield, 1991). This can ultimately lead to lung cancer or other potentially deadly diseases. There has been some effort to curtail BC concentrations through legislation in the US and Western Europe by putting recommended limits on the concentrations of inhalable particles (Mark, 1998).

BC aerosols can also seriously damage the environment in other ways. It can dramatically decrease crop yields since there is a decrease in solar radiation at the surface with an increase of BC (Chameides et al., 1999). BC can also be visually detrimental. With larger BC concentrations there will be a reduction in atmospheric visibility. The reduction of visibility caused by the presence of BC does not affect the visibility as much as sulfates and nitrates. This is because the sulfates and nitrates scatter light, and thus they reduce the contrast of a specific view. BC can also cause the soiling of building materials. The small particles can coat the surface of buildings which can damage the aesthetics of historic landmarks, public buildings as well as residential homes (Hamilton and Mansfield, 1991).

Twelve months of meteorological and radiation data was gathered from one location in central North Carolina. Temperature, dewpoint temperature, wind speed and direction, radiation measurements and aerosol optical depths at 3 different wavelengths were used in this study. Black carbon concentrations were also collected for the same twelve months. Each variable was plotted and analyzed versus BC in order to determine what the relationship between BC and each variable is, if there is one, and why there might be a relationship as well. The importance of this study is to examine these relationships in order to see what effects different amounts of BC have on the atmosphere. BC has been shown to alter the vertical temperature profile as well as other meteorological characteristics of an environment (Moloi 2002).

Originally the idea was to examine all twelve months of data for this study. However, in order to effectively get an idea of the relationship of BC with meteorological variables and radiation measurements it was necessary to single out clear days, that is days in which there were approximately no clouds present throughout the course of the day. Clear days were singled out in order to eliminate the complex effects that clouds have on radiation levels. Visible and ultraviolet radiation versus time graphs were examined in order to determine if a particular day was clear or cloudy. If the radiation graph was smooth without any sharp peaks or valleys a day was considered to be clear. After examining each day of the twelve months it was determined that there was not one totally clear day in the months of July or August. This was not unexpected as the weather tends to be much more active and unstable in the warm summer months in central North

Carolina with the daily development of cumulus clouds due to the increased instability. There were more numerous clear sky days during the fall and winter months as the weather tends to be much more stable during these seasons with much drier and cooler air in place thanks to the frequent passage of cold fronts from the west and northwest.

After determining which days during the twelve months were clear sky days the days were further separated between weekdays and weekend days. This was done in order to look for any daily variation of BC concentrations as well as any other meteorological or radiation differences between weekdays and weekend days. This separation was done for each month.

1.2 Location and Site Description

The first step in initiating this project was to visit the USDA UV-B monitoring station, as well as the State Climate Office of North Carolina's ECONET observational tower. Both are located at the same site off Lake Wheeler Road in Raleigh, North Carolina. This was necessary in order to become familiar with the meteorological instruments and overall setup of the operation so that there could be a greater understanding of how and where the data were originating. Having access to the data and variables from two different monitoring stations at the same location allowed for much easier access and comparison for this investigation.

The research site is located in Wake County, North Carolina, just south of Raleigh, NC (2004 population 326,653), east of Cary, NC (2005 population 110,227), and north of Garner, NC (2000 population 17,757), with a total county population of approximately 750,000. The site is located at 35.72 N and 78.68 W, and is at an elevation of 124 meters. The station began operation on October, 3rd, 2002 [http://uvb.nrel.colostate.edu]. This area is a semi-rural/semi-urban location near the division of the piedmont and coastal plain areas in central North Carolina. There are not any large industrial factories producing air pollution in the Raleigh area, but the location is just south of interstate 440/40, which is a heavily traveled corridor for local residents, as well as travelers passing east or west on interstate 40. The principal local source of black carbon is assumed to be from vehicular emissions, as well as from the burning of trash which is permitted in this unincorporated area.

Air masses typically originate from the west or southwest during the summer months and from the northwest and north during the winter months. Some variations in air mass patterns include strong northeasterly flows coming in off of the Atlantic Ocean in the winter and early spring which sets up a "wedge" pattern. This locks in unseasonably cool, moist air in the North Carolina Piedmont. Another variation can occur with tropical disturbances/systems which can make their way into central NC from the Atlantic Ocean in the summer and fall. Warm, humid, moist conditions result in these situations with the flow entering central NC from the Gulf Stream off the NC coast.

The USDA UV-B monitoring research station places an emphasis on ultraviolet radiation measuring equipment, which is used by the USDA to assess the potential impacts of increasing levels of UV radiation on agricultural crops and forests. Two instruments, which are located in the open environment, include the Ultraviolet Multi-Filter Rotating Shadowband Radiometer (UV-MFRSR) and the Visible MFRSR. The UV-MFRSR measures the total horizontal solar irradiance in the ultraviolet spectrum at wavelengths of 300, 305.5, 311.4, 317.6, 325.4, 332.4 and 368 nanometers. This is accomplished by utilizing seven independent interference filter photodiode detector combinations. The visible MFRSR measures total horizontal surface irradiance in the visible spectrum at wavelengths of 415, 500, 610, 665, 862 and 940 nanometers. The visible MFRSR uses six independent interference filter photodiode detectors, as well as a seventh channel, which is an unfiltered broadband silicon diode detector. Optical depths can be determined by both instruments. A UVB-1 Pyranometer is also located at the site. It measures the global irradiance in the UVB spectral range (280-330 nanometers). The station also has a Vaisala HMP 35A temperature and humidity probe which has a temperature range of -20 to +60 degrees Celsius and relative humidity range of 0-100%. A 210SZ LICOR photometer is pointed downward in order to measure the surface reflectance (albedo) [http://uvb.nrel.colostate.edu].

Some additional instruments that are not standard USDA UV-B equipment but are located at the station include a Magee Scientific Aethalometer, which provides a real-time, 15 minute average measurements of the black carbon concentrations. BC is measured with an Aethalometer by calculating the optical attenuation of light by particles collected on a fiber filter tape through which passes the sample of air. Optical attenuation

from BC is calculated by using the decrease in light transmission through this tape and using the measured sample volume (Allen et al., 1999). Black carbon measurements used in this investigation were sampled at 15 minute intervals, which were then integrated into hourly averages. The BC sampling was taken in on the roof of the NCSU Air Quality building, at a height of approximately 20 feet. A PVC tube was exposed to the environment allowing for outside air to be taken into the Aethalometer which was located inside of the building. Total scattering coefficients are also measured using two Nephelometers. Sulfur dioxide, ozone, carbon monoxide, nitric oxide, and nitrogen dioxide concentrations are also measured and recorded at the Lake Wheeler Road site.

The State Climate Office ECONET tower is the other station. This tower holds monitoring equipment which measures an extensive amount of meteorological variables at two different levels, 2 meters and 10 meters. Air temperature (both levels), relative humidity (both levels), wind speed and wind direction, precipitation, pressure, solar radiation, soil temperature and soil moisture are some of the variables which were observed and recorded once every hour, on the hour. The main purpose for the establishment of the ECONET tower network is to improve weather information and forecasts. In addition, the ECONET network is collecting this data for future climate research.

The next step after becoming familiar with the instrumentation and site specifics at Lake Wheeler was to access, collect, and then to analyze all of the applicable data sets. June 2003 through May 2004 was the time period selected for this particular examination. Black carbon concentrations and their relationships to air temperature, dewpoint temperature, relative humidity, winds and various radiation measurements form the focus and outline for this project. Organization of the data for varying seasonal and synoptic conditions was first accomplished, followed by the interpretation and analysis processes.

1.3 Other Investigative Studies

Previous scientific studies involving Black Carbon aerosols have been conducted around the world and each of them have had their own unique set of BC characteristics and local/regional effects. In each study there is a specifically identified source of BC, unique for each location.

A recent study of BC concentrations in Botswana and Sweden was performed in 1999 and 2000 by Moloi et al. This study noted that fossil fuels are considered to be the primary source of BC in Europe, while bio-mass burning is the main source of BC in Africa (Cachier, 1998). Moloi et al. found that in Botswana there were BC emissions resulting from very small amounts of traffic, wood burning used as a domestic energy source, and emissions from a large coal mine and coal-powered power plant. In Sweden, it was found that BC was present mainly due to numerous industries, diesel engines, and long range transport from other countries. An additional study performed in Kenya from 1999-2000 by Gatari and Boman found that the primary source of BC resulted from the burning of agricultural waste and other biomass burning, including naturally occurring savannah and forest fires (Gatari and Boman, 2003). It is also noted that biomass burning has been found to be the major source of carbonaceous aerosols in the tropics in general (Delmas et al., 1991).

Another study conducted at Mace Head, Ireland from 1995-1998 had a very unique source of BC emissions. During the BC sampling a peak was discovered on June 23. 1996. This peak was determined to be linked to the annual St. John's night ritual of bonfires (Derwent et al., 2001). These numerous individual fires produced copious amounts of smoke and BC. The study also found that there was a BC seasonal variation with the maximum amount of BC occurring in the springtime and the minimum occurring in the summertime (Derwent et al., 2001). During the springtime the primary air-mass source is the Atlantic Ocean, while in the summertime there was polluted air advected into the area from surrounding areas.

Multiple BC aerosol investigations have also been carried out in China. Streets et al. conducted a review of several previously performed observational studies in 2000. They concluded that China's high BC emission concentrations were primarily due to the elevated coal usage and biofuels. Roughly one-fourth of global anthropogenic BC emissions are believed to originate in China (Cooke et al., 1999). Another significant source of BC emissions in China is from the burning of crop residues in the field, as a means of disposal after harvesting (Streets et al., 2001). Approximately 80% of crop residue is combusted in Asia (Crutzen and Andreae, 1990). The BC has also greatly reduced atmospheric visibility in China, as well as India, which has been estimated to

have reduced agricultural productivity by 10-20% (Chameides et al., 1999). In addition to the reduction in visibility, the BC that gets deposited on plant leaves themselves results in an even great loss of productivity. BC also produces regional climate variations. The large concentrations of BC in China and India may be responsible for the increases in flooding in the south and drought in the north (Menon et al., 2002). Even though China is a major global source of BC, it is predicted that there will be a 9% decline in BC emissions between 1995 and 2020, even with the continued increase in the consumption of fossil fuels, due to a shift towards more advanced combustion sources and more effective emissions controls (Streets et al., 2001).

A study of BC aerosols in the high arctic in Alert, Canada was performed from 1989-1990 by Hopper et al. This study also found a seasonal variation of BC concentrations with maximum values occurring between January and March, and minimum values occurring during the summer months. The winter maximum BC concentration is a common feature known as the Arctic Haze (Barrie, 1986). It results from reduced scavenging of aerosols during the cold Arctic winter, and the extension of the Arctic front to include significant source regions of atmospheric pollutants within the Arctic air mass (Barrie, 1986; Barrie and Bottenheim, 1991). The majority of the aerosols in the high arctic arrive there after being transported over thousands of miles from other areas of the globe.

A seasonal variance in BC concentrations was also found during a study at Mount Krvavec, Slovenia in 1996-1997 by Bizjak et al. The lowest BC concentrations occurred in December 1996 (150 ng/m^3), while the highest BC concentrations were found in July 1997 (450 ng/m^3). Other stations located in a similar high-altitude Alpine location were also found to have the highest BC concentrations in the summer and the lowest in the winter (Bizjak et al., 1999). This is due to the extension of the planetary boundary layer which typically contains polluted air up to the highest Alpine peaks (Baltensperger et al., 1991). It was also found that the lowest amounts of BC occurred during the night and the highest during the day. The low BC amounts at night can be attributed to the temperature inversion layer formation (Bizjak et al., 1999).

Another location which saw a diurnal BC concentration variation was at Saint-Denis on la Reunion Island, a tropical island located in the Southern Indian Ocean, where

a study was conducted from 1996-1998 by Bhugwant et al. This variation in BC was due to the observed traffic pattern. Daytime BC amounts were found to be 2-4 times larger than the nighttime values (Bhugwant et al., 2000). The highest levels of BC were found to be in the morning during rush hour and frequent traffic jams, as well as during the nighttime rush hour. The time between the daily rush hours becomes longer during the longer days in the summertime, which pushes back the secondary daily maximum by a couple of hours. Weak vertical mixing at the beginning and ending of day also aides in keeping the BC particles suspended (Bhugwant et al., 2000). A daily variation in BC concentrations was also found at Saint-Denis with the highest concentrations occurring during weekdays with lower values occurring on the weekends. This can also be attributed to the traffic patterns with less activity occurring the weekends. According to the French National Institute for Statistics and Economic Studies (INSEE), the main source of BC on la Reunion Island is from diesel engines in all of the vans and buses, as well as 45% of the cars (INSEE, 1998).

The diesel fuel that is used in these engines is of poor quality, which results in even higher concentrations from the vehicles (Bhugwant et al., 2000). There was a lower concentration of BC on holidays, such as Christmas Day (December 25th), with a higher concentration observed on Christmas Eve (December 24th), due to an increase in traffic at night with more people going out to attend religious services (Bhugwant et al., 2000).

Major sources of aerosols, other than BC, are volcanic eruptions. Volcanic eruptions do not directly emit BC. A volcanic eruption did occur on la Reunion Island during the study. There was not an occurrence of significant BC concentrations due to the burning of vegetation by the lava flowing from the volcano. There was a large increase in BC concentrations following the eruption. This increase was due to the extreme traffic that occurred from tourists wanting to get a glimpse of the volcano site. There was even a pattern to the BC profile most likely related to the presence of security guards that were in control of how many cars were allowed in the area at the time (Bhugwant et al., 2000).

A 40-year empirical analysis study on BC emissions in the United Kingdom was recently performed by Novakov and Hansen. They found that there was a rapid decline of atmospheric BC between 1962 and the early 1990's in the United Kingdom (Novakov

and Hansen, 2004). This large decline is attributed to improvements of technologies, and with continued improvements there could be an additional larger reduction of global BC emissions. They found that BC emissions in industrialized countries have been reduced as the use of coal by the non-power generation sectors decreased (Novakov and Hansen, 2004). Also, diesel BC emission factors decreased from 1992-1999 due to improving engine technologies. However, even though the use of coal has decreased and likewise the relative BC emissions, there has been a leveling off of BC seen in more recent years due primarily to the increased consumption of diesel fuels (Novakov and Hansen, 2004).

Summertime BC concentrations were measured during the summer of 1990 in the United States in southwestern Pennsylvania, near the city of Pittsburgh, by Allen et al to look for daily and weekly variations in BC concentrations. The main sources of anthropogenic BC were from vehicular emissions, and from the burning of residential and commercial trash. There was a noticeable diurnal variation, with the maximum amount of BC occurring between 7 a.m. and 9 a.m. local time, which was due to the increase in surface BC emissions from rush hour traffic (Allen et al., 1999). There was no prominent evening rush hour peak observed, but a broad peak did occur from 8 p.m. to 11 p.m. local time, either due to the local trash burning after dark and/or from the transport from distant urban centers (Allen et al., 1999). There was also a daily variation of BC levels in southwestern PA. This was mainly due to the time trash burning is allowed and occurs on a regular basis in southwestern PA. Some towns allow the open burning of trash, while others only allow it on certain days, such as only on Wednesdays and Saturdays. Sundays had the lowest BC concentrations, while Thursdays had the highest levels, and Wednesday had the 2nd highest levels of BC (Allen et al., 1999).

2. METHODOLOGY & DATA DESCRIPTION

Black carbon concentrations for June 2003 through May 2004 were obtained from Dr. William Barnard at the USDA UV-B monitoring site. Archived meteorological variables were obtained from the SCO ECONET observational site. Air temperature and relative humidity were also recorded at the USDA-UVB site, but there were several instances of missing data. The data selected from the SCO ECONET was 100% complete, and thus it was the obvious choice for this particular study.

After collecting the data it was organized and inputted into Microsoft Excel. The purpose was to better display the gathered data in the same format in order to clarify the interpretation process. Most of the meteorological data was recorded as hourly observations, while the majority of the radiation measurements and aerosol optical depth measurements were recorded as 3-minute readings. In order to graph the meteorological and radiation variables versus black carbon concentrations it was necessary to calculate hourly averages for all of the radiation and aerosol optical depth (AOD) readings at each of the examined wavelengths. The collected data for each month included BC concentrations in nanograms per cubic meter, air temperature and dewpoint temperature in Celsius and in Kelvin, relative humidity percentage, wind speed in miles per hour, and finally wind direction in degrees (0 to 360). Solar radiation and photosynthetically active radiation (PAR) were also collected and utilized from the SCO ECONET station. Net irradiance, diffuse radiation and direct radiation were measured by the UVMFRSR and the VIS-MFRSR, and the data employed was at 332nm (UV spectrum), 500nm and 610nm (Visible spectrum). Net irradiance is the total incoming radiation at the specified wavelength. Diffuse radiation is radiation at the specified wavelength that has taken into account any interaction with aerosols, clouds, etc as a result of passing through the Earth's atmosphere before reaching the surface. Direct radiation is radiation at the specified wavelength that does not take into account any interaction with aerosols, clouds, etc as a result of passing through the earth's atmosphere. DDR/10, or the diffuse-to-direct radiation ratio divided by 10, was also computed for each month at each of the 3 selected wavelengths, and plotted versus BC concentrations.

A select number of USDA UVB monitoring sites are also equipped with a barometer which measures atmospheric pressure, and some stations are also equipped with a UVA radiation sensor. Neither of these two instruments are installed at the Raleigh, North Carolina location. All data was quality controlled in order to recognize and address any inaccurate data values, and to prevent false representations from occurring. Constructing box-plots with KaleidaGraph software, as well as the use of Microsoft Excel allowed this to be accomplished. Certain BC concentration data values were eliminated through this process after they were singled out as outliers on the respective box-plots and determined to be inaccurate or false readings.

Visualizations of the variables gathered were presented in plots created with Microsoft Excel. Time series plots of BC concentrations were constructed for clear days on weekdays and weekend days for each month. BC concentrations were plotted versus each meteorological variable including temperature, dewpoint, relative humidity, wind speed and wind direction for each month. The graphs were constructed with BC on the y-axis and the respective meteorological variable on the x-axis. Clear weekdays for the entire month were plotted together, as were clear weekend days for the entire month. Radiation and AOD data at the 3 wavelengths were also graphed versus BC concentrations. By plotting BC concentrations with each of the individual variables together in the same graphical distribution, an association or lack thereof between BC and each variable should be prevalent just by studying the overall visual characteristics and patterns of the plots versus time.

3. RESULTS

Seasonally, Black Carbon concentrations are typically highest during the summer months and lowest during the winter months. In the summer there are more daylight hours in the northern hemisphere, which means that there will be more incoming solar radiation throughout the day which will be interacting with aerosols. There are also higher amounts of BC in the summer due to an increase in travel and recreational activities involving transportation. In the winter, daylight is shorter and people tend to travel less and stay indoors more often.

There are some occasions when we might experience lower than usual BC concentrations in the summer time and higher than usual concentrations in the summertime. If tropical cyclones interact with the coastal Carolinas then there can be lower amounts of BC due to a greater marine wind regime influence. With more marine air coming into the piedmont of North Carolina there will be much lower BC. It is possible to have higher concentrations of BC with a tropical cyclone nearby. If the cyclone is positioned in a manor such as to the north or northeast of Raleigh (inland), then a northwesterly flow generated by the counter-clockwise rotation of the cyclone could bring in continental polluted air from the Tennessee Valley into the piedmont of NC. In the winter season there are typically low amounts of BC concentrations and aerosols in general. On occasion a large biomass-burning event occurring at a location

upstream of the wind regime progressing into the piedmont of North Carolina can result in extremely high BC concentrations. Precipitation such as rain or snow also lowers the BC concentrations. Therefore, if precipitation is occurring, then BC concentrations will be lowered. Also, as the intensity of precipitation increases there will be a larger amount BC reduced yielding lower BC concentrations in the near surface atmosphere.

There are also daily variations of BC concentrations in Raleigh, North Carolina. The highest concentrations typically occur from Monday thru Friday due to rush hour traffic where the average commute is 34 minutes for the Raleigh-Durham area. The lowest concentrations of BC occur on the weekends. Exceptions to this may include extended holiday weekends when travel on the roadways would be much higher than the average weekend.

With the stated information in mind we can use the data gathered for this study from June 2003 through May 2004, clear days only, in order to support the described average amounts of BC. An examination of the time series plot of BC concentrations for the only clear sky day in the month of June 2003, June 25, reveals that BC concentrations ranged from a minimum of 1064.00 ng/m^3 to a peak of 1569.30 ng/m^3. Unfortunately June 25, 2003 was the only clear day during the month of June. This can be attributed to a more active weather pattern and more unstable conditions occurring during the summer months in central North Carolina. Similarly, no clear sky days were found during the months of July and August 2003 when a field of cumulus clouds develops nearly everyday in the summer months in central NC. BC concentrations for the remaining months ranged as follows: for the weekdays of September 19 and 25, 2003 from 555.00 ng/m^3 to 1050.00 ng/m^3, for the weekdays October 15-16, 20 and 22, 2003 from 139.50 ng/m^3 to 1771.80 ng/m^3, for the weekend day of October 19, 2003 from 366.00 ng/m^3 to 1216.80 ng/m^3, for the weekdays of November 20-21, 2003 from 97.75 ng/m^3 to 1287.50 ng/m^3, for the weekend of November 22-23, 2003 from 503.25 ng/m^3 to 1772.70 ng/m^3, for the weekdays of December 15, 25-26, and 30-31, 2003 from 22.50 ng/m^3 to 726.75 ng/m^3, for the weekend day of December 27, 2003 from 93.75 ng/m^3 to 261.50 ng/m^3, for the weekdays of January 22-23, 2004 from 128.25 ng/m^3 to 779.50 ng/m^3, for the weekend days of January 3 and 11, 2004 from 101.25 ng/m^3 to 786.50 ng/m^3, for the weekend days of February 8 and 28, 2004 from 53.50

ng/m^3 to 284.50 ng/m^3, for the weekdays of March 11-12, 19, 23 and 29, 2004 from 71.75 ng/m^3 to 529.50 ng/m^3, for the weekdays of April 5 and 28, 2004 from 46.25 ng/m^3 to 311.15 ng/m^3 and for the weekdays of May 4, 6-7, 2004 from 120.25 ng/m^3 to 548.00 ng/m^3. Please note that there was limited data available for some of the months involved in this study due to either removal because of data contamination or because the BC concentration measuring equipment was down for a limited amount of time and thus it was not able to record data for every single possible time interval. As shown above the highest BC concentrations occurred in both October and November, with the lowest concentrations of BC occurring from December through May.

As mentioned, normally BC concentrations would be the highest during the summertime months when travel is high and temperature and solar radiation are typically highest. The lowest amounts would normally occur in the wintertime months when travel is much lighter and temperatures and solar radiation levels are much lower. In the wintertime frequent cold fronts from the west and northwest (occasionally also from the northeast, i.e. “backdoor” cold fronts) move through central North Carolina while in the summertime the airmass can be stagnant for days with light winds and high pressure. However, as previously mentioned there can be instances in the summertime when a flow from the southeast or east off of the Atlantic Ocean moves into the piedmont of North Carolina which would result in lower BC concentrations with the ocean airmass.

BC concentrations were also plotted versus temperature, measured in degrees Kelvin, for June 2003 and all subsequent months. The temperature was the highest during the summer months and lowest during the winter months. Temperatures are expected to increase with increasing concentrations as BC absorbs incoming solar radiation which alters the vertical temperature profile. As mentioned in the introduction BC has been found to be a major contributor to increasing global temperatures and global warming. Temperature did increase with increasing BC on June 25, 2003, on weekdays in October 2003, on weekdays and weekend days in January 2004, on weekdays in March, April and May 2004. However, temperature increased with decreasing BC amounts in September 2003, on the weekend day of October 19, 2003, on both weekdays and weekend days in December 2003, on weekend days in February 2004, with no noticeable increase or decrease of temperature with increasing BC on both weekdays and

weekend days in November 2003. It is likely that the days that saw an increase in temperature along with decreasing amounts of BC occurred with southerly to southwesterly winds which would be an airmass source with lower BC concentrations.

Next, dewpoint temperature, which is calculated using instantaneous temperature and relative humidity, is displayed in degrees Kelvin and was plotted versus BC concentrations. Dewpoint temperatures were the highest in the summer months when central North Carolina experiences the highest moisture content in the atmosphere with southerly wind regimes ushering in deep moisture from the Gulf of Mexico and the gulf stream over the Atlantic Ocean. Relative humidity, a percentage measurement of the amount of moisture present in the air was also measured and plotted as a time series and versus BC concentrations. The relative humidity range is 0-100%. Relative humidity can be quite misleading as it is only a percentage. For example, a value of 100% relative humidity could occur with temperatures as low as 30 degrees Fahrenheit (or lower), or it could occur with temperatures as high as 75 degrees Fahrenheit. Thus a relative humidity of 100% means that the dewpoint temperature is the same as the air temperature. Dewpoint temperature is a measurement of the actual moisture content of the atmosphere and thus it is best to examine dewpoint over relative humidity if trying to find a relationship between moisture content and BC concentrations.

Unlike the relationship that BC has with temperature, here BC concentrations normally decrease as dewpoint temperature increases as is evident by the negative sloping linear regression line, thus there is an inverse relationship. BC aerosols, like most aerosols, are hygroscopic, meaning when that when more water vapor is present in the atmosphere there will be lower amounts of BC since the water vapor will be attracted to the aerosols which will decrease the radiative effects of the BC aerosols. BC particles can grow with higher humidity and fall out when they get to be large enough particles. In this study BC concentrations decreased with increasing dewpoint temperatures in the months of June and September, on October 19, 2003, on December 27, 2003, on February 8 and 28, 2003. However, BC concentrations increased with increasing dewpoint on weekdays in October 2003 and during the weekend of November 22-23, 2003, on weekdays in December 2003, and on weekdays in January, March and May, 2004.

Wind speed, measured in miles per hour, was the next meteorological variable examined and graphed versus the BC concentrations. It is expected that as wind speed increased, BC concentrations decreased. If wind speeds are low and the air is stagnant then BC concentrations will tend to accumulate more near the surface and in the atmosphere since there is nothing to disperse the BC. However, if wind speeds increase then BC will get scattered and can be transported elsewhere. Higher wind speeds in the winter allow for lower BC concentrations. There are typically higher wind speeds over the course of the winter with frontal systems constantly moving through the piedmont of North Carolina from the west, northwest or sometimes even northeast. There are instances when higher BC concentrations can be seen with increasing wind speeds. If there is a strong northwesterly or northerly wind then BC concentrations may spike since this observations station sits just to the south of interstate 40/440 which is a main source for BC at this site due to the large amounts of vehicular traffic on the interstate.

With wind direction playing a major role in BC concentrations it was of course necessary to also examine the wind direction at 2m at this location. Wind direction was measured and plotted from 0 to 360 degrees with 360 being north, 45 degrees being northeast and so on. As mentioned, the highest amounts of BC were present with wind direction coming from the north. The lowest amounts of BC were present when the wind direction was coming from the south. This would clearly be lower since the Atlantic Ocean lies to the south through east of the piedmont of North Carolina, which is a marine air mass. Marine air masses usually contain extremely low amounts of BC, if any at all. Land-falling tropical cyclones can bring a massive influx of maritime air into the piedmont of North Carolina which will result in dramatically low BC concentrations during the normally high BC concentration season.

Radiation measurements were examined in several different categories and were each plotted versus BC concentrations. The radiation measurements that were observed and analyzed include:

- Solar radiation (SR), the total incoming radiation observed at the surface at all wavelengths
- Photosyntetically active radiation (PAR), the amount of radiation available for photosynthesis at the surface

- Net irradiance, the total radiation observed at the surface at a specific wavelength
- Diffuse radiation, the amount of radiation observed at the surface that has encountered aerosols, clouds, etc, at a specific wavelength
- Direct radiation, the amount of radiation observed at the surface that has not encountered any particles, etc while passing through the atmosphere, at a specific wavelength.

Total incoming solar radiation (SR), measured in watts per square meter, was the first radiation measurement to be examined versus BC concentrations. PAR, measured in micromols per square meter, was the second radiation measurement analyzed for this investigation. as the amount of solar radiation increased so did the amount of BC concentrations. The expectation was to see higher amounts of solar radiation and PAR with lower BC concentrations. If there is less BC present at the surface then more solar radiation should reach the surface. It was also expected that with less BC concentrations there would be high amounts of PAR reaching the surface which would yield more incoming radiation available for photosynthesis. The results from this study regarding solar radiation and PAR were slightly mixed. For the majority of the clear days both solar radiation and PAR increased with increasing BC concentrations, except for February 2004 which saw a very slight increase in BC concentrations with increasing solar radiation and PAR.

Net irradiance, or total radiation data were available at seven wavelengths in the ultra-violet light spectrum, as well as seven wavelengths in the visible light spectrum. For this particular study two wavelengths from the visible spectrum were chosen, 500nm and 610nm, and one wavelength from the ultra-violet spectrum was chosen, 332nm. BC tends to have the greatest effect at in the visible light spectrum between 500 and 610 nm, while BC also tends to have the greatest effect at 332nm in the ultraviolet light spectrum. Since data was collected at the other remaining 11 wavelengths, it is available for any future investigation involving BC aerosols. Lower amounts of BC were expected to occur with resulting increasing amounts of net irradiance. However, there are some high values of BC that occurred at the same time of high values of net irradiance.

Secondly, diffuse radiation was evaluated and plotted versus BC concentrations. Diffuse radiation is a measurement of the amount of radiation at the surface after

interacting with particulate matter in the atmosphere. The values of diffuse radiation were low as expected with clear days only being examined for this study. Higher amounts of BC concentrations at the surface would be expected to yield higher amounts of diffuse radiation. BC does absorb both direct and diffuse radiation.

Next, direct radiation was collected and graphed for this investigation. Direct radiation values were higher compared to diffuse radiation values as expected since only clear days were examined for this study. Low levels of direct radiation were expected to occur with high concentrations of BC. Thus with higher amounts of BC present we would expect to see lower amounts of direct radiation since more incoming radiation will be encountering the higher levels of BC.

The results from this study for radiation measurements were mixed. For June 25, 2003 an increase in all radiation measurements at all examined wavelengths occurred with increasing BC concentrations. All radiation measurements, including net irradiance, diffuse radiation and direct radiation at all three wavelengths increase for all of the days examined in September through December 2003 as well as March through May 2004, except on December 2003 weekdays when direct radiation increased at 500 and 610nm with decreasing BC concentrations. Conversely, all radiation measurements increased with decreasing amounts of BC in January and February 2004 except for diffuse radiation at 610nm in January 2004.

Aerosol optical depths at three different wavelengths were also collected. AOD is the attenuation of light passing through the atmosphere at a specific wavelength, or the measure of atmospheric extinction through a vertical column of atmosphere. High AOD values represent a larger concentration of aerosols within a column of atmosphere which yields lower visibility. AOD was collected at 332nm (ultra-violet), 500nm and 610nm (both visible). BC aerosols tend to have the greatest impact at 332nm in the ultra-violet spectrum and 500nm and 610nm in the visible spectrum. AOD for cloud and aerosol, the AOD collected for solely clouds and aerosols, and total AOD were gathered and analyzed for each of the three selected wavelengths.

The results for this study are as follows. First, some AOD measurements were not available at all three selected wavelengths during some of the clear days and thus there are no corresponding figures in section 5. No AOD values were available on June

25, 2003, and limited data was available for September 2003 so they were not examined. For weekdays in October 2003 AOD increased with higher amounts of BC. Data was again limited on the sole clear weekend day in October 2003, the 19th, but the data that was available showed increasing AOD with increasing BC at 332nm, and increasing AOD with decreasing BC at 500 and 610nm. The same occurred on the weekdays of November 20-21, 2003. AOD increased with increasing BC on the weekend of November 22-23, 2003. Overall AOD increased with decreasing BC during the weekdays of December 2003. On weekdays and weekend days of January 2004 AOD increased with increasing BC, as well as on weekend days in February 2004. AOD increased with decreasing BC at all wavelengths for weekdays in March 2004. For the weekdays of April 2004 only 332nm AOD was available and there was neither an increase nor decrease of AOD seen with increasing BC. Lastly, on weekdays in May 2004 AOD increased with increasing BC concentrations.

4. CONCLUSIONS

For this study the results of BC on meteorological variables and radiation measurements varied. After examining temperature it was found that for most clear days temperature increased with increasing BC concentrations. However, there were some days where temperature increased with decreasing amounts of BC. This is a complex matter, but in this situation it appears to have occurred due to predominantly southerly to southwesterly winds occurring which would yield higher temperatures and lower BC amounts at the same time as wind regimes originating from the south contain lower BC concentrations than wind originating from the north or northwest directions. Dewpoint temperatures were expected to increase with lower amounts of BC which did occur on some days, but not all. Again, there are a variety of factors at work that can cause these variations including wind direction and air mass origination along with localized effects.

In regards to radiation measurements, including solar radiation, PAR, net irradiance, diffuse radiation and direct radiation, it was originally anticipated that lower amounts of radiation would occur at the surface when more BC is present. However, the majority of clear days exhibited just the opposite with higher amounts of radiation occurring when more BC was present.

Aerosol optical depths did exhibit predicted characteristics. The majority of clear days yielded increasing aerosol optical depths with increasing amounts of BC which should occur as AOD is a measurement of the attenuation of light, thus with more BC present there should be higher AODs and higher aerosol optical depths lead to lower radiation levels.

There are definitely negative effects of having higher amounts of BC in the atmosphere and at the surface and there are several ways that the human population can help to decrease the amount of anthropogenic BC that continues to rise in output across the globe. The main way would be to improve automotive technologies by developing cleaner fuel-burning cars, and ideally eliminate vehicles altogether that use fossil fuels. There is some promising research and developments occurring with hydrogen fuel cell technology. Diesel engines are the main type of engine used in cars in Europe, as well as other parts of the world. These cars can be outfitted with converters to allow for the burning of biofuels, which is diesel combined with corn oil. There are also proven engine systems that utilize the oils that can be, in many cases, recovered for free from restaurants' kitchens. This fuel will produce lower amounts of BC concentrations compared to pure conventional diesel, and a converter can be purchase for a diesel engine car for a relatively inexpensive cost. Besides, the cost of fuel savings alone would far outweigh the cost of the converter for the car.

Improvements can also be made in infrastructure. The numbers of cars and trucks on the road continue to increase while at the same time the roads that carry these additional vehicles are not being widened or kept up as they ideally should be. Public transportation would also greatly help to reduce BC concentrations. Electric buses, electric trains and subways can all be utilized in urban settings. The key is locating them in most effective location where the largest amount of public population would use these alternative methods of travel. They can also be very expensive to design and build, as has been seen in the Triangle of North Carolina where once there was a vision of cheap, electric light-rail, there was instead a diesel powered light-rail system that came in over projected costs by several hundreds of millions of dollars.

There can also be progress made in coal power plant technology. Coal power plant smoke stacks can be outfitted with "scrubbers" which work to reduce the amount of

pollutants being released as a byproduct of the energy generating process. Coal power plants could also be eliminated altogether and the energy that is produced by them can be generated from other sources, including solar, wind, hydro and nuclear power. The only cost involved with solar and wind power is the cost of the equipment used to output and transmit the electricity.

The environment also needs to be better protected, especially the rain forests. Rain forests continue to get clear cut and harvested, removing vital ecological systems from the globe. There are many negative factors that result from this, including an increase of CO2, an increase in floods due to the newly flat surfaces that result from deforesting, and a loss of rare and exotic plant and animal life.

Certain countries have agreed to the Kyoto Protocol which calls for a reduction in carbon dioxide. One way that European countries are planning on reducing carbon dioxide is by marketing and pushing diesel automobiles for their societies. While this will reduce carbon dioxide from automobiles it will result in a large increase in BC aerosols. BC aerosols were not part of the Kyoto agreement. It is important to not lose sight of the large picture by focusing on reducing all anthropogenic aerosols that have and may be altering our planet's climate instead of simply focusing on reducing just one specific aerosol.

BC aerosols have both indirect and direct effects on the earth's climate. If BC concentrations continue to increase then there could be damaging effects to the earth's climate. It is especially important to study and investigate BC around the world and it is necessary to continue to develop new, cleaner technologies in order to reduce pollution in our atmosphere and environment before it is too late. There are new technologies that can be implemented and used to reduce BC aerosols. Countries and governments must recognize the importance of BC aerosols and use the new technologies to the fullest extent.

5. FIGURES

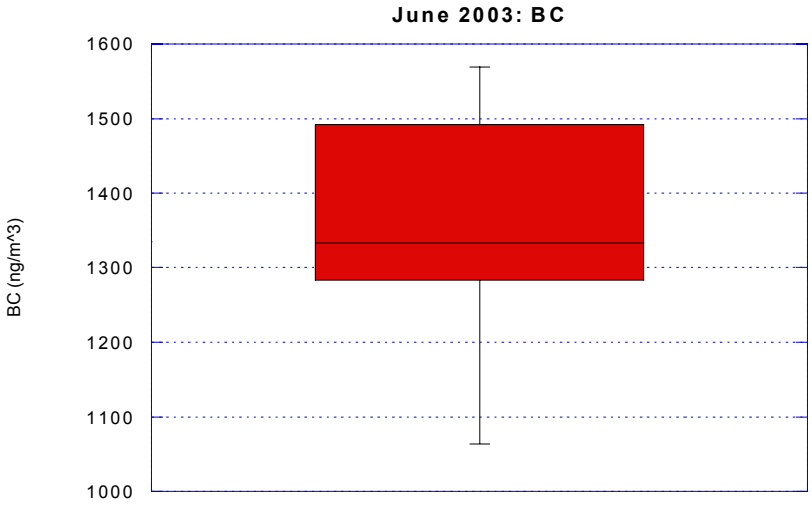

Figure 1. June 2003 Black Carbon Concentrations (ng/m^3)

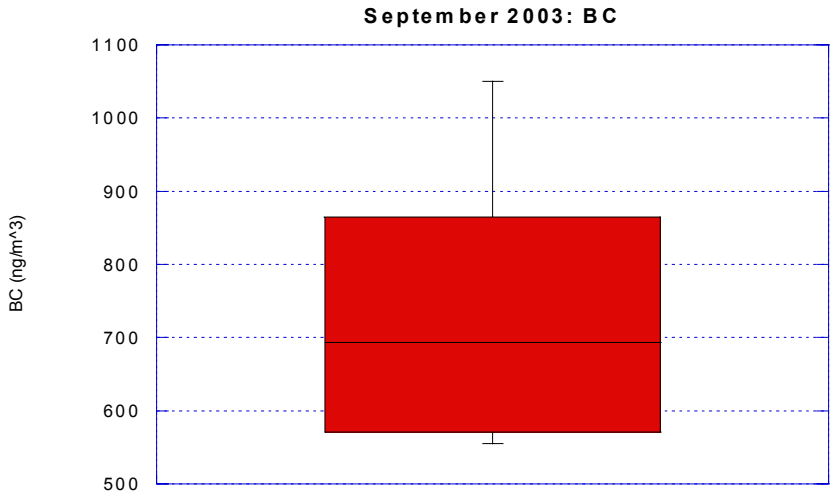

Figure 2. September 2003 Black Carbon Concentrations (ng/m^3)

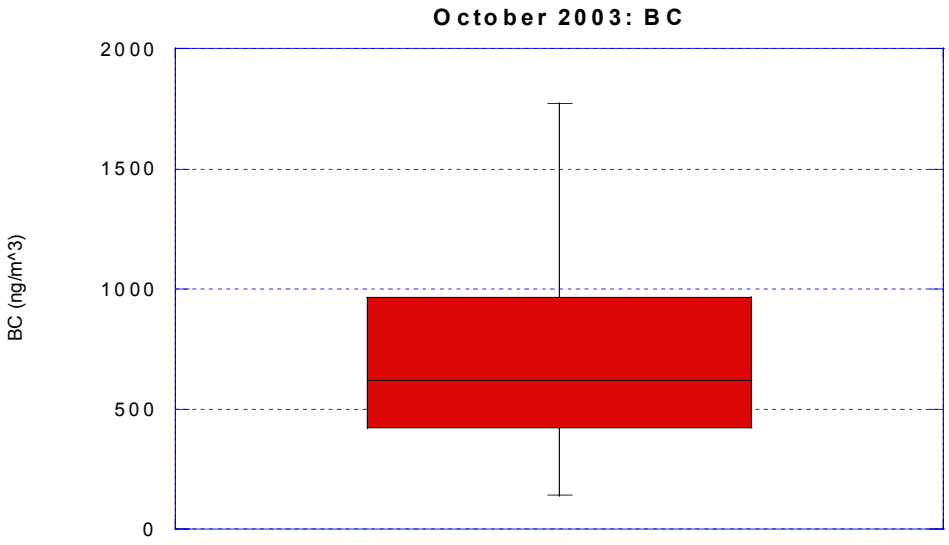

Figure 3. October 2003 Black Carbon Concentrations (ng/m^3)

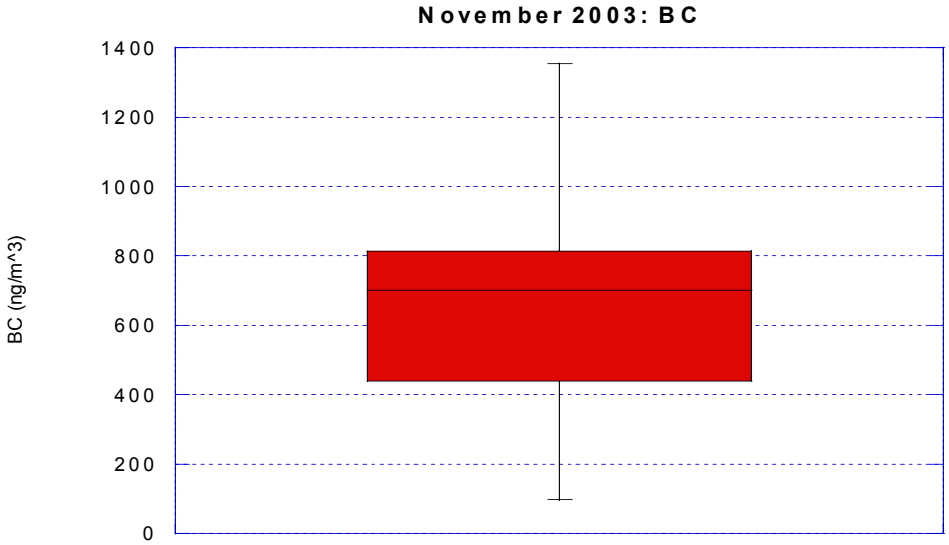

Figure 4. November 2003 Black Carbon Concentrations (ng/m^3)

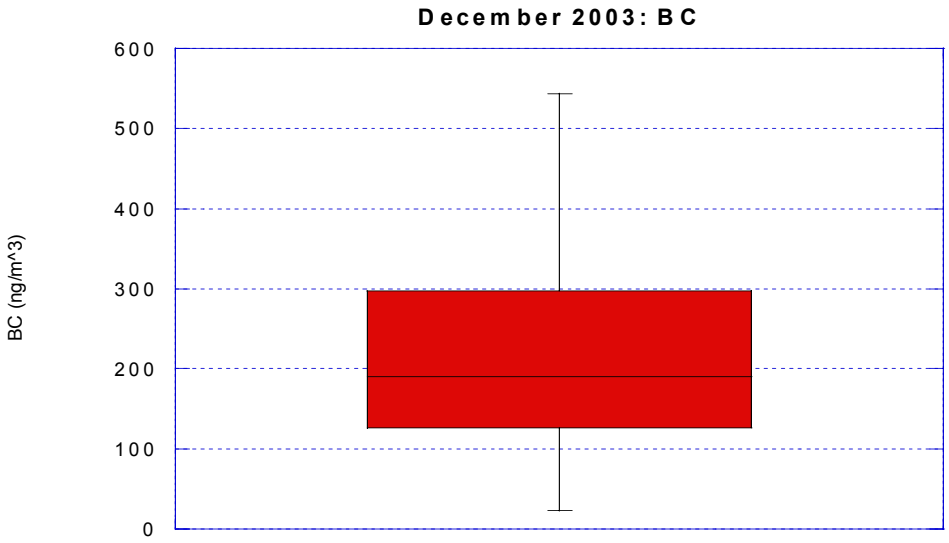

Figure 5. December 2003 Black Carbon Concentrations (ng/m^3)

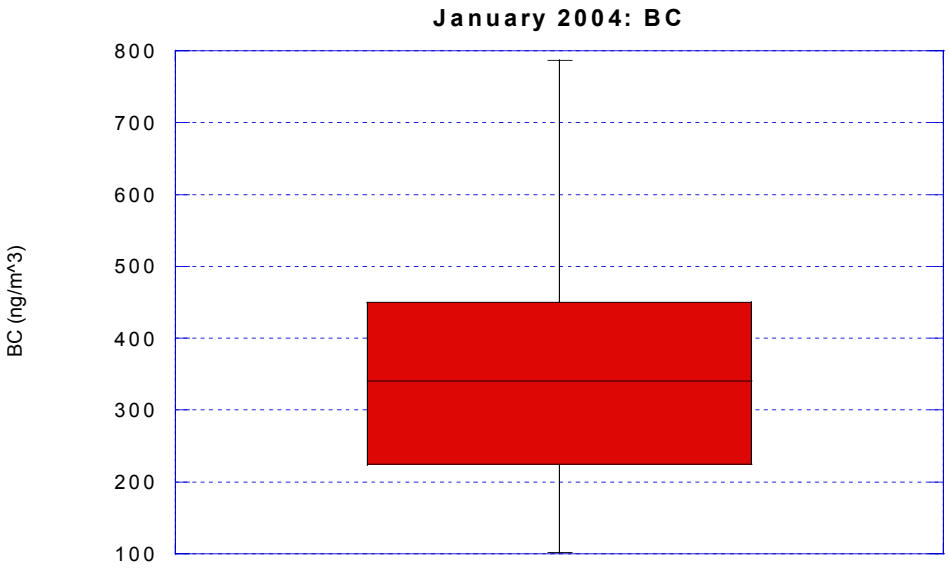

Figure 6. January 2004 Black Carbon Concentrations (ng/m^3)

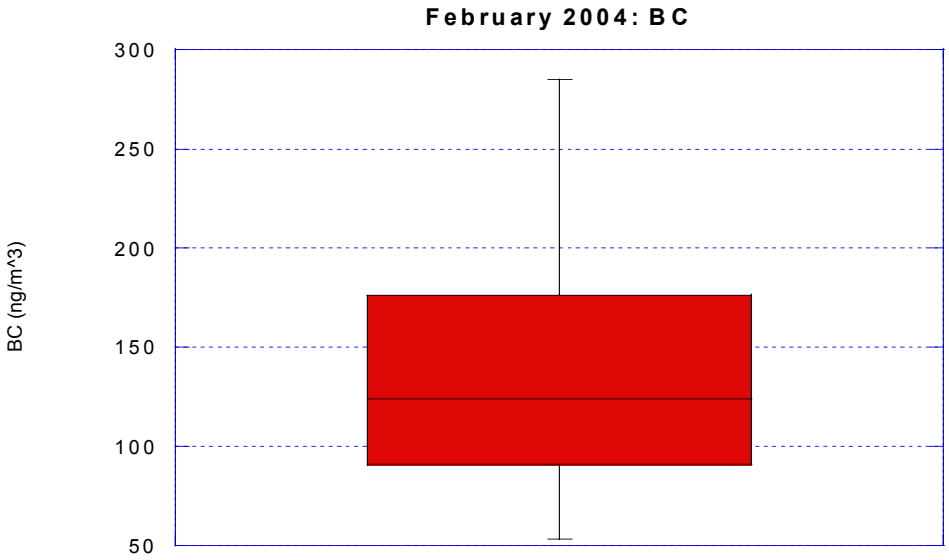

Figure 7. February 2004 Black Carbon Concentrations (ng/m^3)

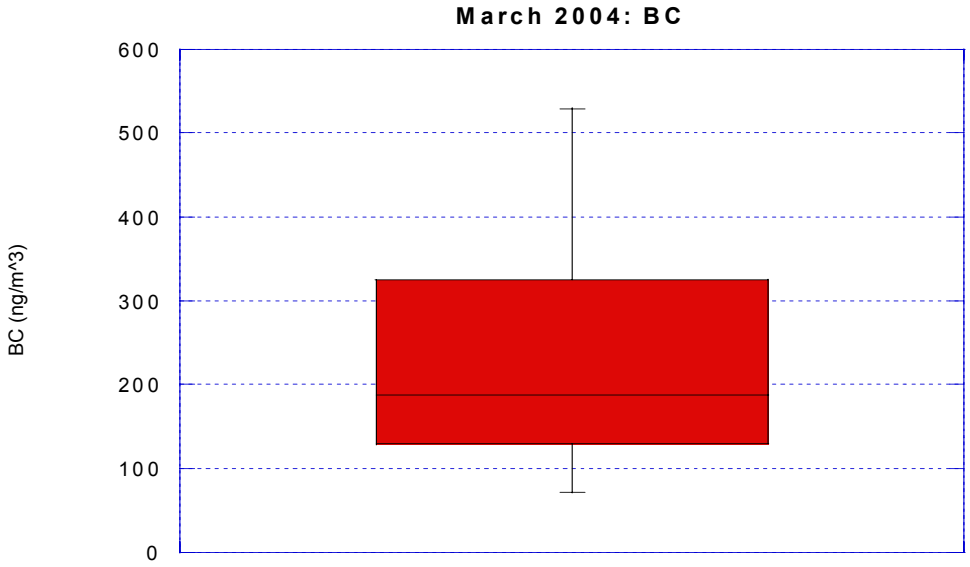

Figure 8. March 2004 Black Carbon Concentrations (ng/m^3)

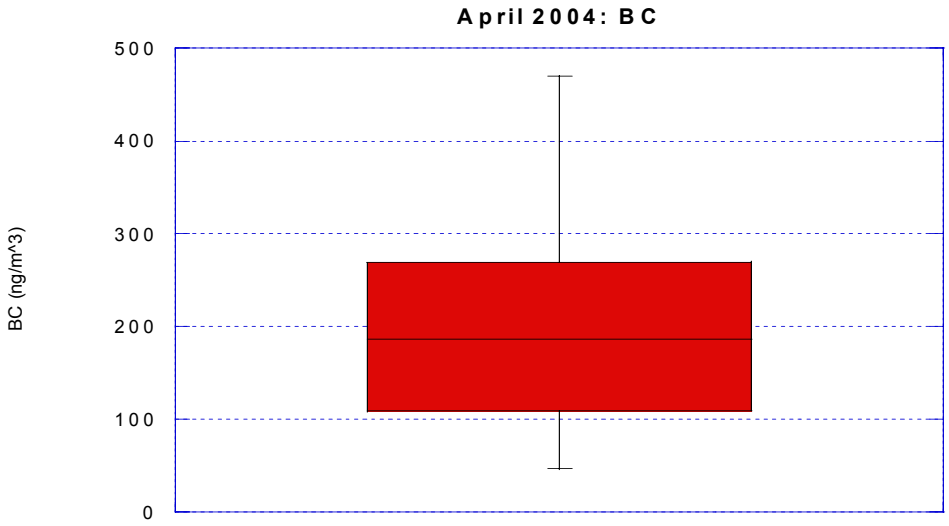

Figure 9. April 2004 Black Carbon Concentrations (ng/m^3)

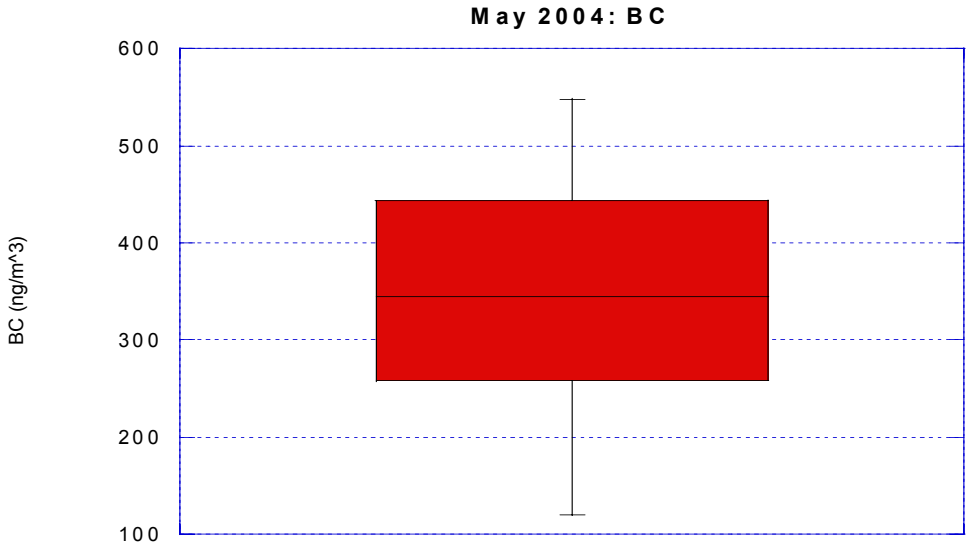

Figure 10. May 2004 Black Carbon Concentrations (ng/m^3)

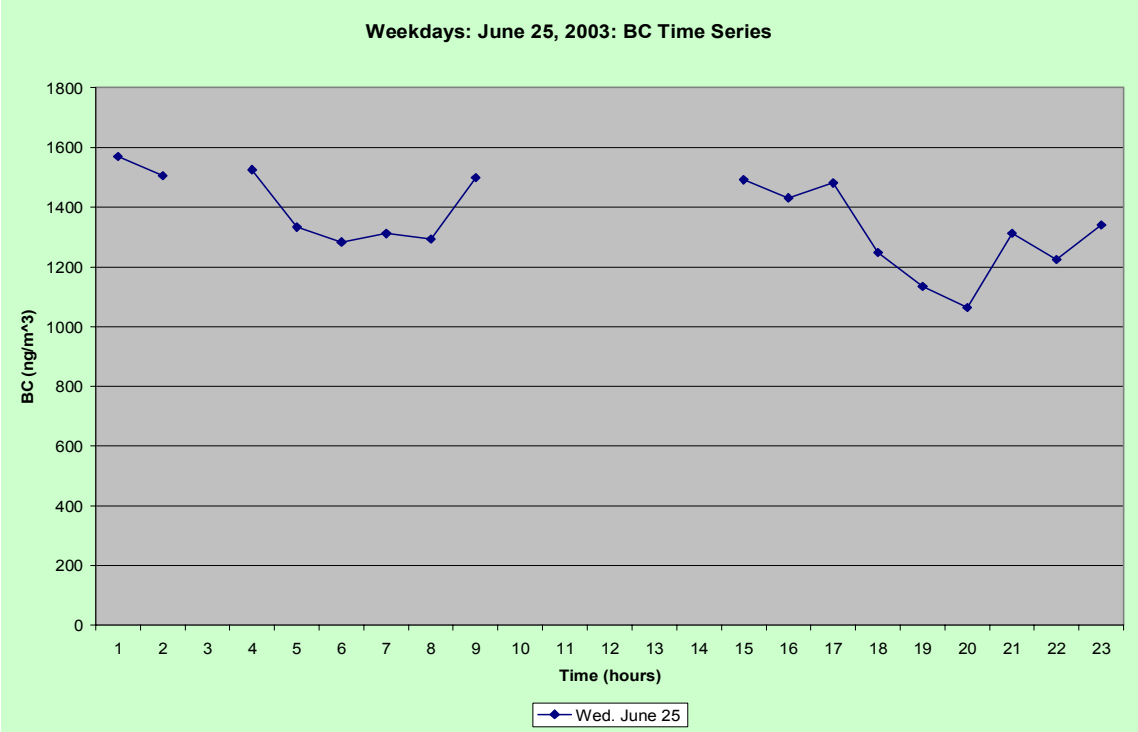

Figure 11. June 2003 Weekdays Black Carbon Concentrations (ng/m^3) Time Series

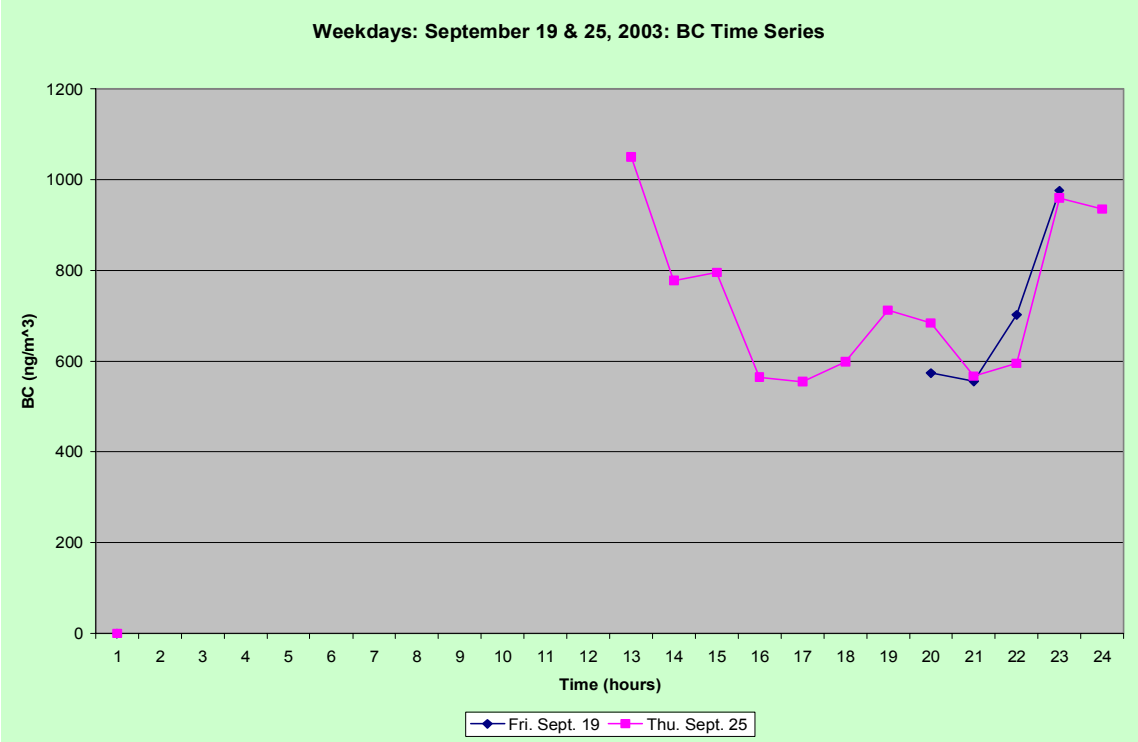

Figure 12. September 2003 Weekdays Black Carbon Concentrations (ng/m^3) Time Series

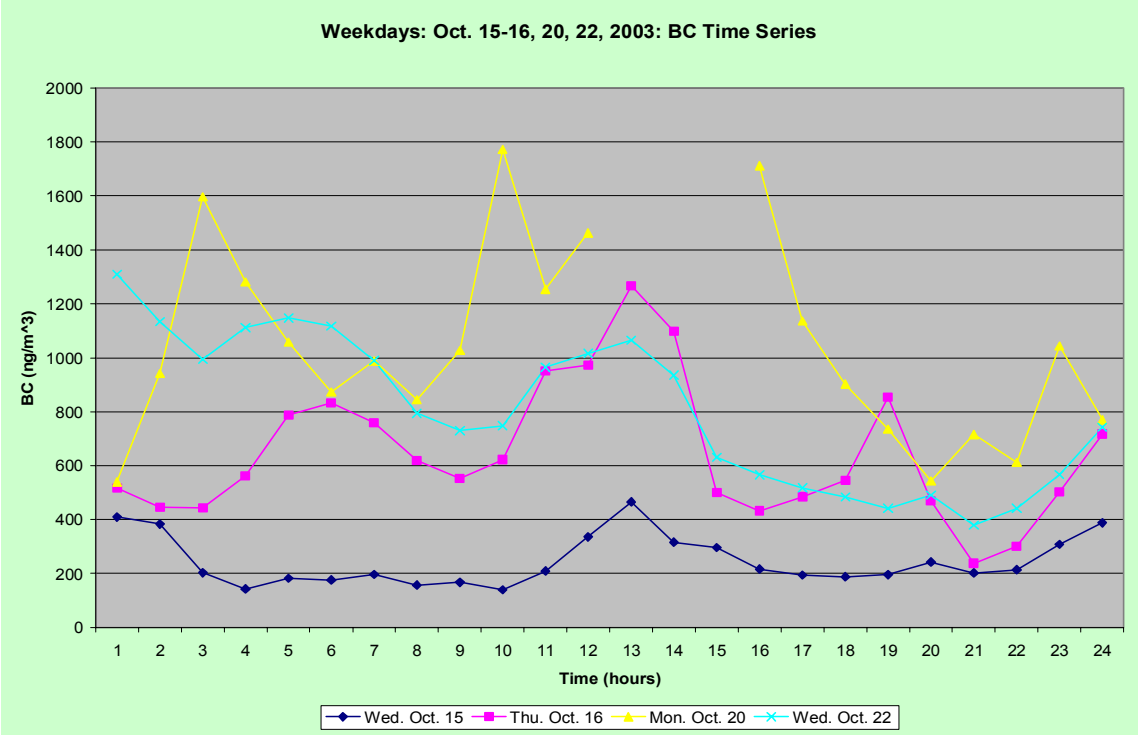

Figure 13. October 2003 Weekdays Black Carbon Concentrations (ng/m^3) Time Series

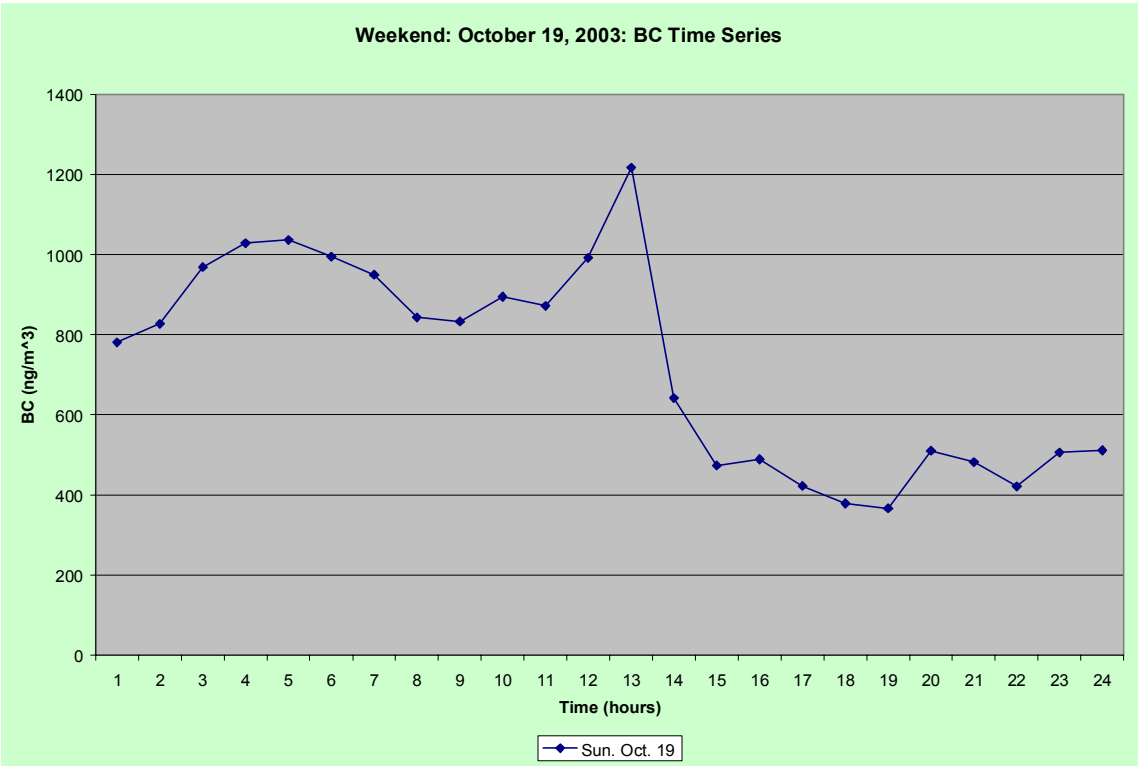

Figure 14: October 2003 Weekend Black Carbon Concentrations (ng/m^3) Time Series

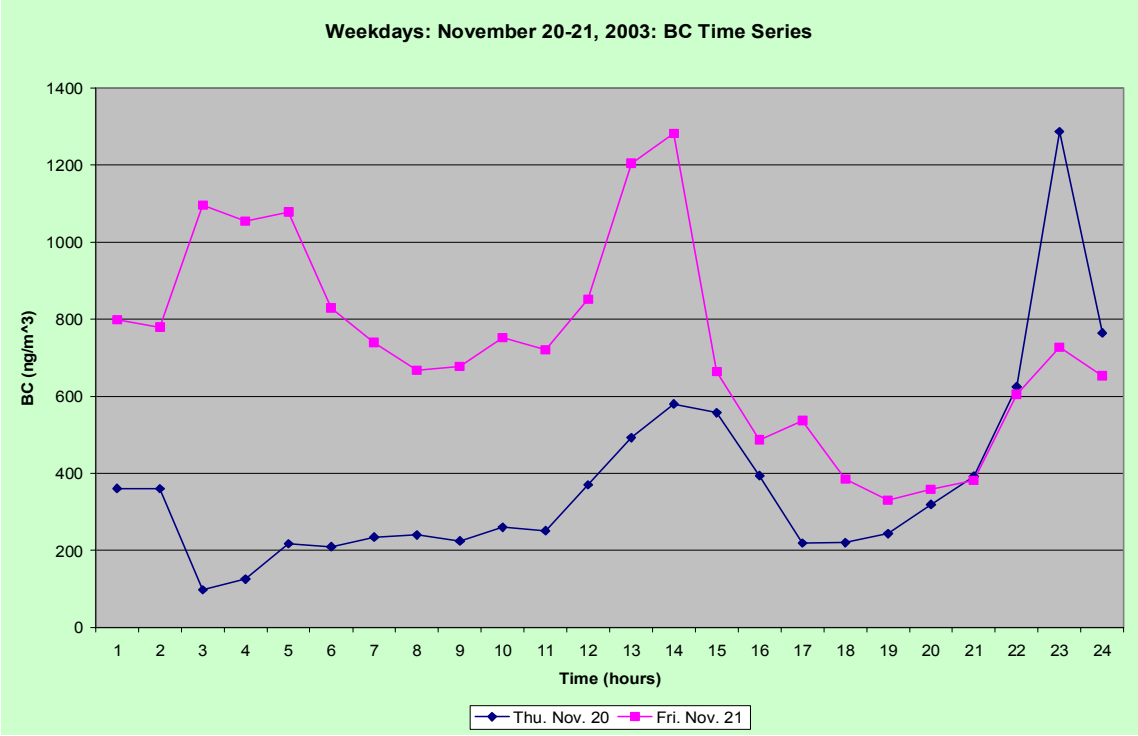

Figure 15. November 2003 Weekdays Black Carbon Concentrations (ng/m^3) Time Series

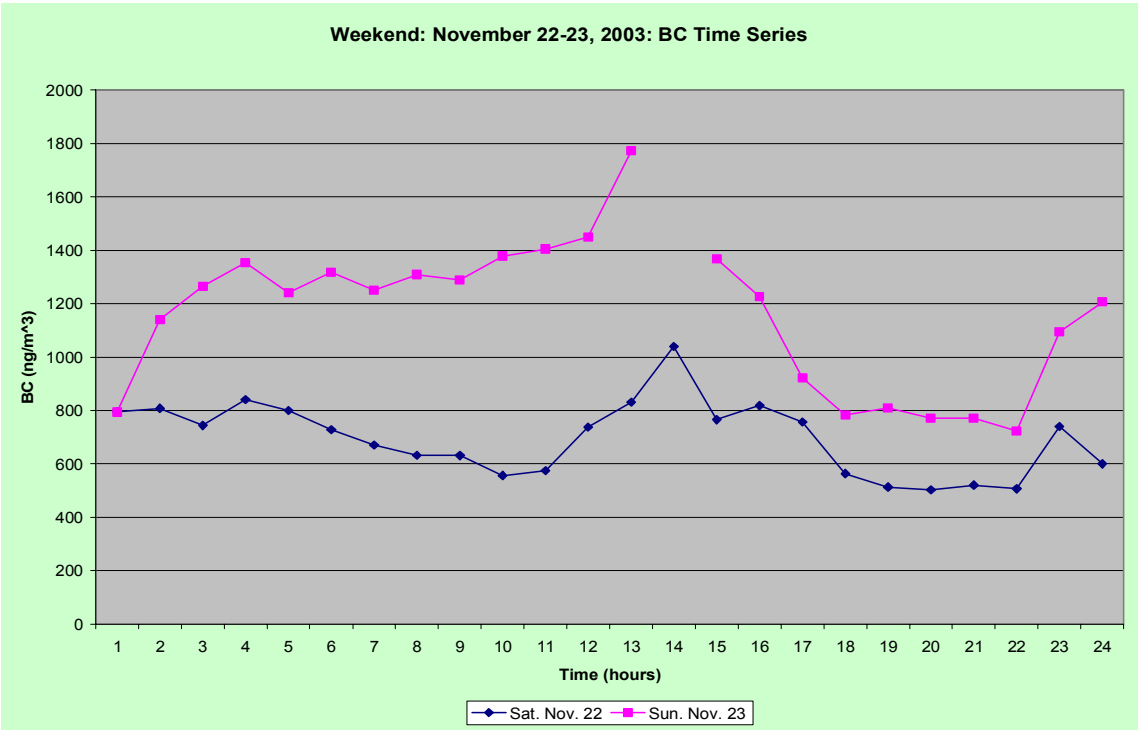

Figure 16. November 2003 Weekend Black Carbon Concentrations (ng/m^3) Time Series

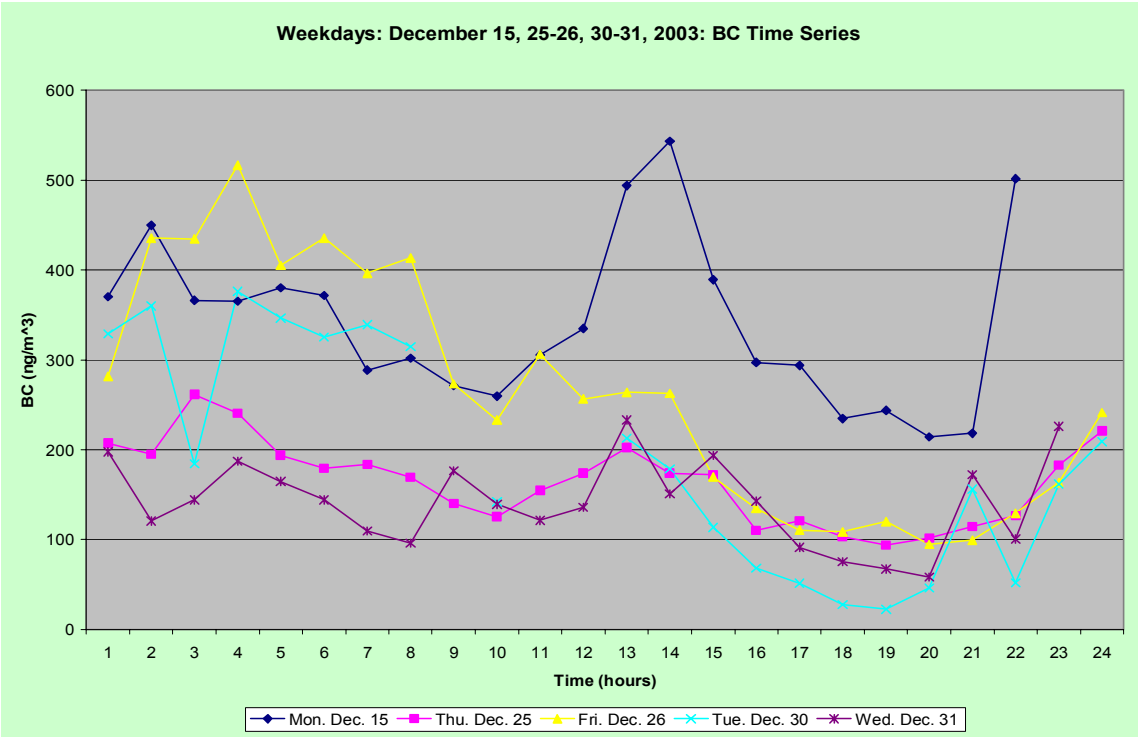

Figure 17. December 2003 Weekdays Black Carbon Concentrations (ng/m^3) Time Series

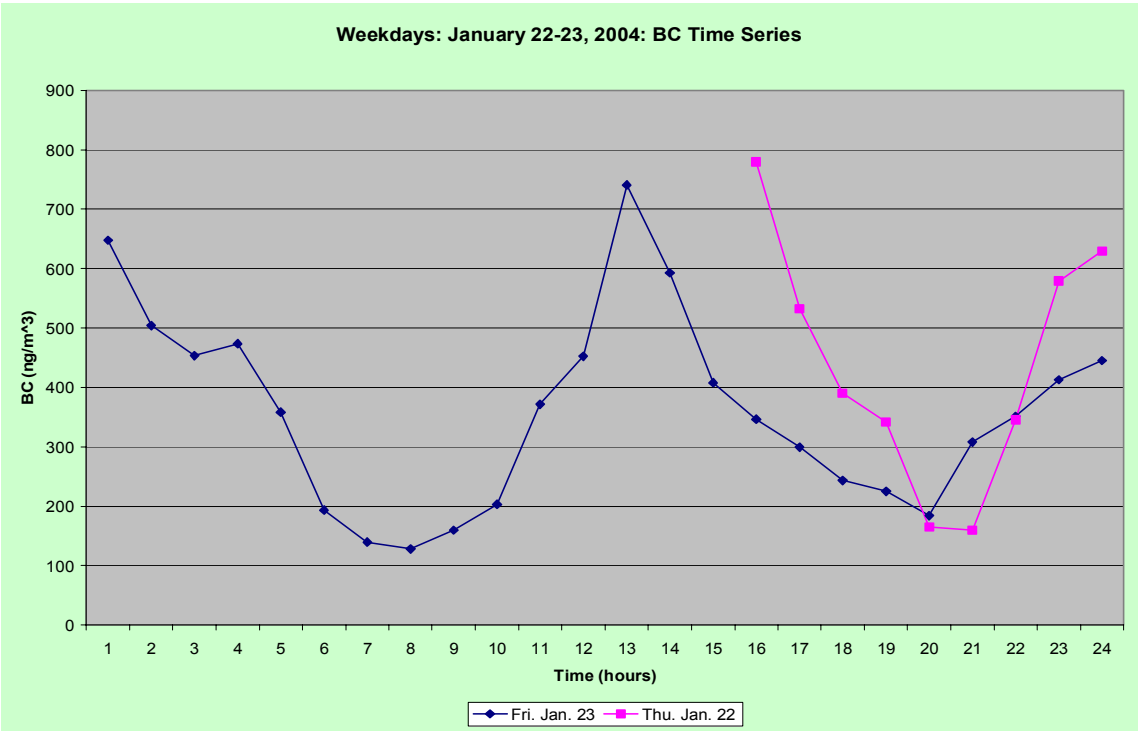

Figure 18. January 2004 Weekdays Black Carbon Concentrations (ng/m^3) Time Series

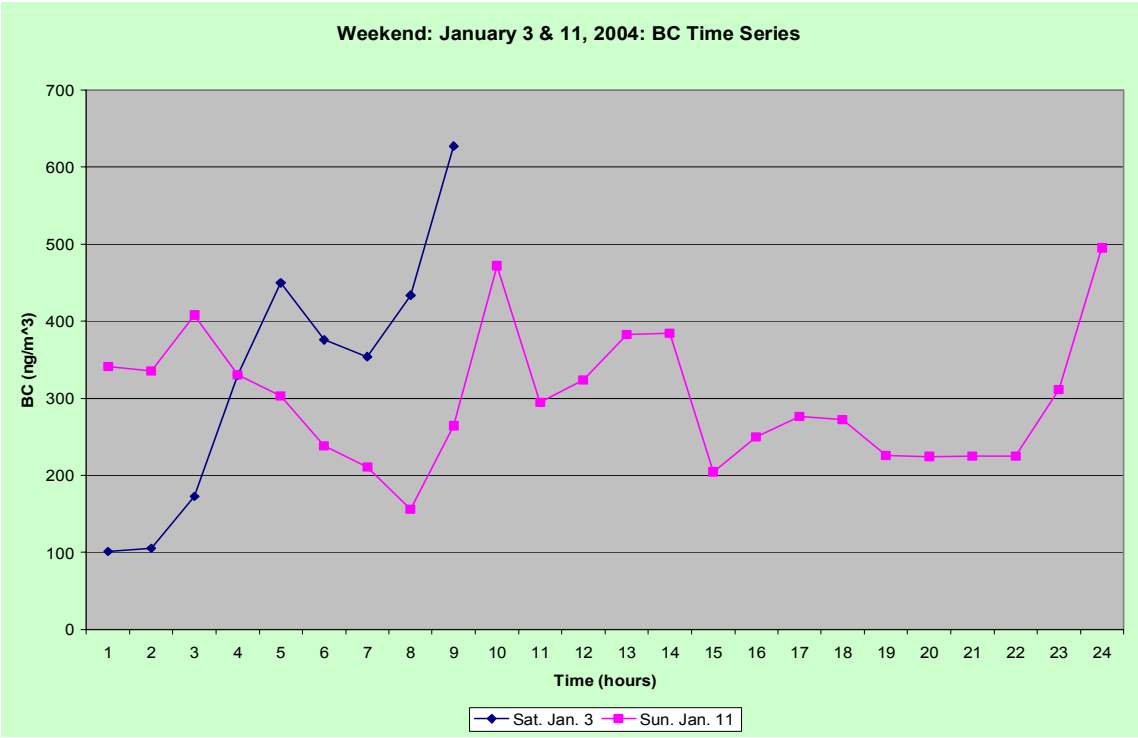

Figure 19. January 2004 Weekend Black Carbon Concentrations (ng/m^3) Time Series

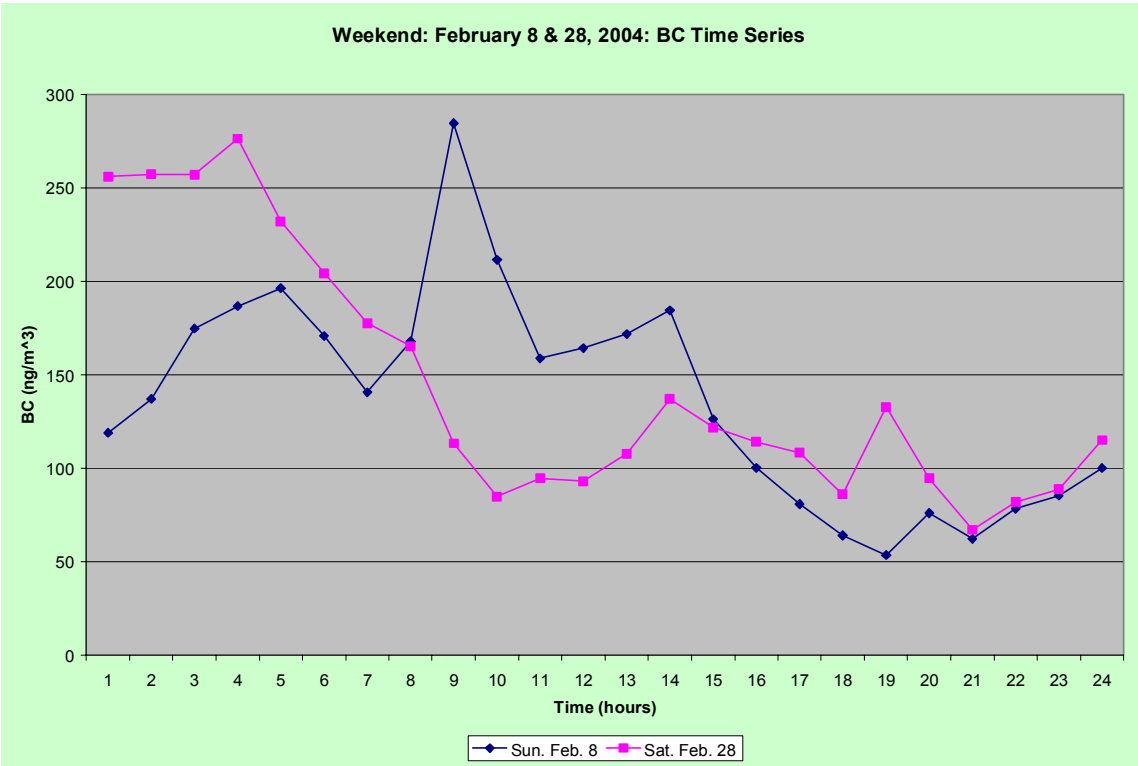

Figure 20. February 2004 Weekend Black Carbon Concentrations (ng/m^3) Time Series

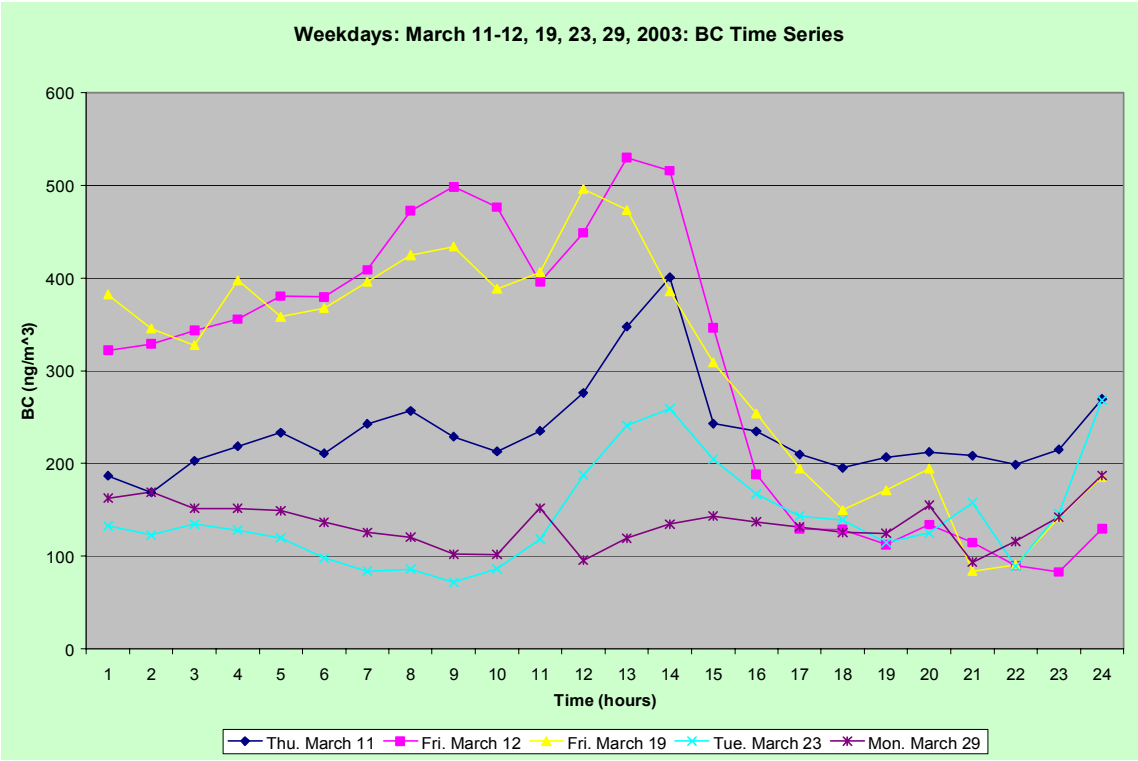

Figure 21. March 2004 Weekdays Black Carbon Concentrations (ng/m^3) Time Series

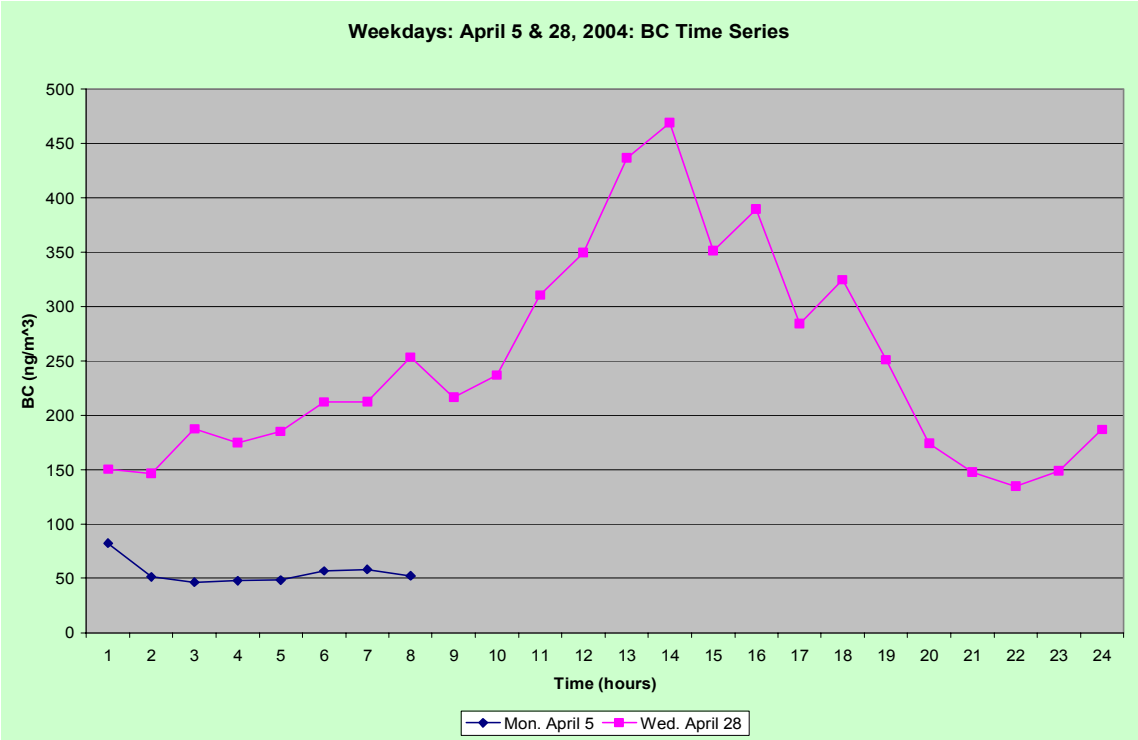

Figure 22. April 2004 Weekdays Black Carbon Concentrations (ng/m^3) Time Series

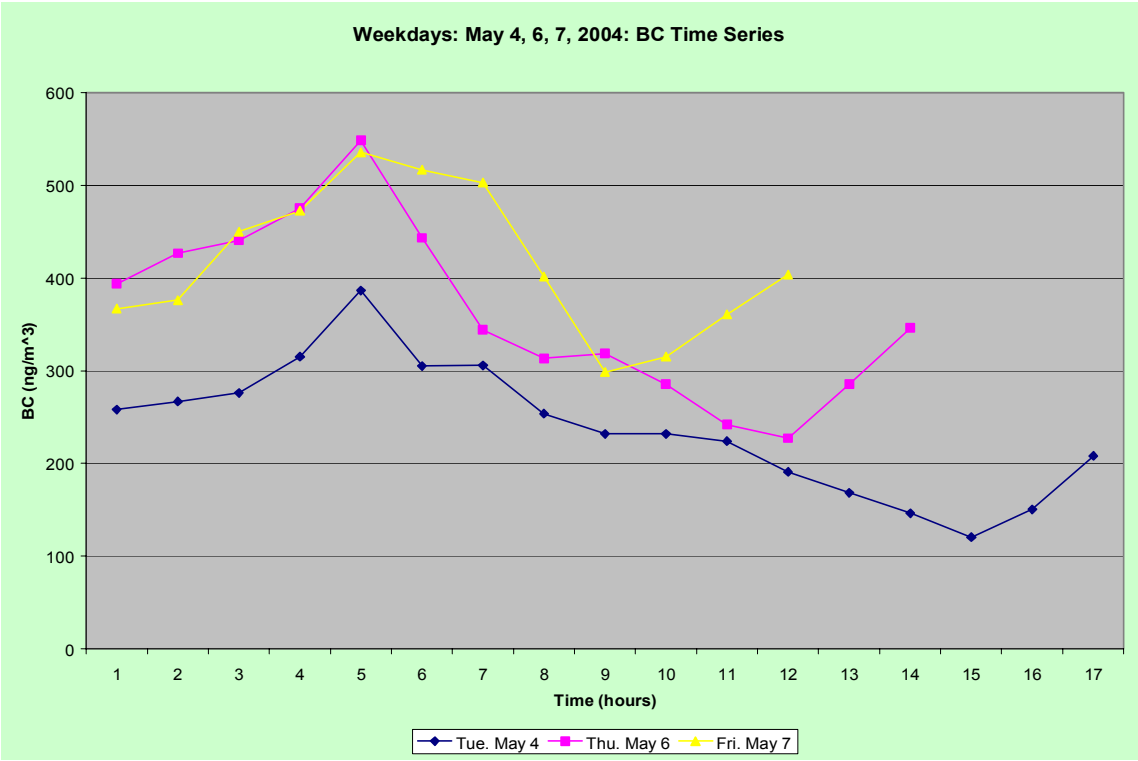

Figure 23. May 2004 Weekdays Black Carbon Concentrations (ng/m^3) Time Series

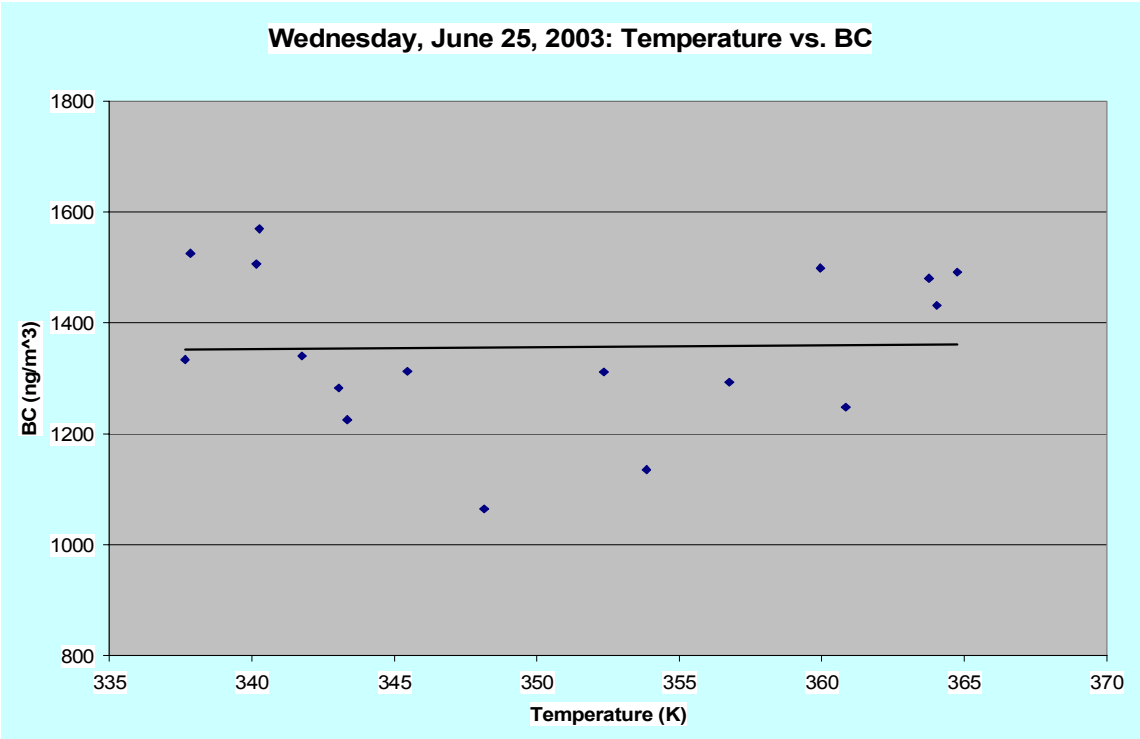

Figure 24. June 2003 Weekday Temperature (K) vs. BC Concentrations (ng/m^3)

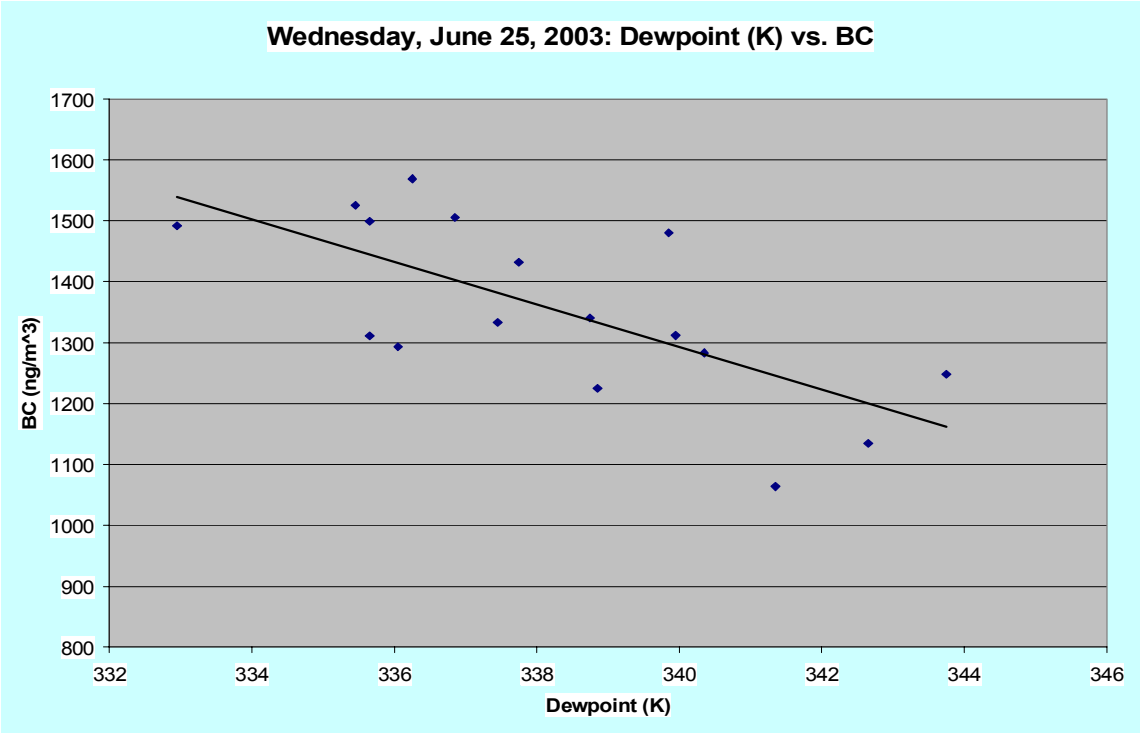

Figure 25. June 2003 Weekday Dewpoint (K) vs. BC Concentrations (ng/m^3)

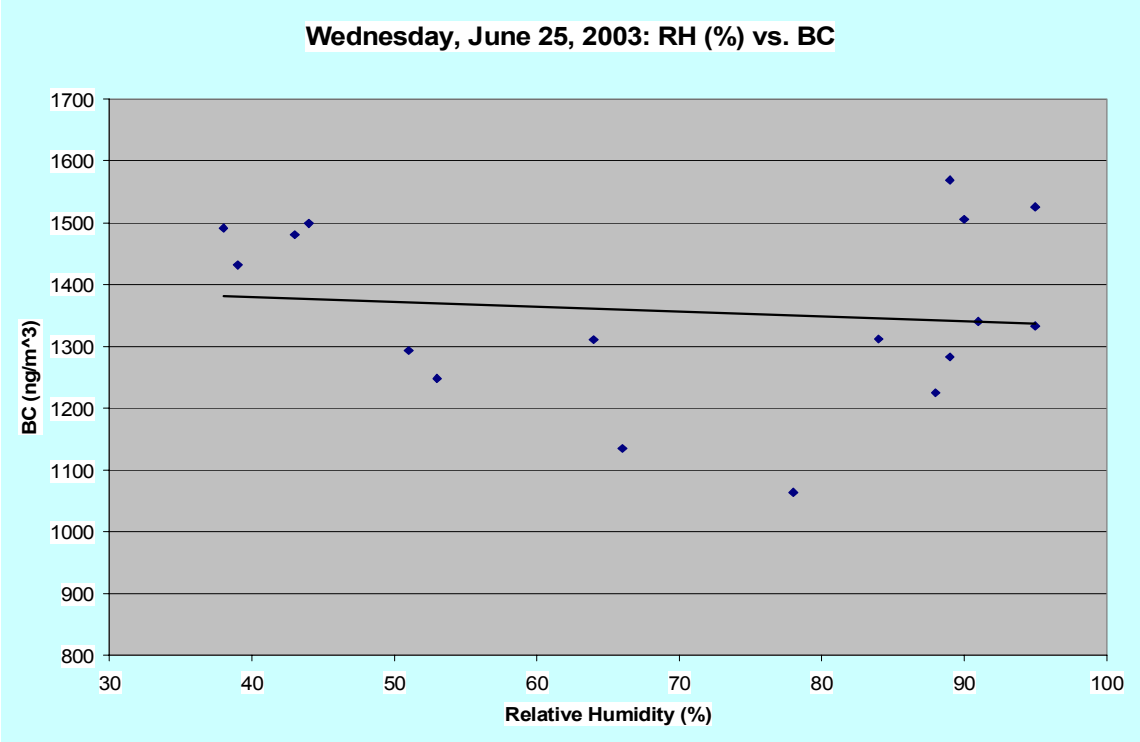

Figure 26. June 2003 Weekday Relative Humidity (%) vs. BC Concentrations (ng/m^3)

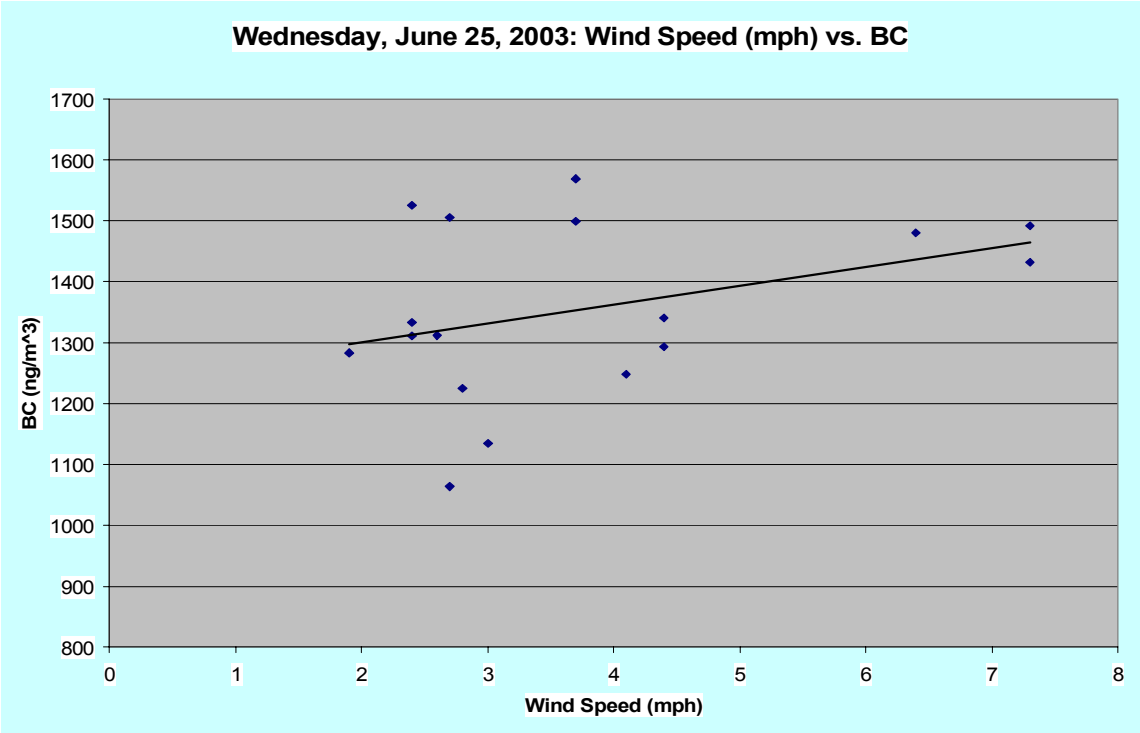

Figure 27. June 2003 Weekday Wind Speed (mph) vs. BC Concentrations (ng/m^3)

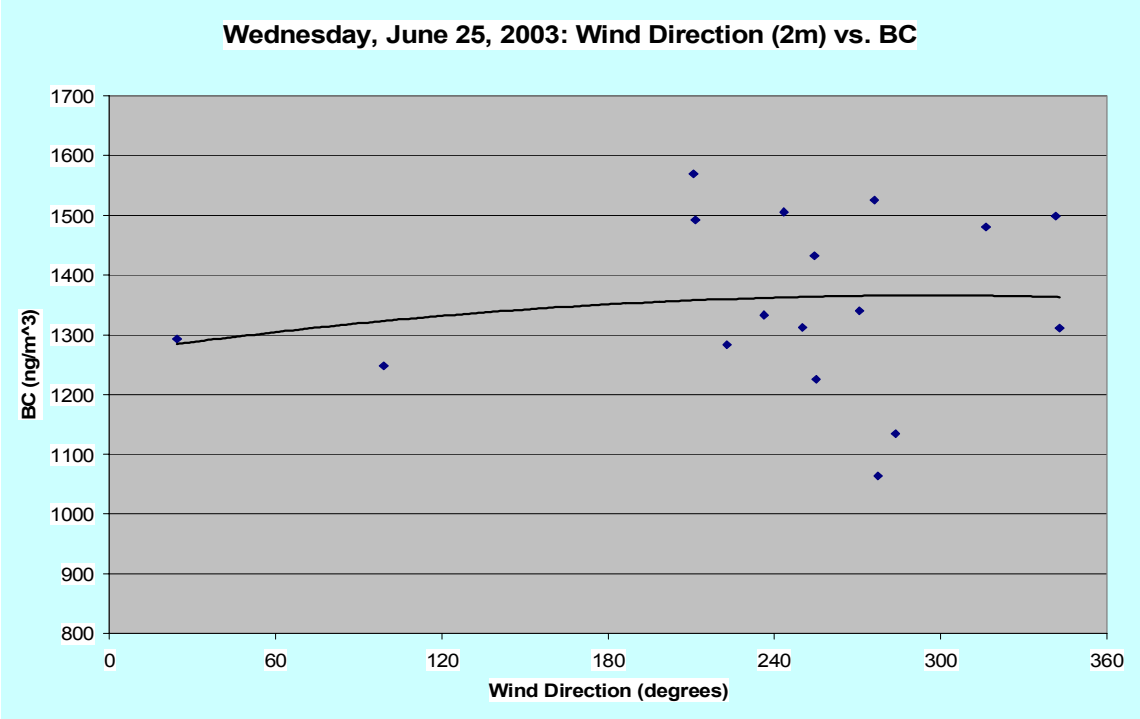

Figure 28. June 2003 Weekday Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

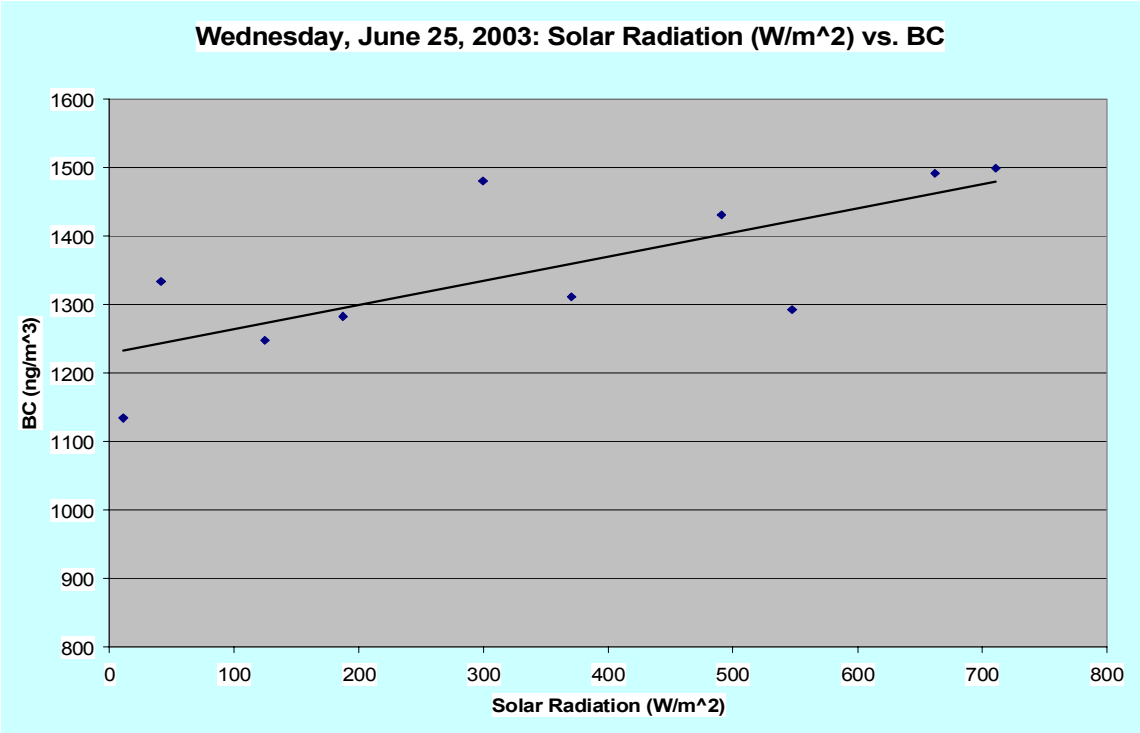

Figure 29. June 2003 Weekday Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

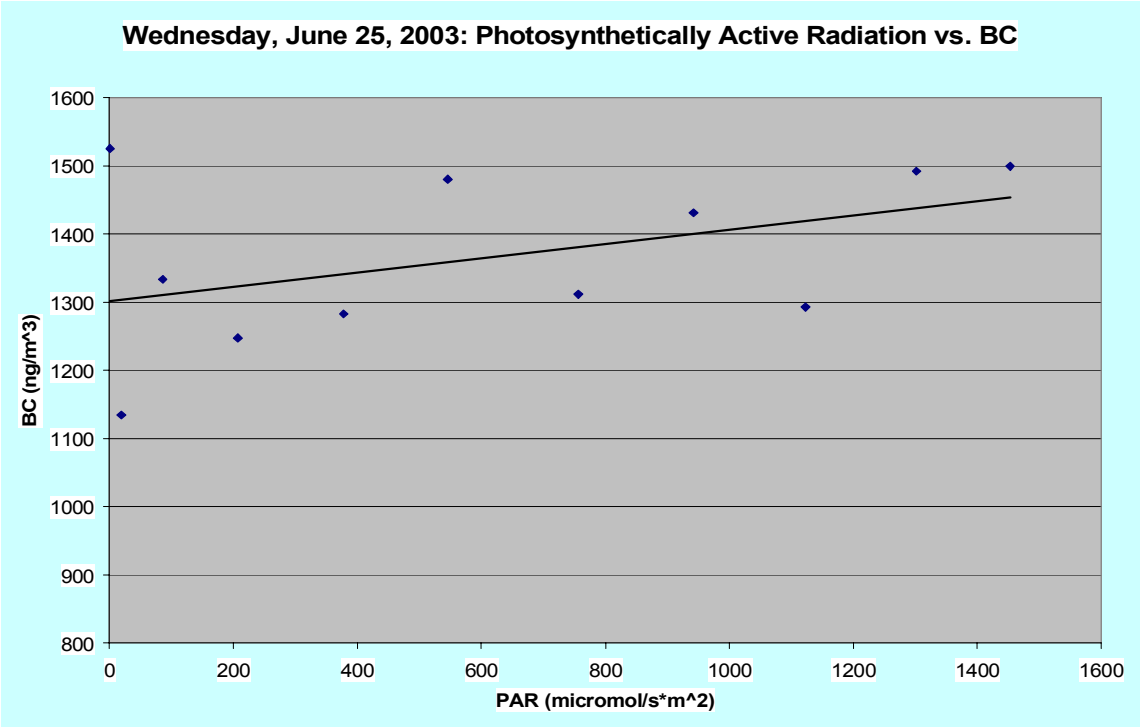

Figure 30. June 2003 Weekday PAR (micromol/s*m^2) vs. BC Concentrations (ng/m^3)

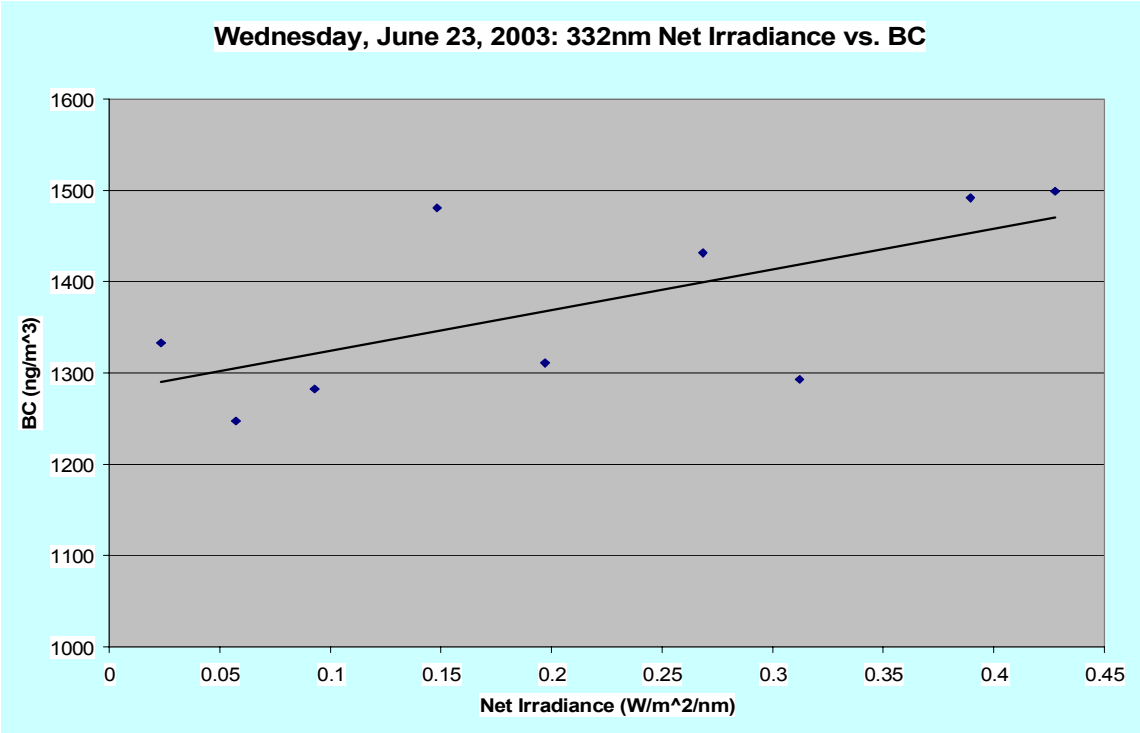

Figure 31. June 2003 Weekday 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

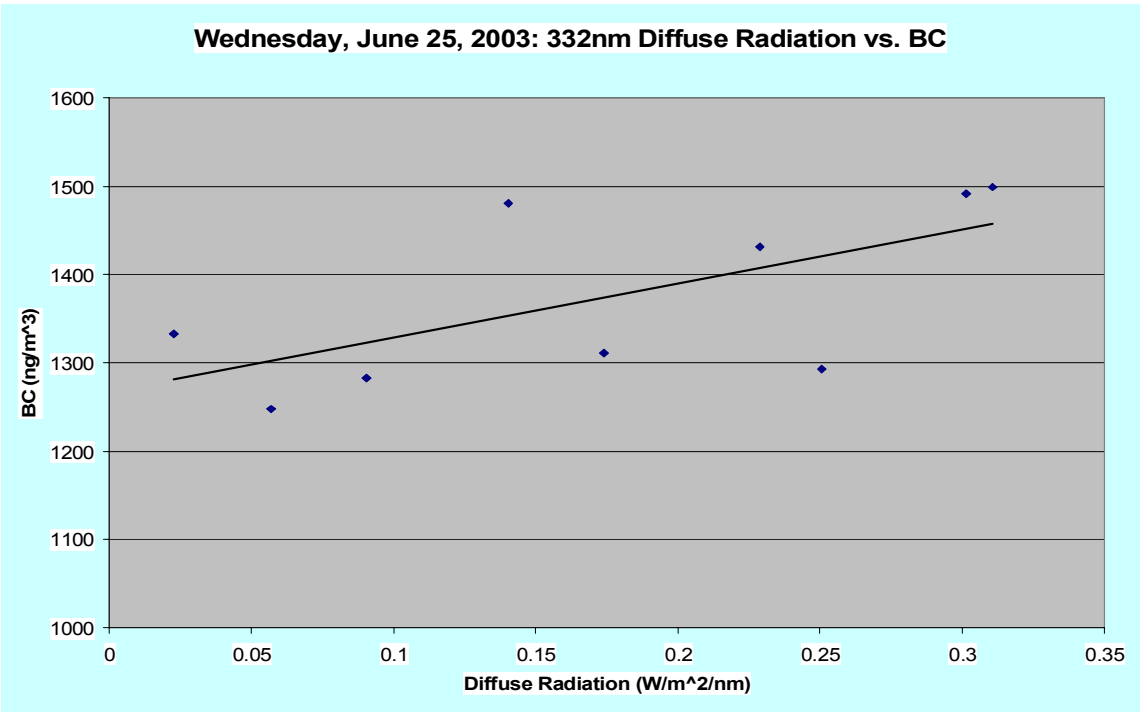

Figure 32. June 2003 Weekday 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

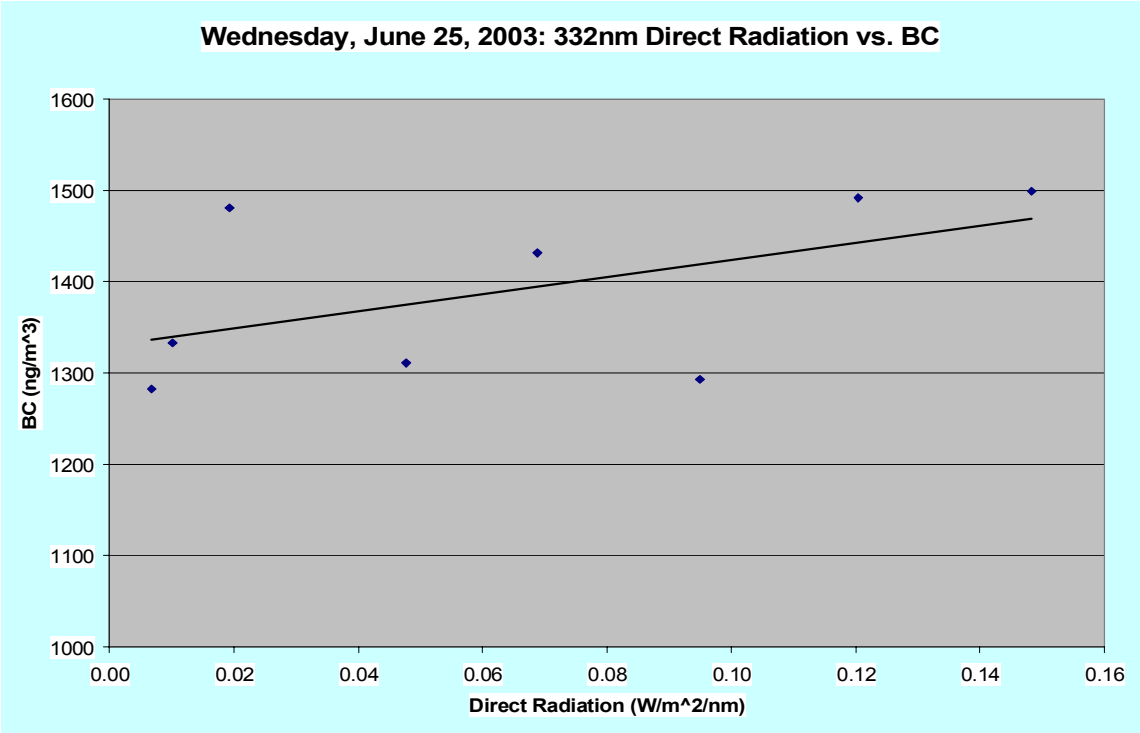

Figure 33. June 2003 Weekday 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

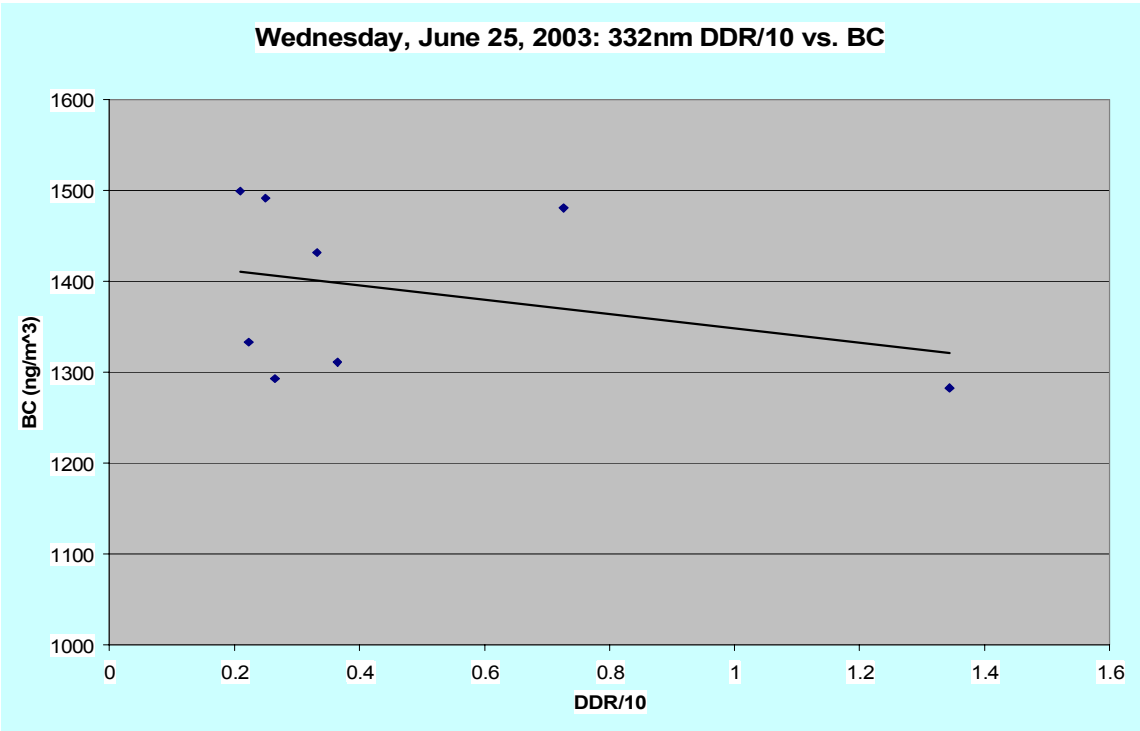

Figure 34. June 2003 Weekday 332nm DDR/10 vs. BC Concentrations (ng/m^3)

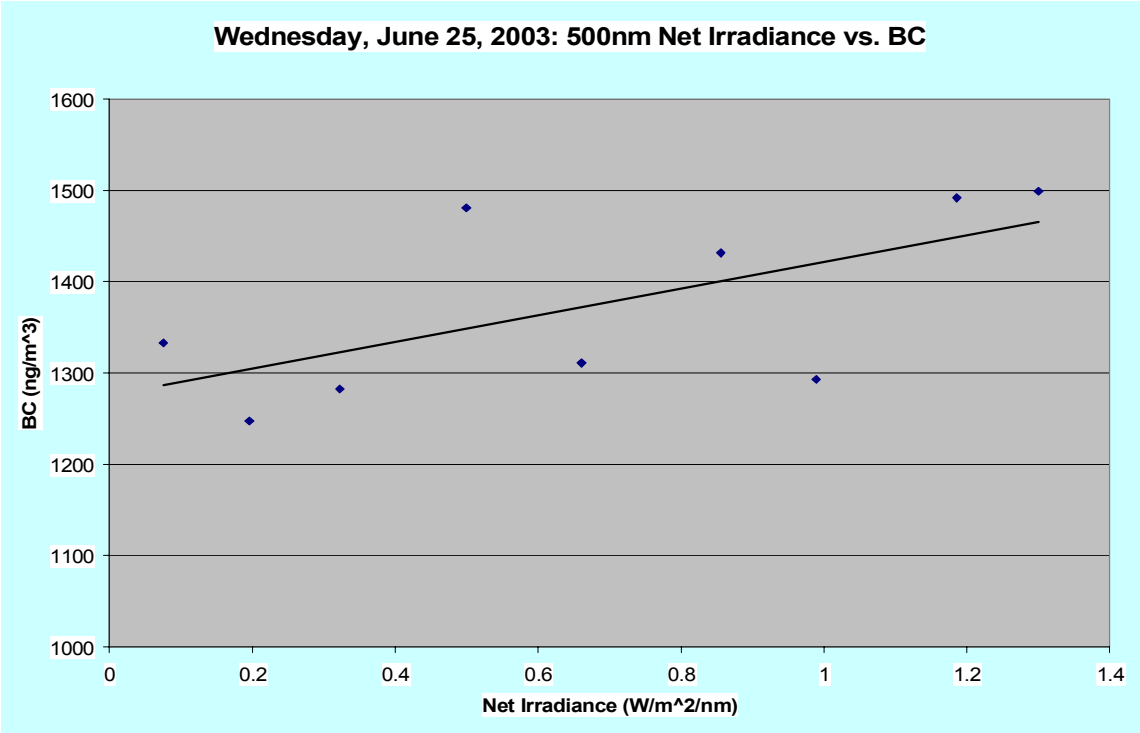

Figure 35. June 2003 Weekday 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

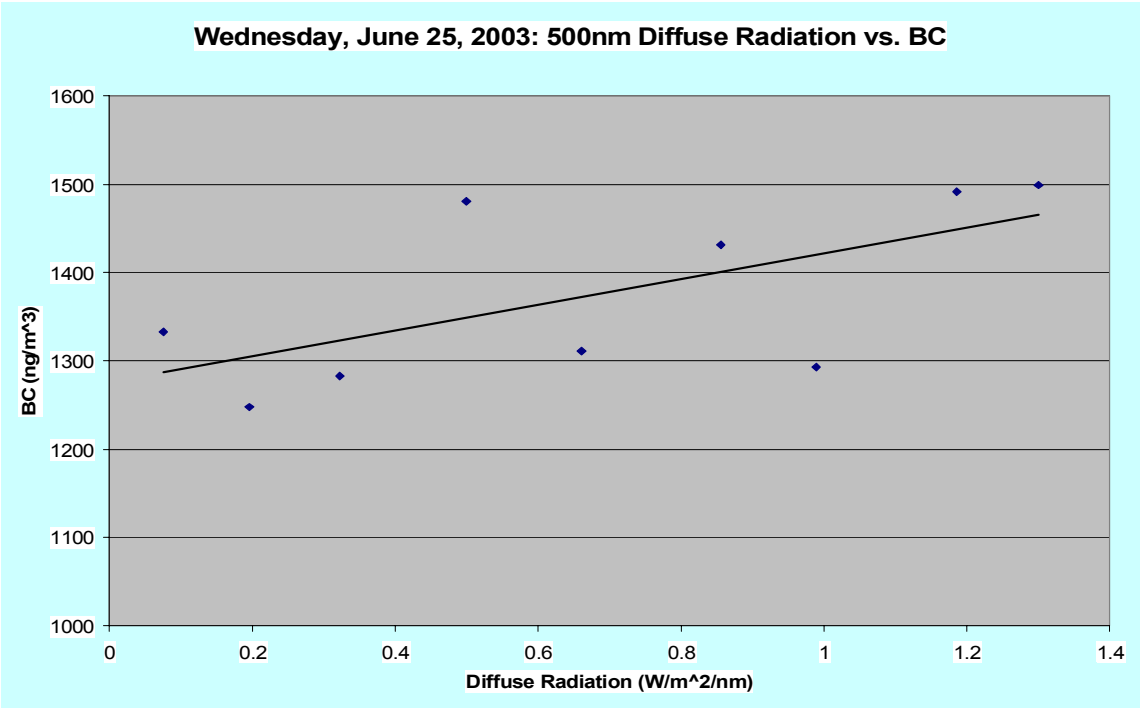

Figure 36. June 2003 Weekday 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentration (ng/m^3)

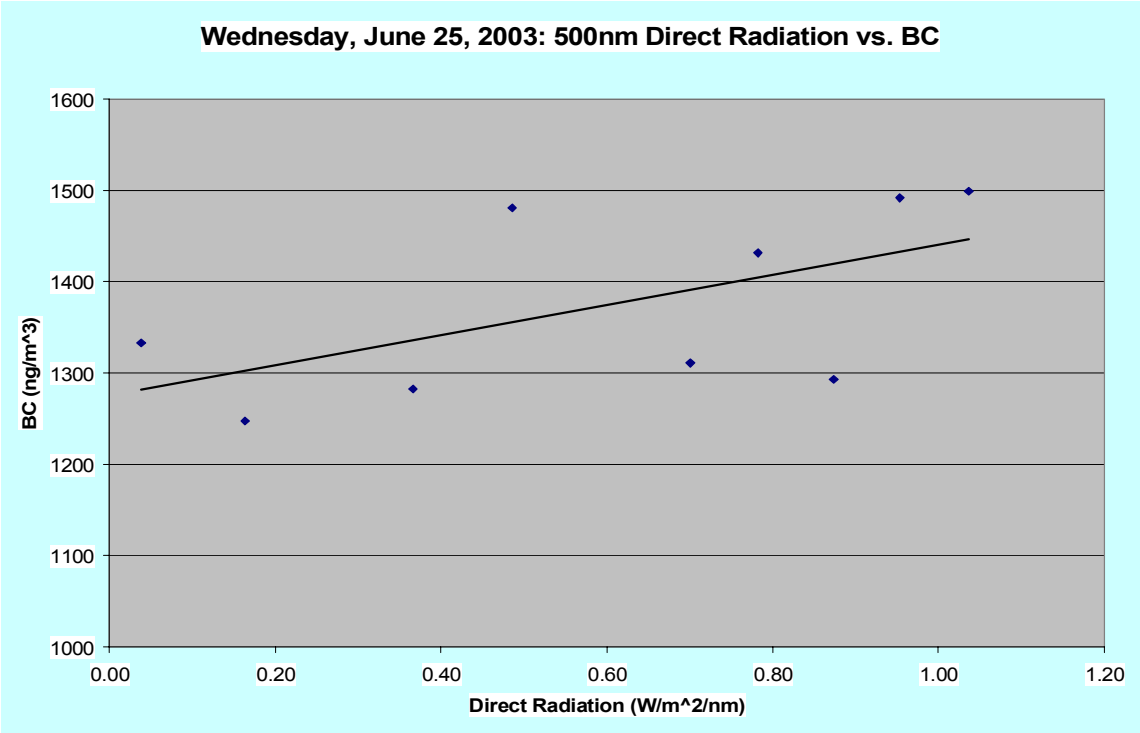

Figure 37. June 2003 Weekday 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

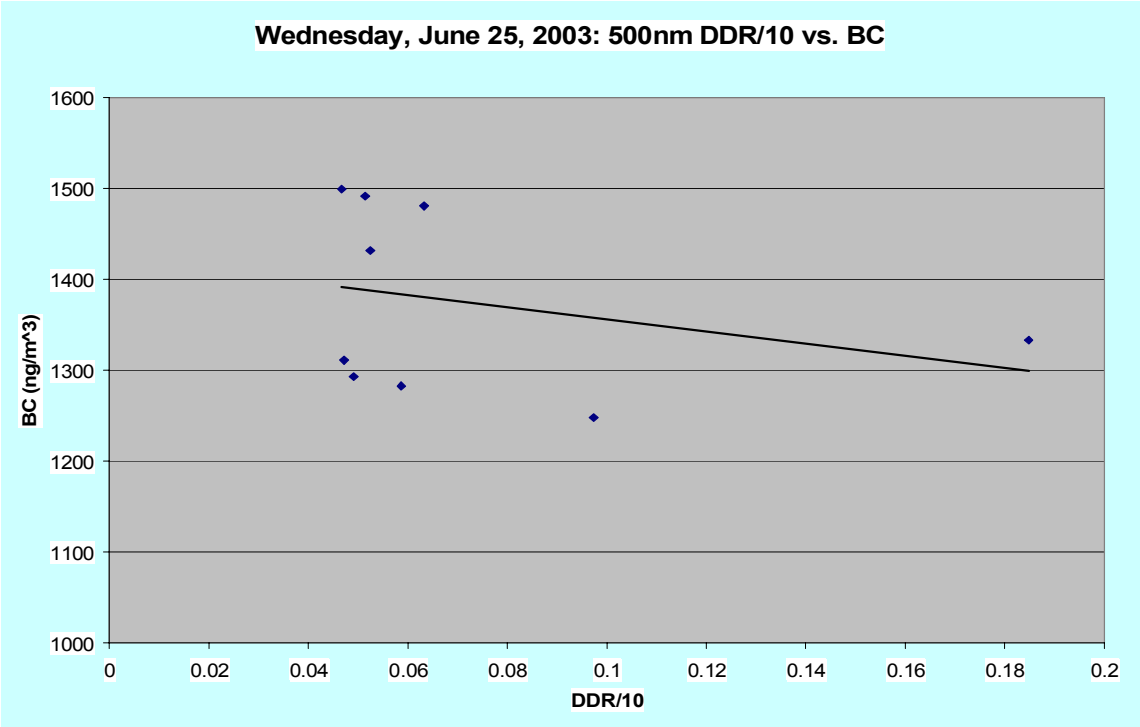

Figure 38. June 2003 Weekday 500nm DDR/10 vs. BC Concentrations (ng/m^3)

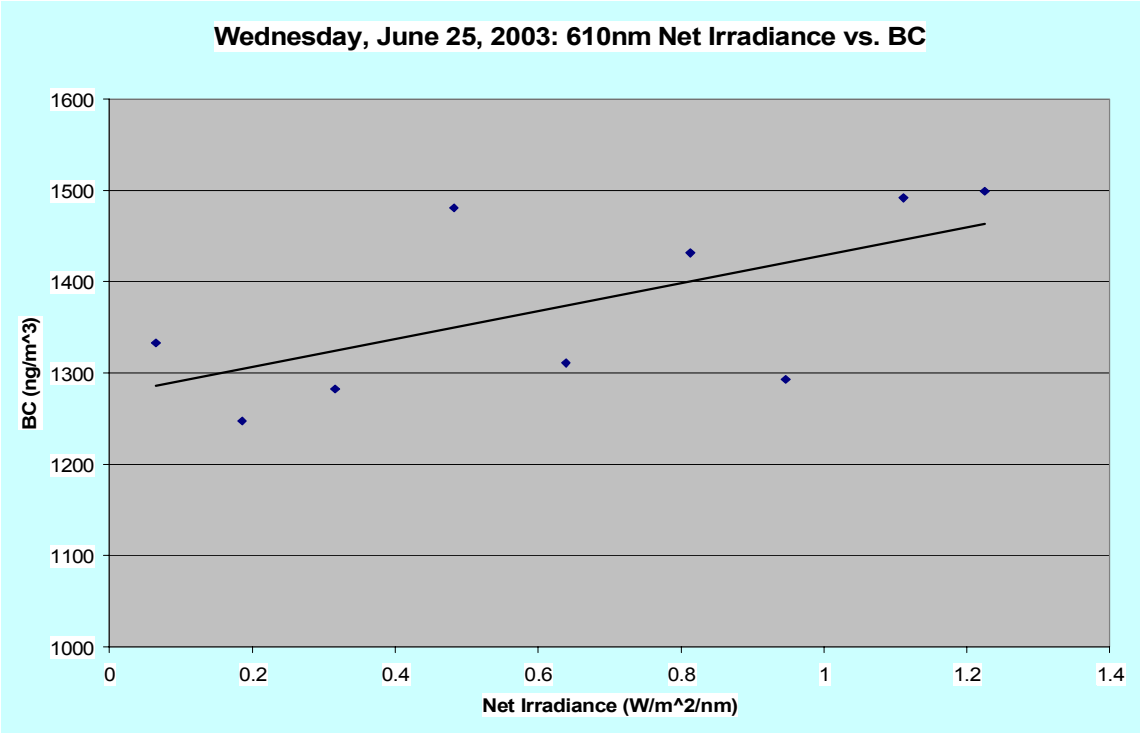

Figure 39. June 2003 Weekday 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

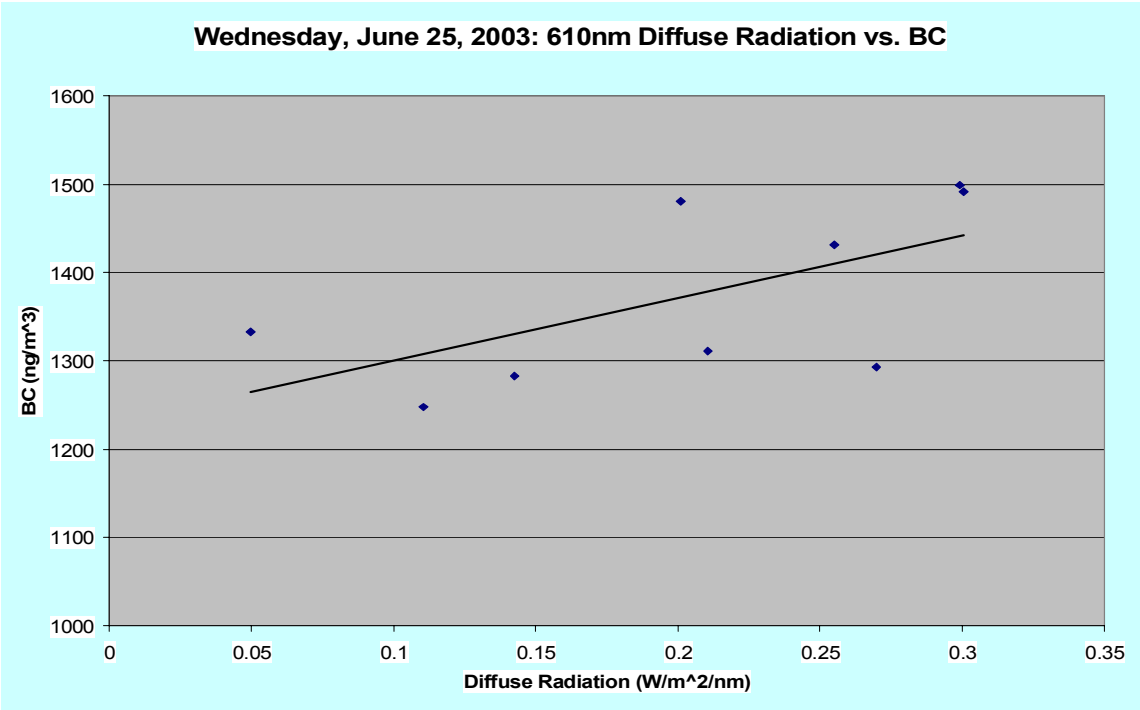

Figure 40. June 2003 Weekday 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

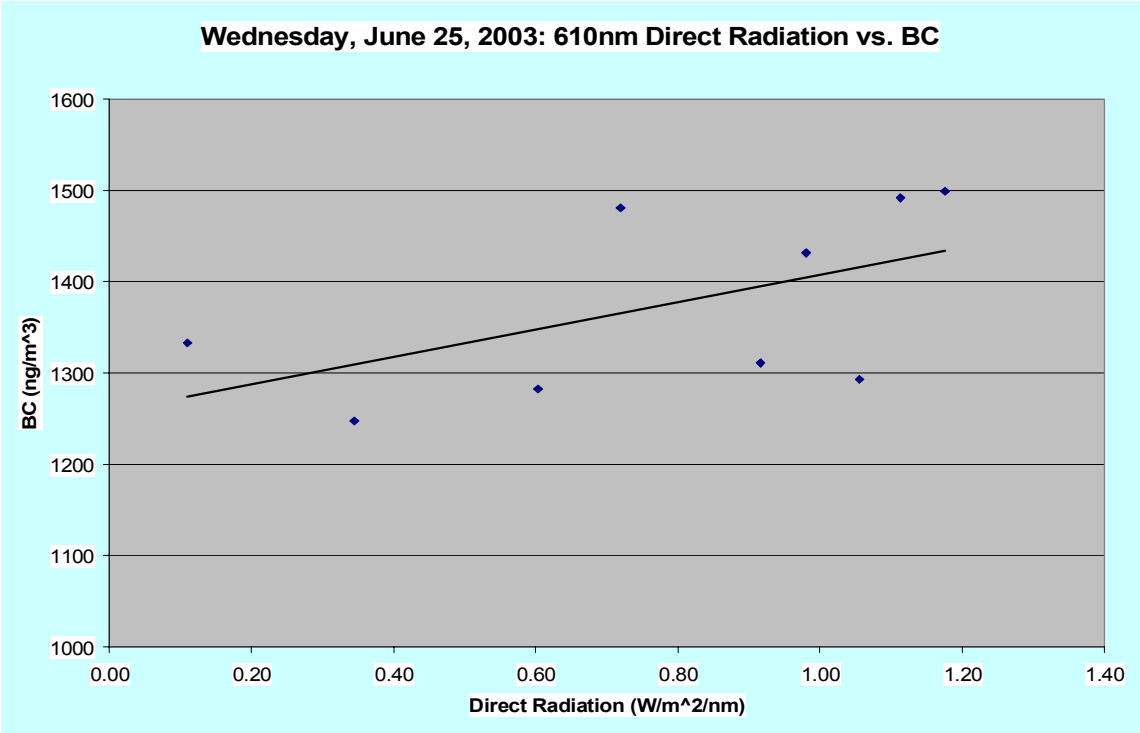

Figure 41. June 2003 Weekday 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

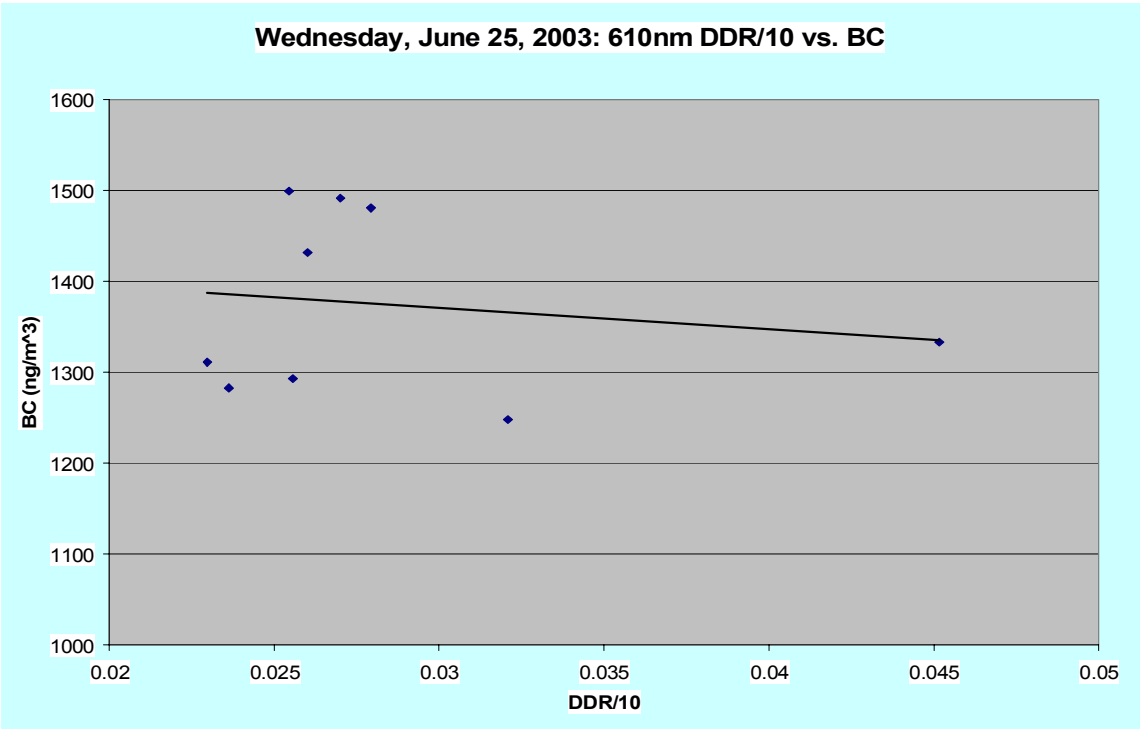

Figure 42. June 2003 Weekday 610nm DDR/10 vs. BC Concentrations (ng/m^3)

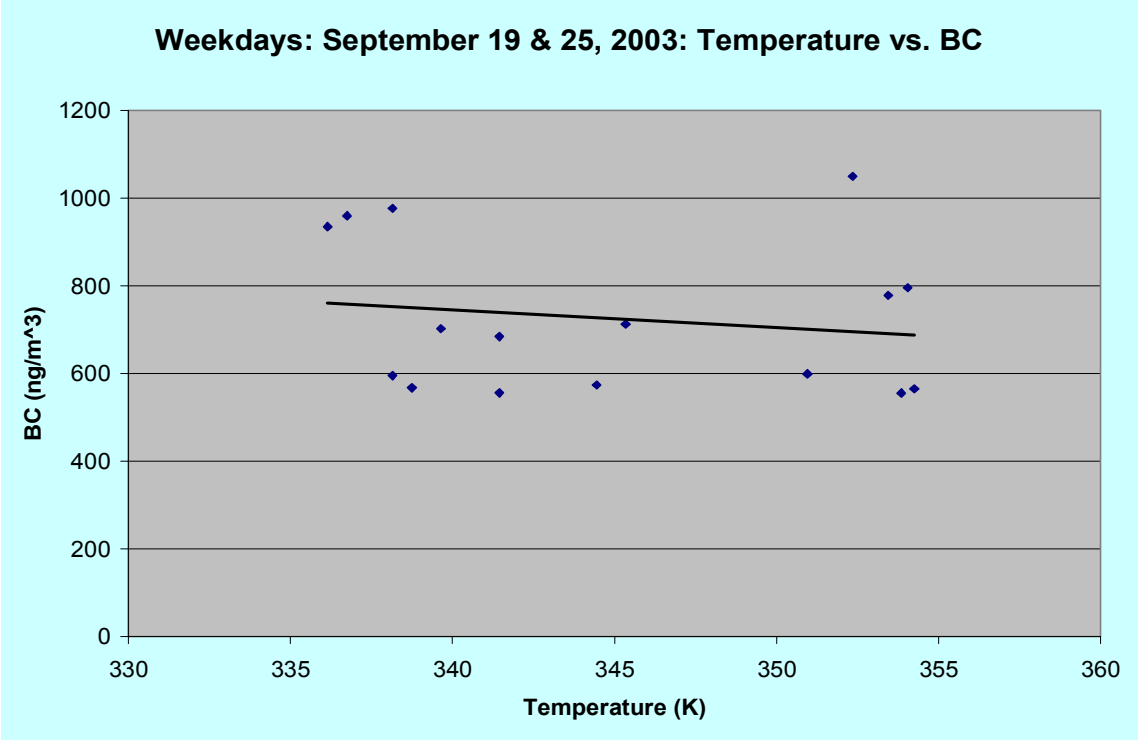

Figure 43. September 2003 Weekdays Temperature (K) vs. BC Concentrations (ng/m^3)

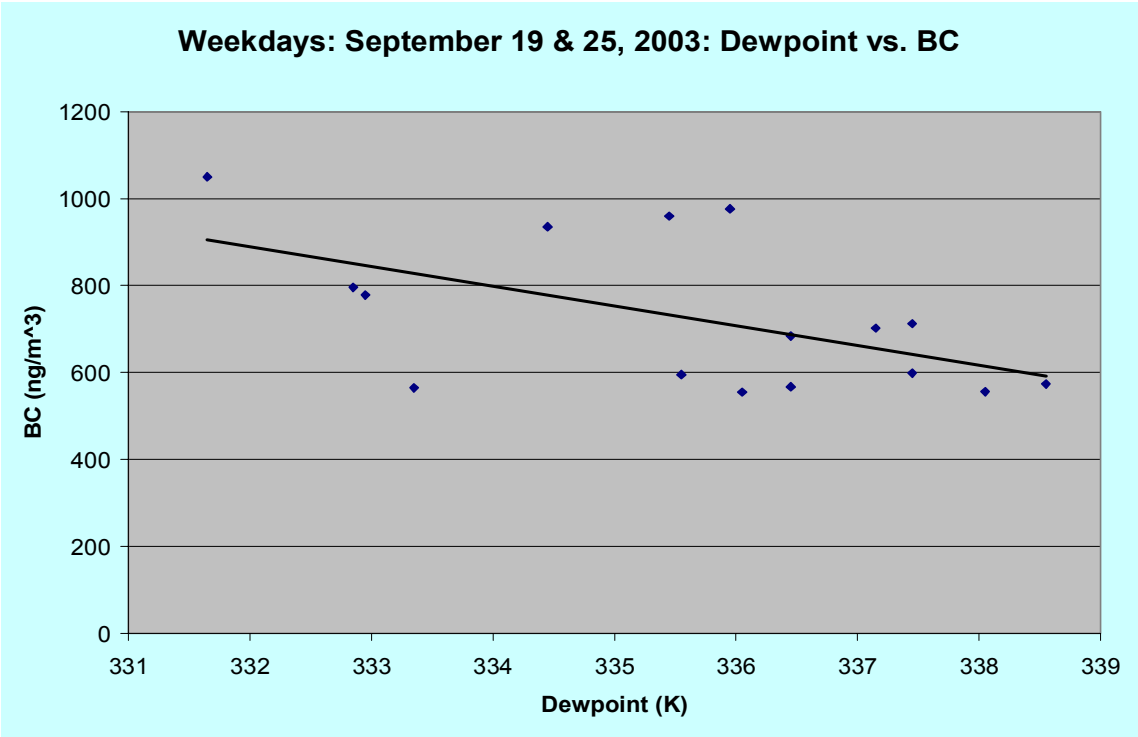

Figure 44. September 2003 Weekdays Dewpoint (K) vs. BC Concentrations (ng/m^3)

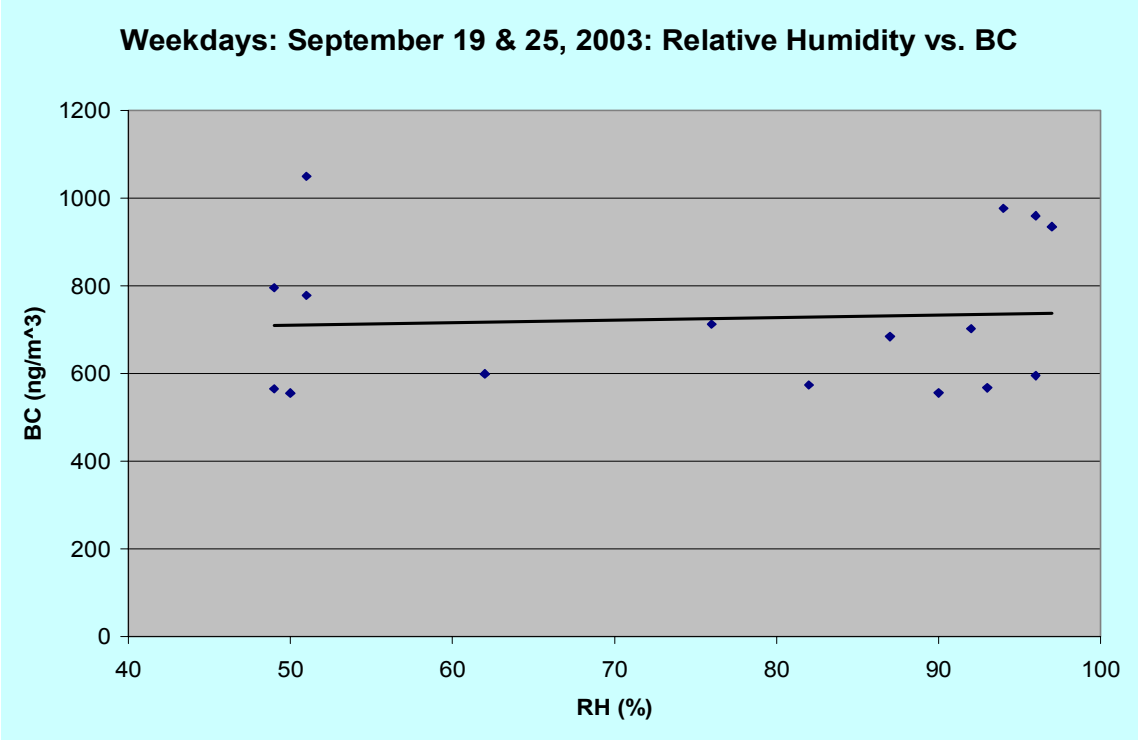

Figure 45. September 2003 Weekdays Relative Humidity (%) vs. BC Concentrations (ng/m^3)

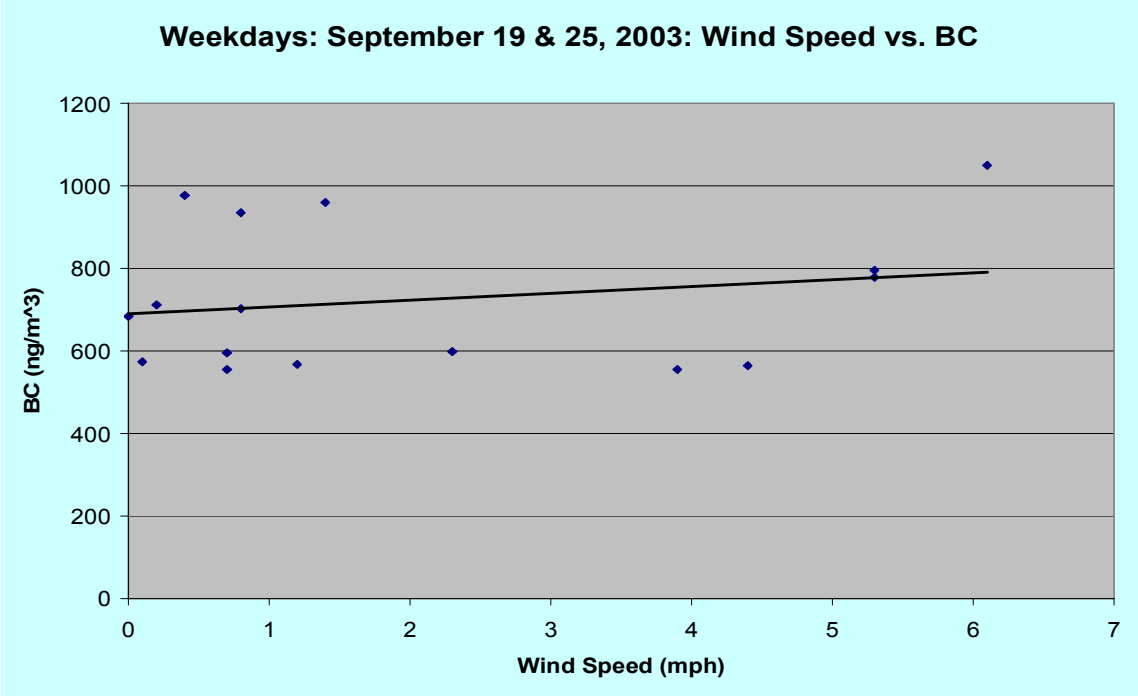

Figure 46. September 2003 Weekdays Wind Speed (mph) vs. BC Concentrations (ng/m^3)

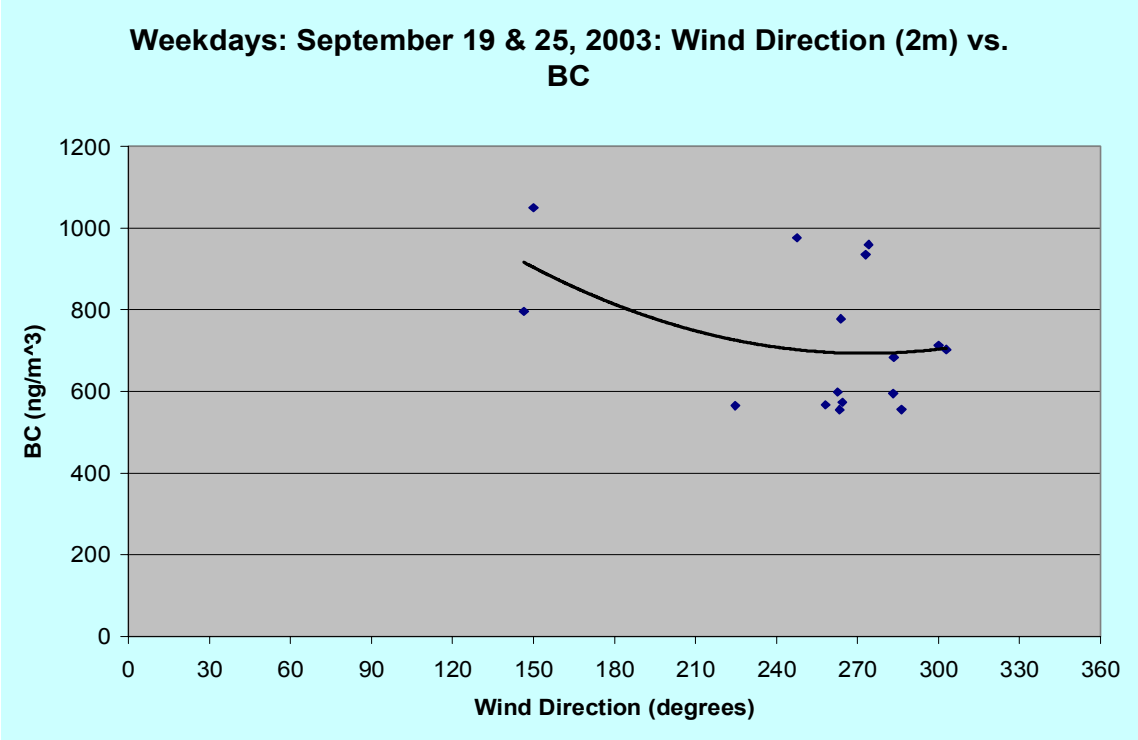

Figure 47. September 2003 Weekdays Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

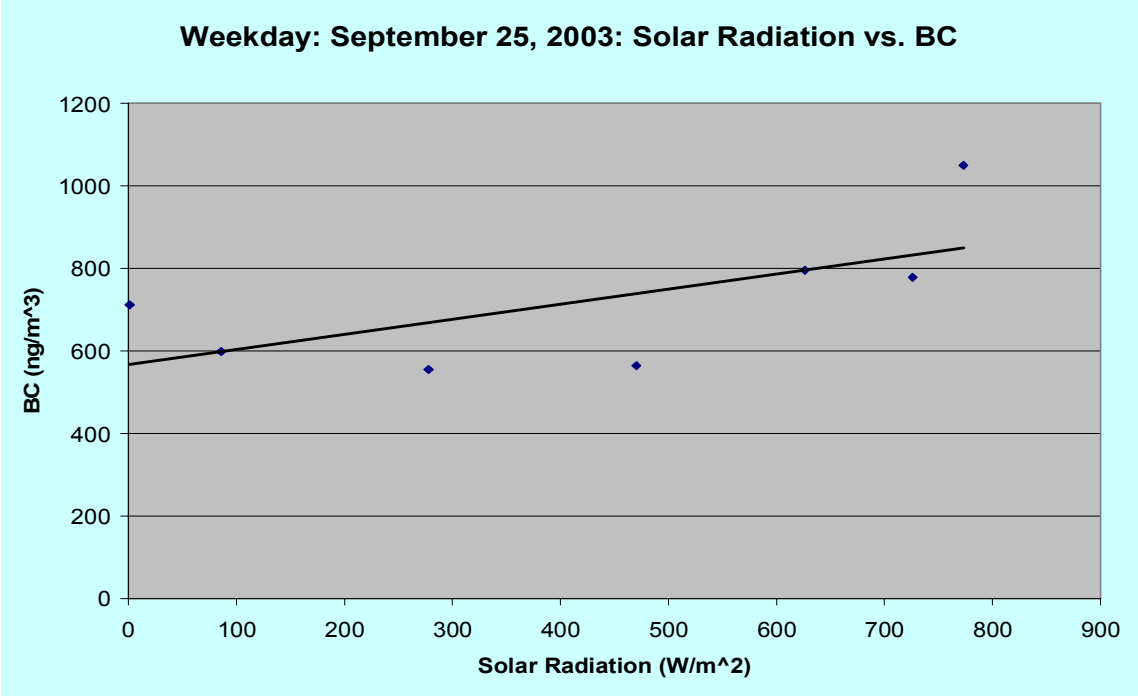

Figure 48. September 2003 Weekday Solar Radiation (W/m^2) vs. BC Concentrations (ng/m^3)

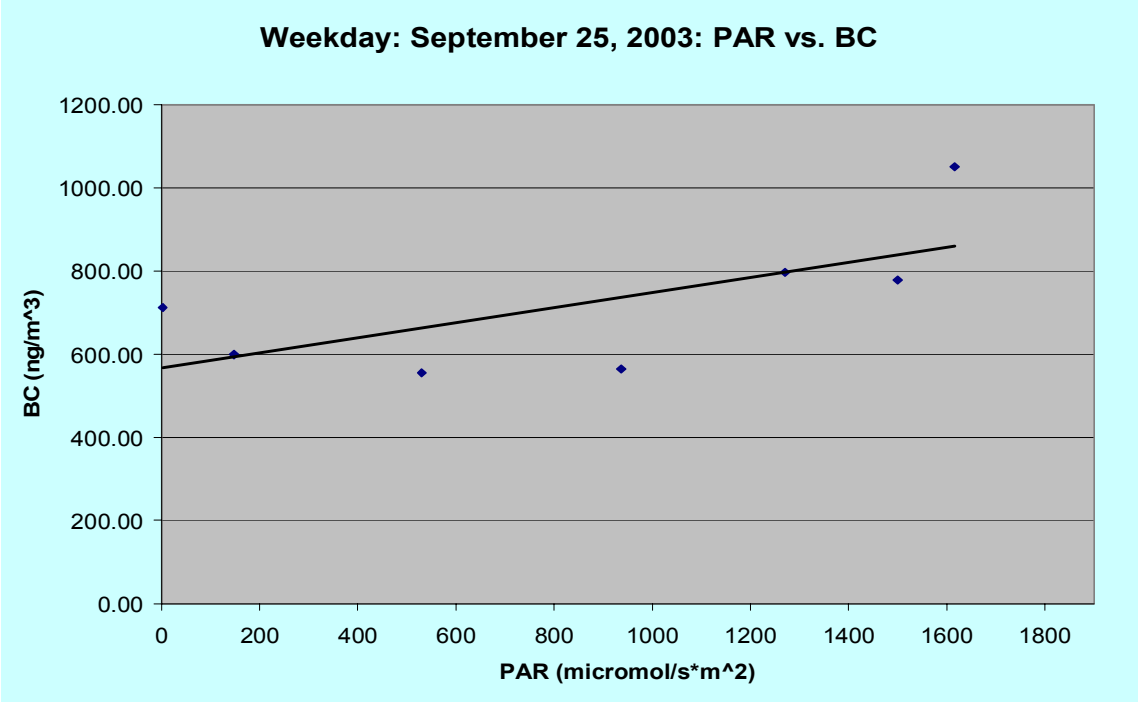

Figure 49. September 2003 Weekday PAR (micromols/s*m^2) vs. BC Concentrations (ng/m^3)

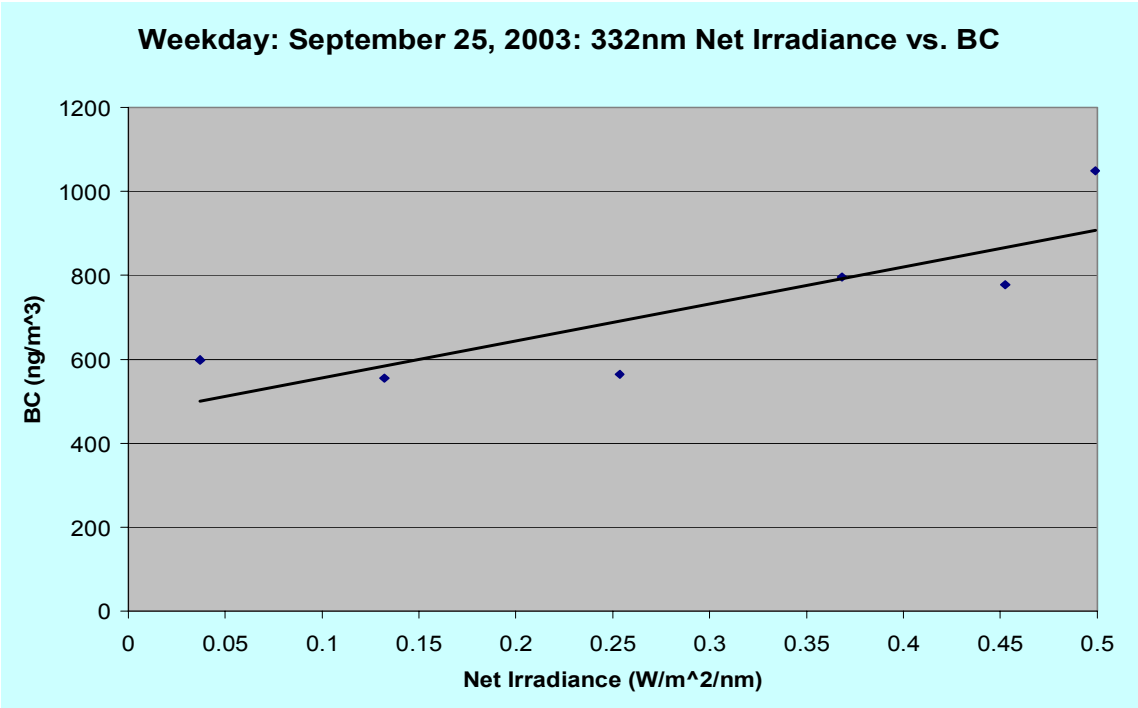

Figure 50. September 2003 Weekday 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

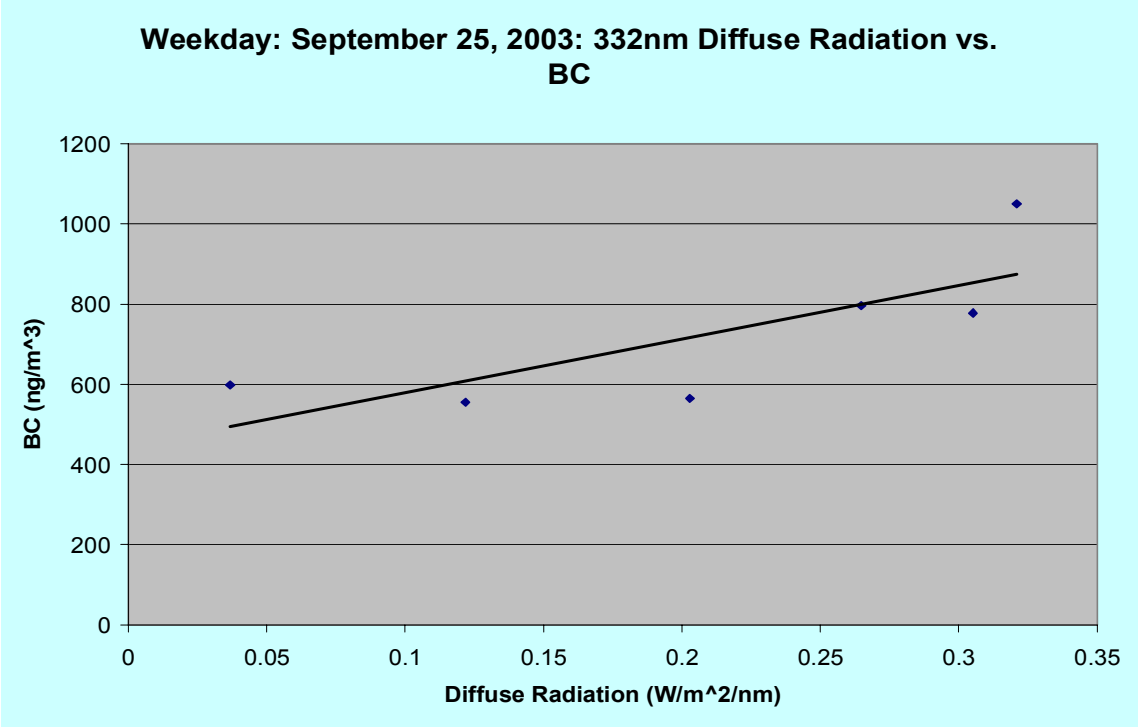

Figure 51. September 2003 Weekday 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

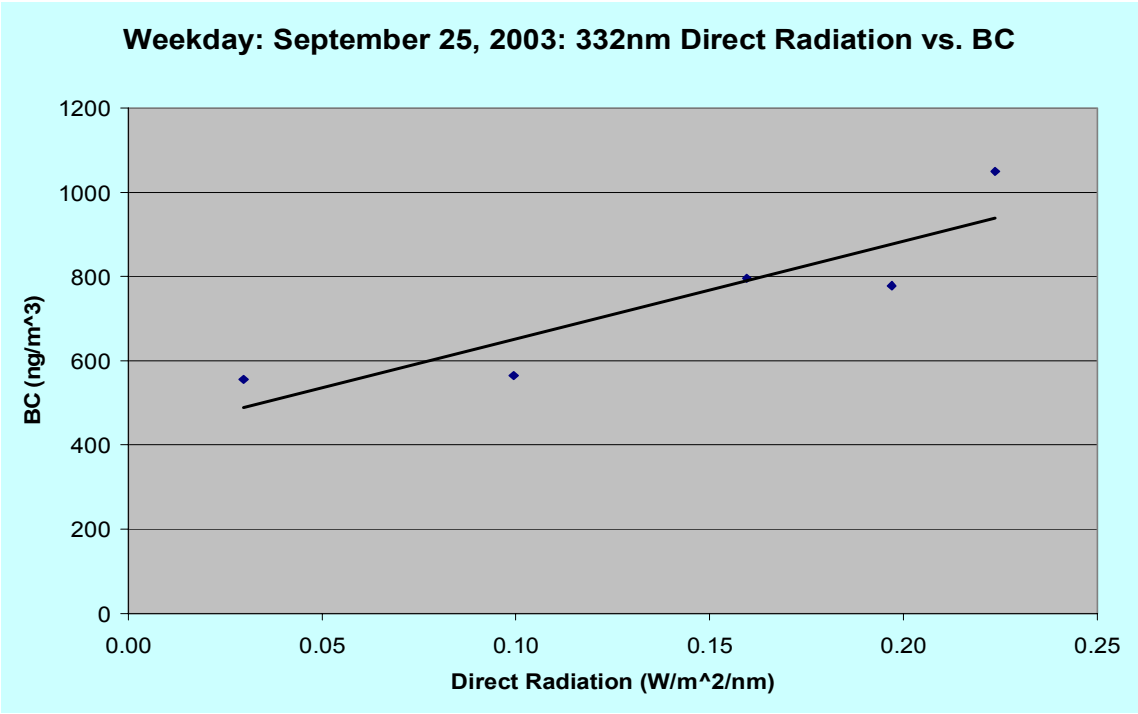

Figure 52. September 2003 Weekday 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

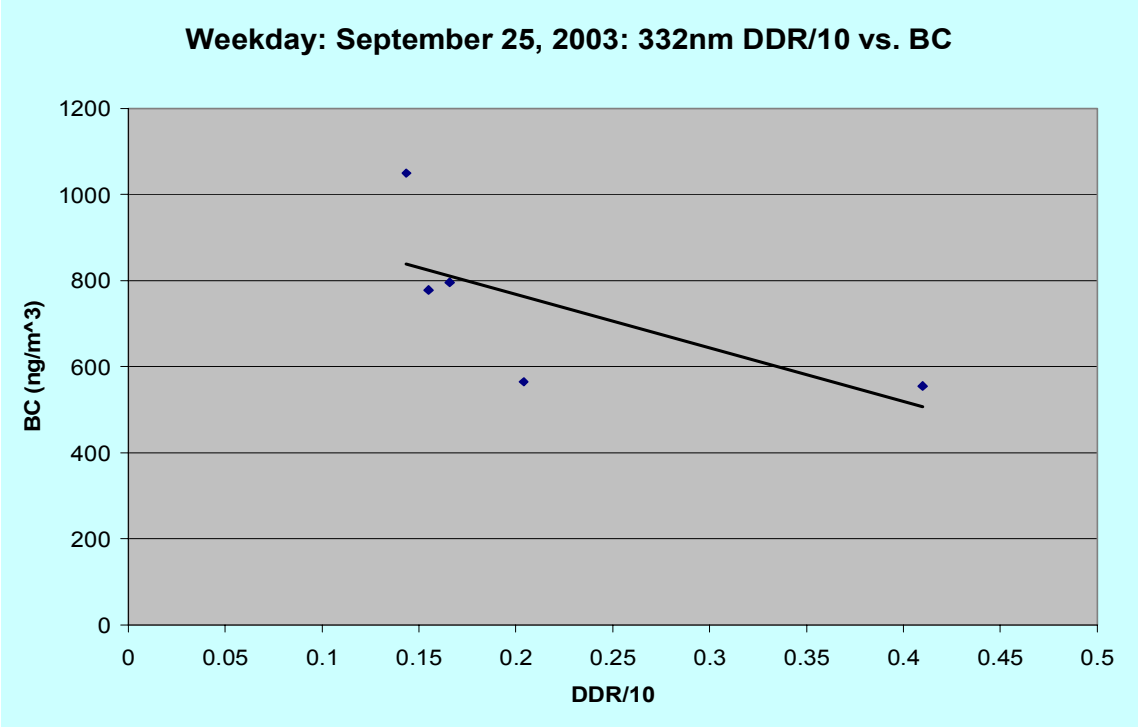

Figure 53. September 2003 Weekday 332nm DDR/10 vs. BC Concentrations (ng/m^3)

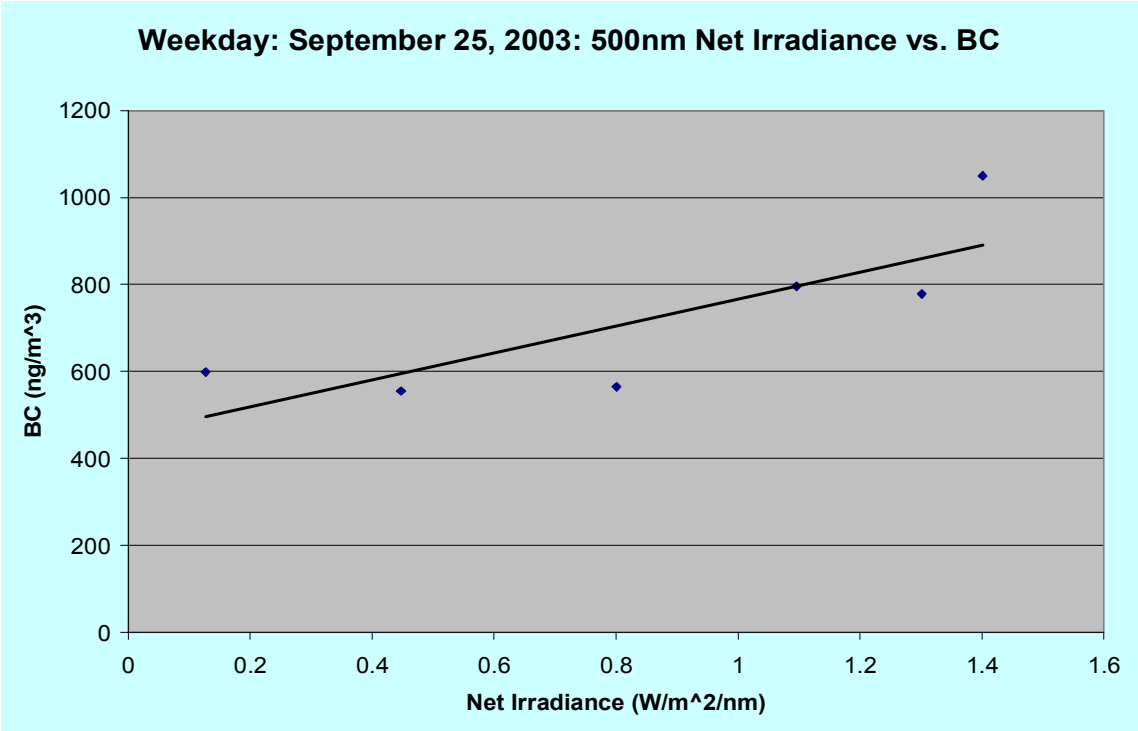

Figure 54. September 2003 Weekday 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

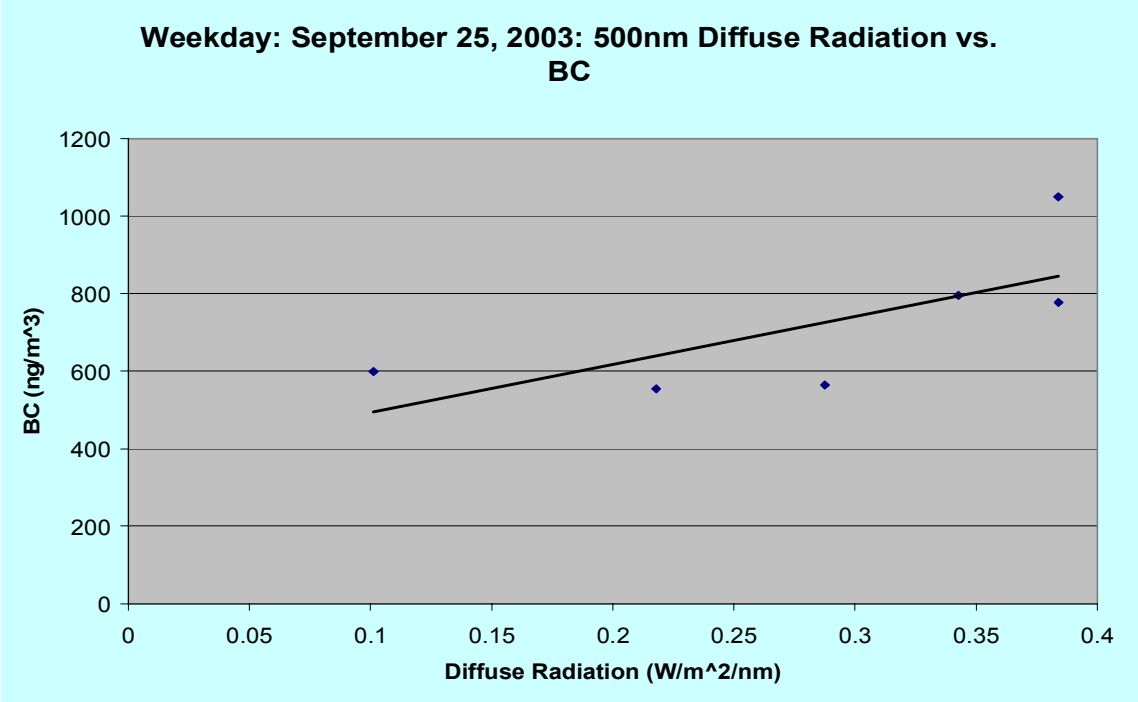

Figure 55. September 2003 Weekday 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

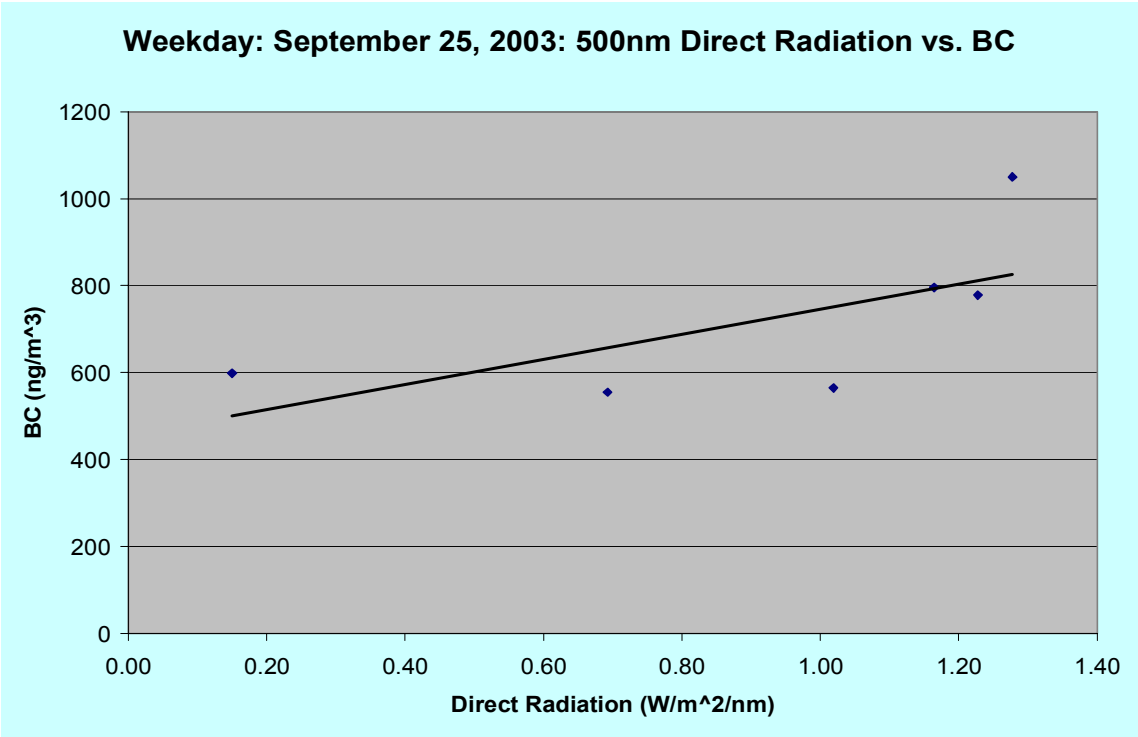

Figure 56. September 2003 Weekday 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

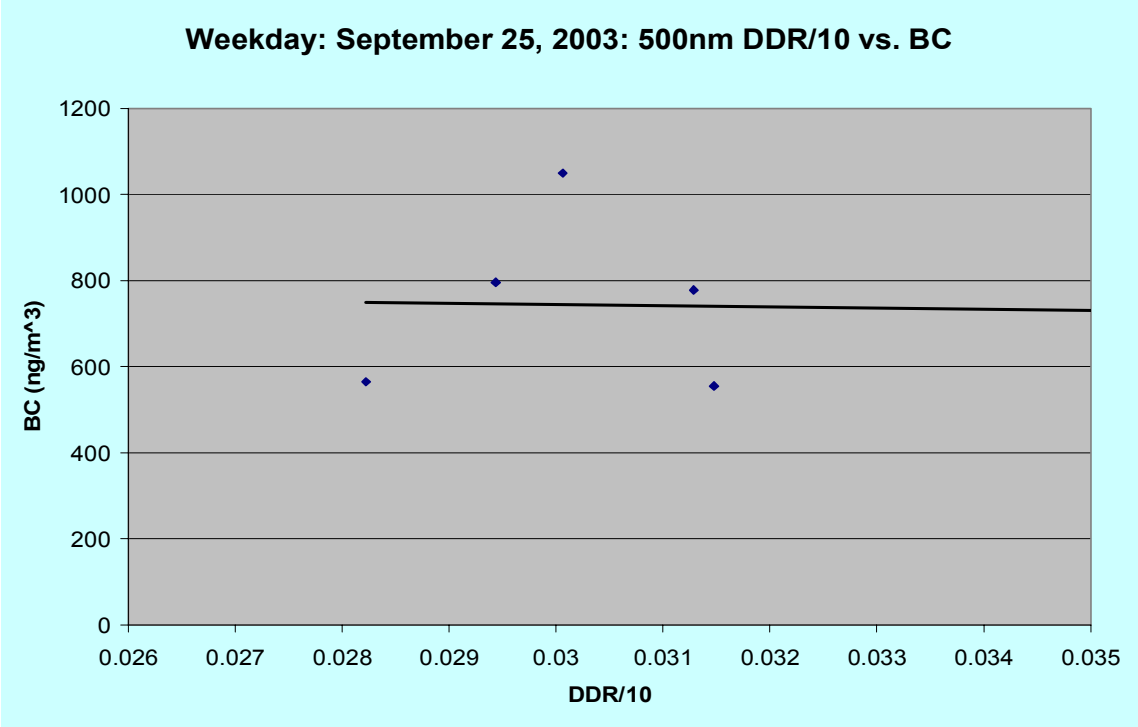

Figure 57. September 2003 Weekday 500nm DDR/10 vs. BC Concentrations (ng/m^3)

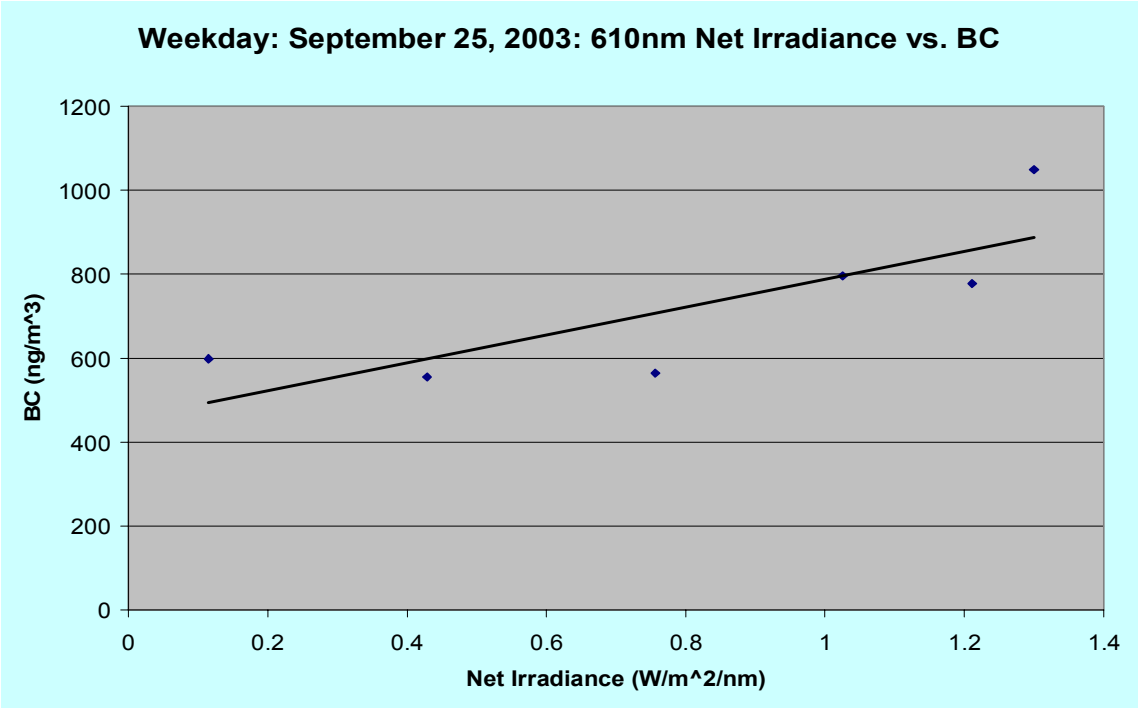

Figure 58. September 2003 Weekday 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

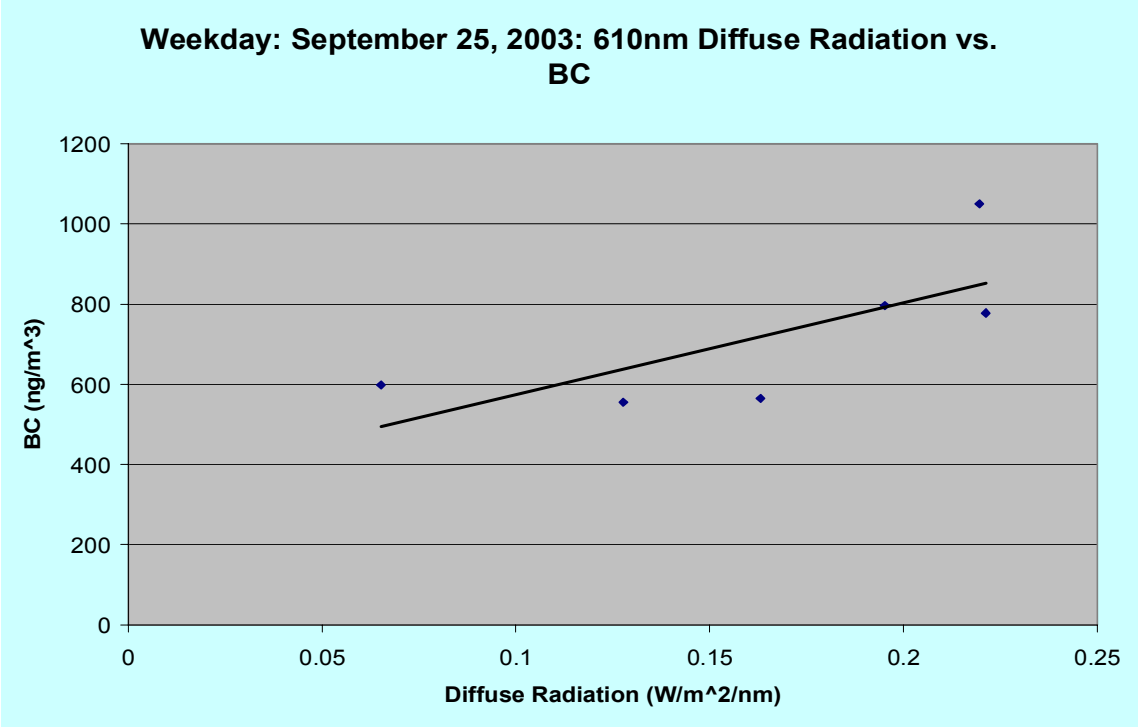

Figure 59. September 2003 Weekday 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

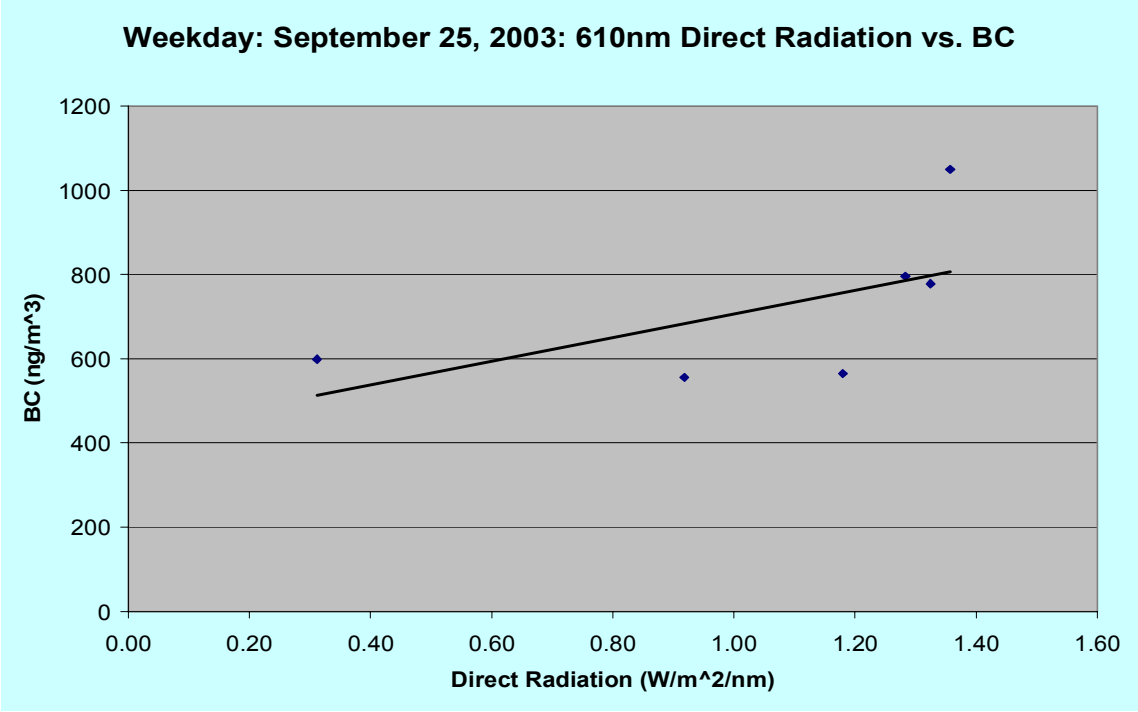

Figure 60. September 2003 Weekday 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

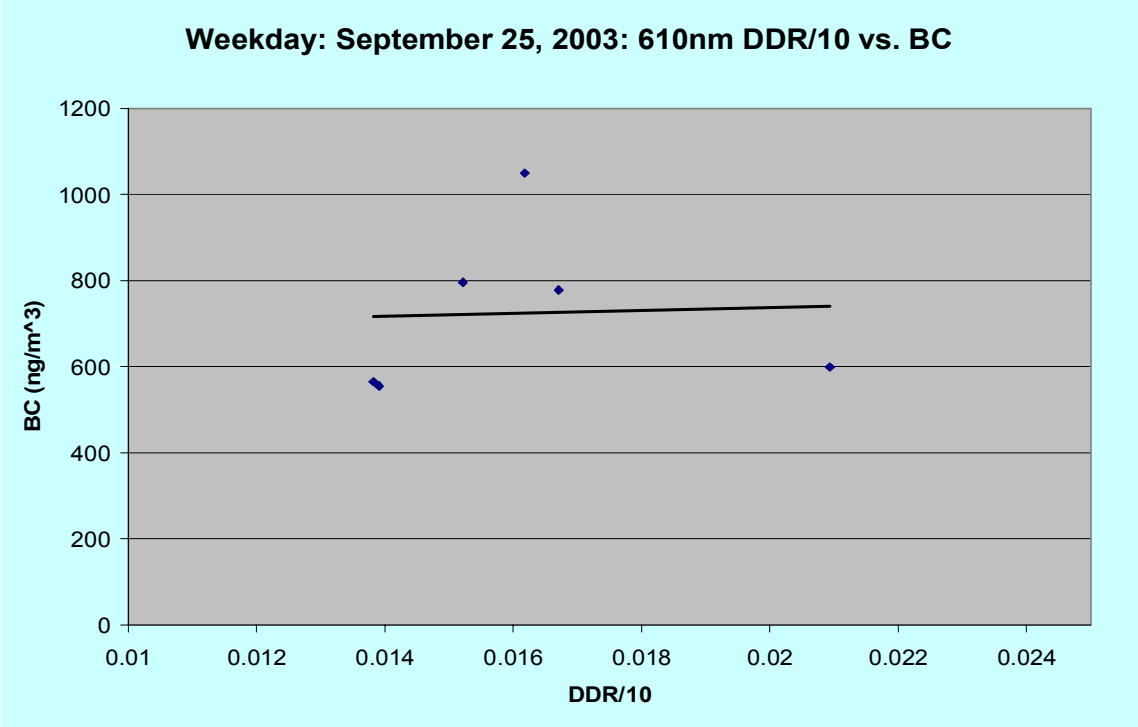

Figure 61. September 2003 Weekday 610nm DDR/10 vs. BC Concentrations (ng/m^3)

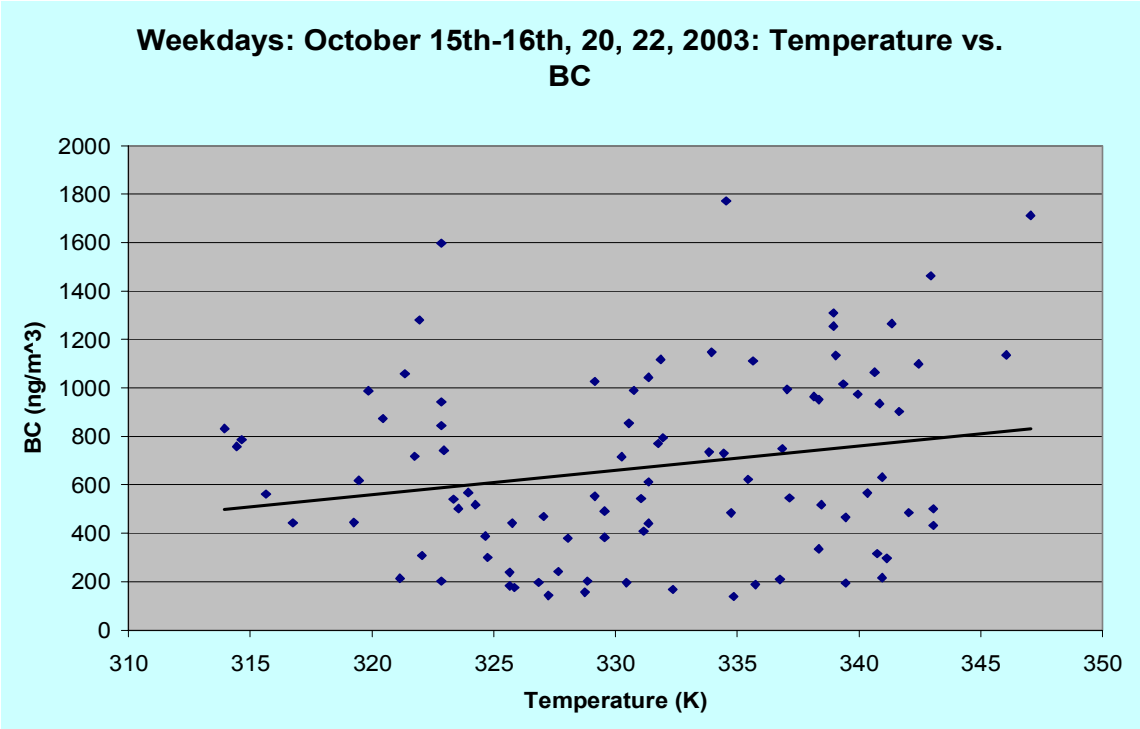

Figure 62. October 2003 Weekdays Temperature (K) vs. BC Concentrations (ng/m^3)

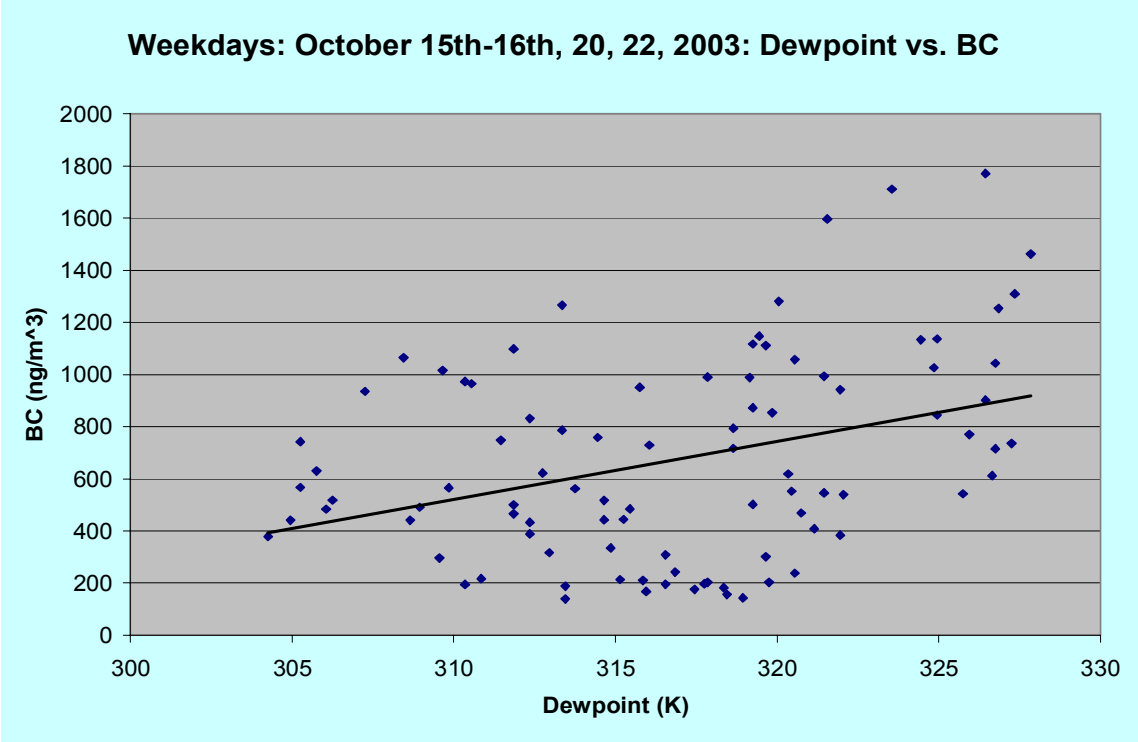

Figure 63. October 2003 Weekdays Dewpoint (K) vs. BC Concentrations (ng/m^3)

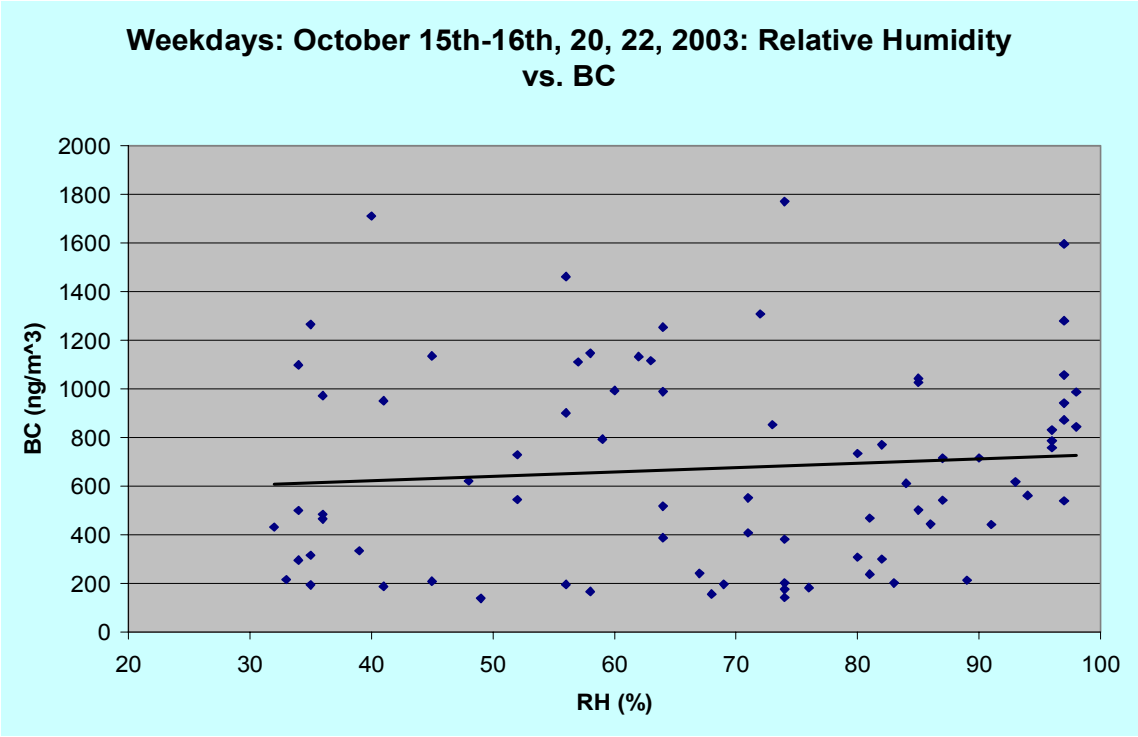

Figure 64. October 2003 Weekdays Relative Humidity (%) vs. BC Concentrations (ng/m^3)

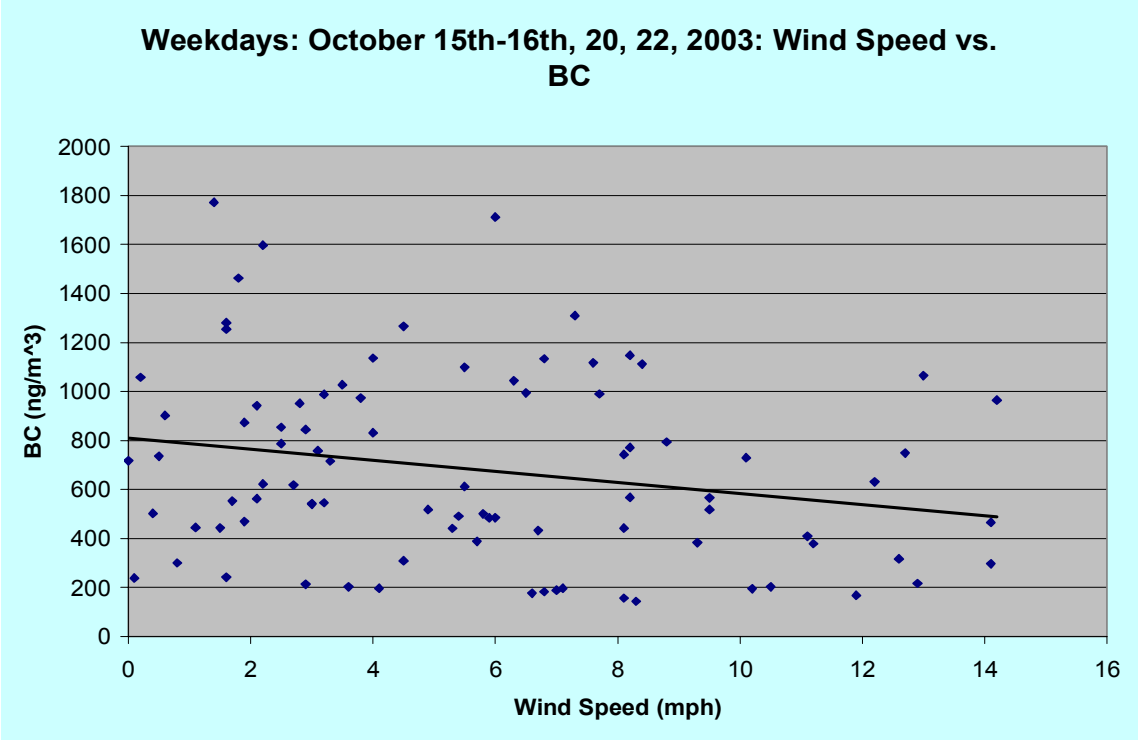

Figure 65. October 2003 Weekdays Wind Speed (mph) vs. BC Concentrations (ng/m^3)

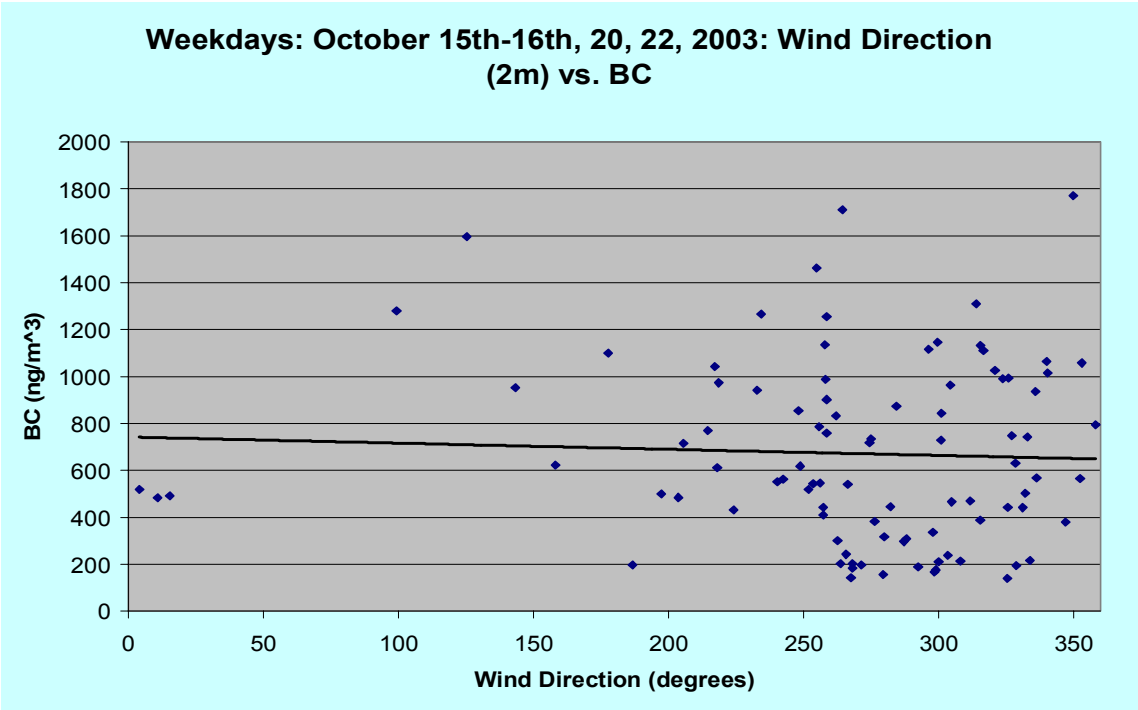

Figure 66. October 2003 Weekdays Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

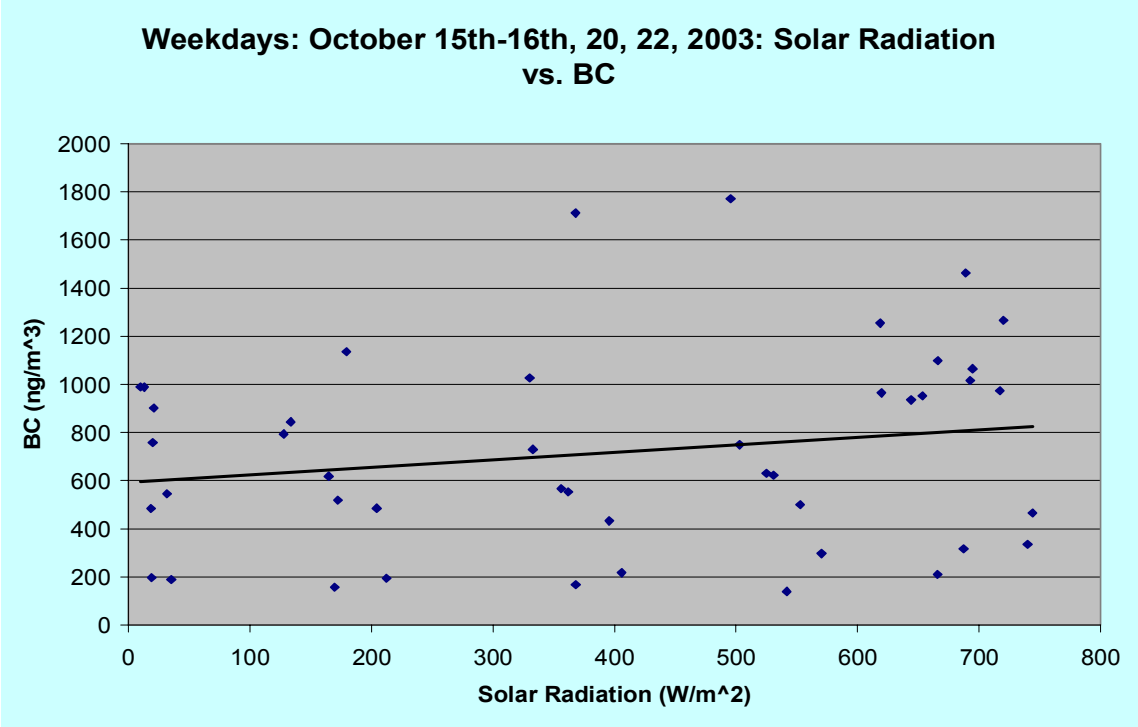

Figure 67. October 2003 Weekdays Solar Radiation (W/m^2) vs. BC Concentrations (ng/m^3)

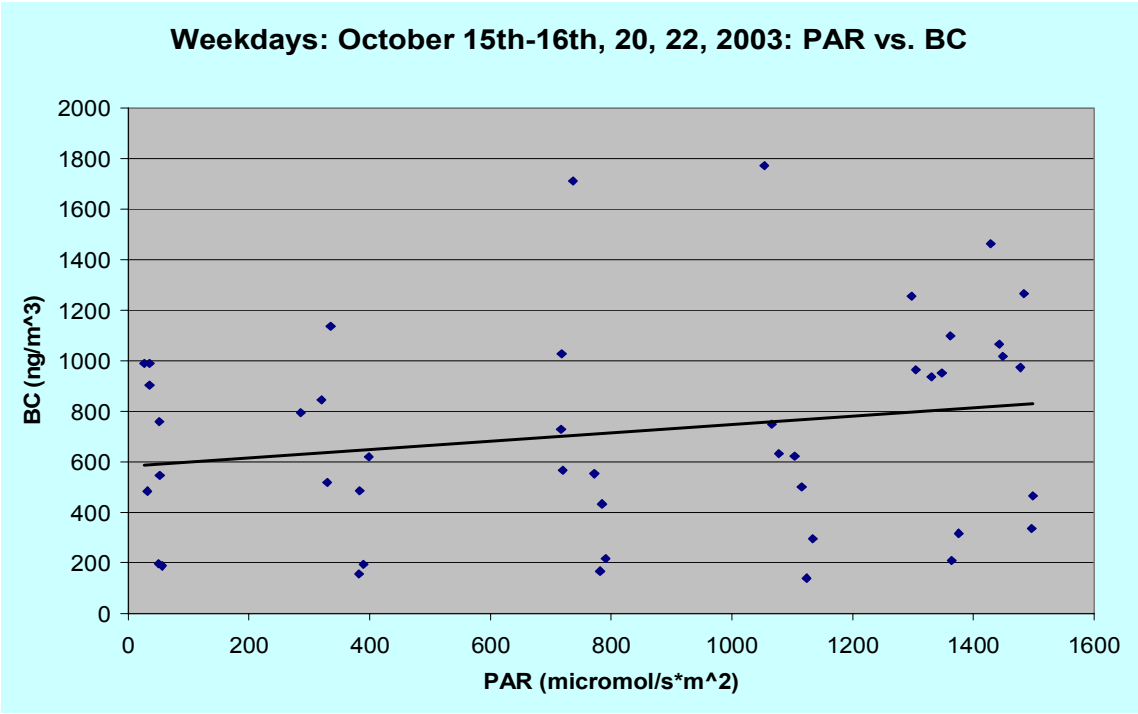

Figure 68. October 2003 Weekdays PAR (micromole/s*m^2) vs. BC Concentrations (ng/m^3)

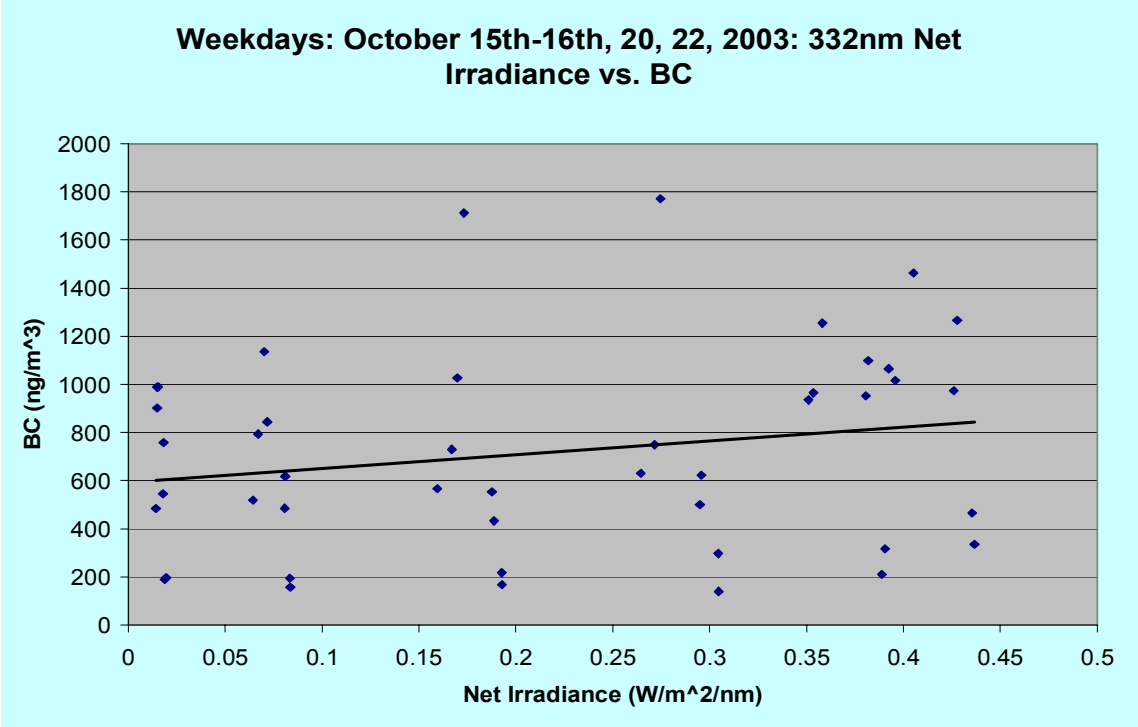

Figure 69. October 2003 Weekdays 332nm Net Irradiance vs. BC Concentrations (ng/m^3)

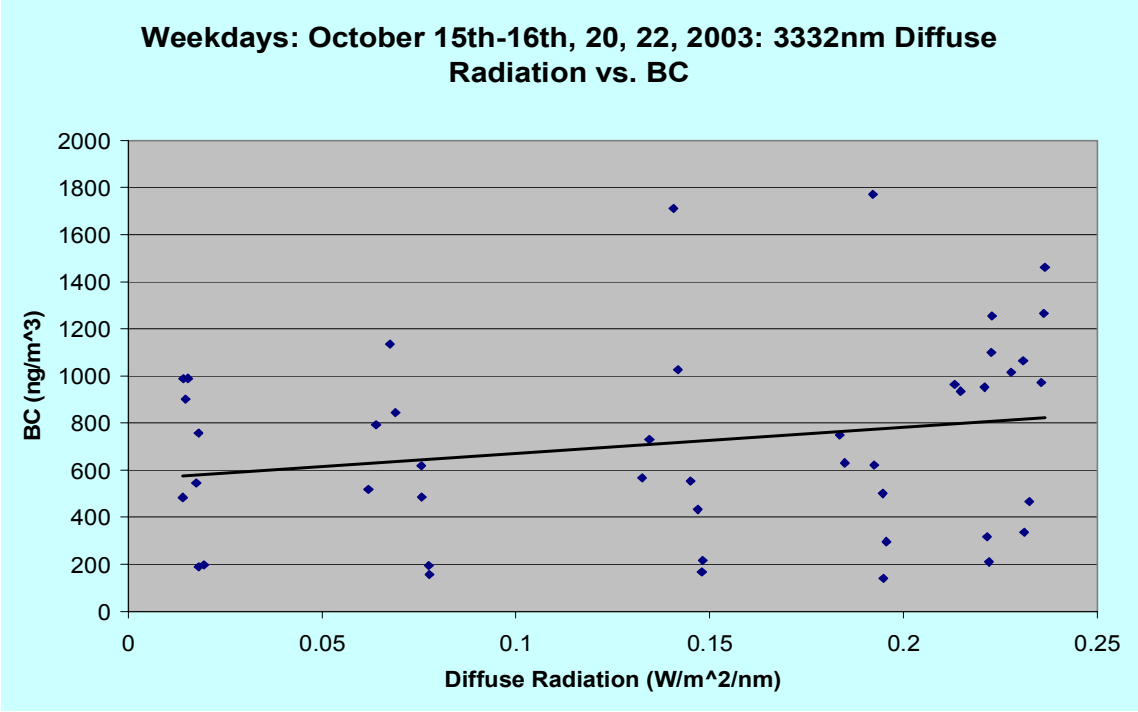

Figure 70. October 2003 Weekdays 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

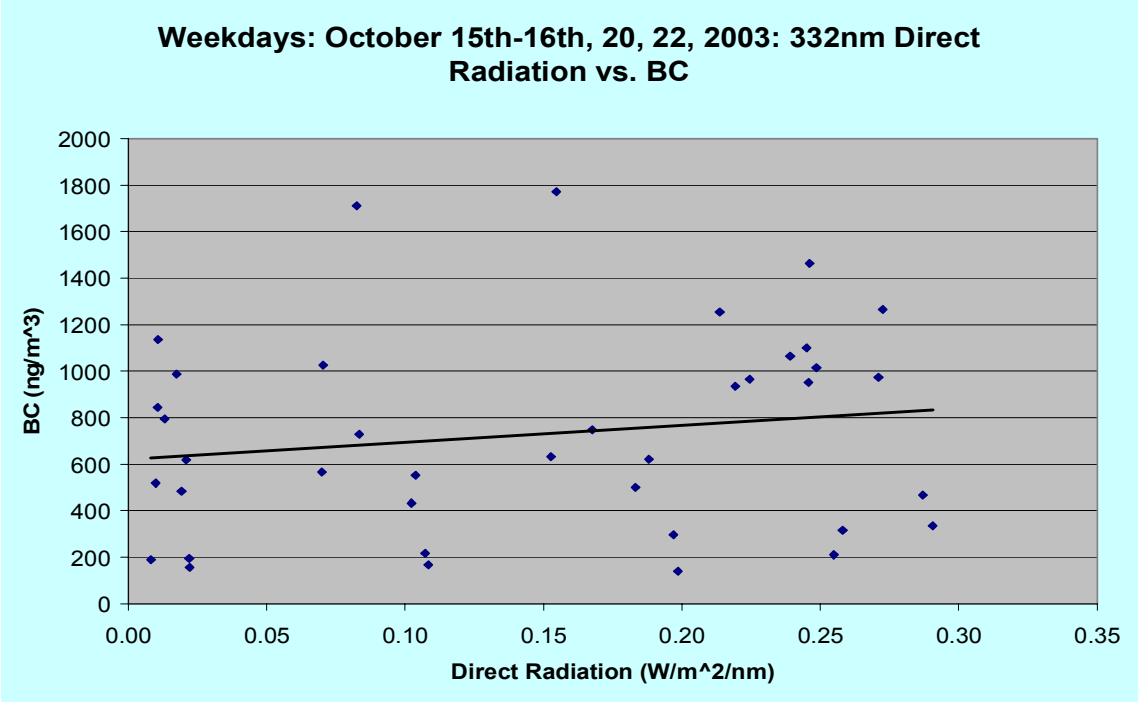

Figure 71. October 2003 Weekdays 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

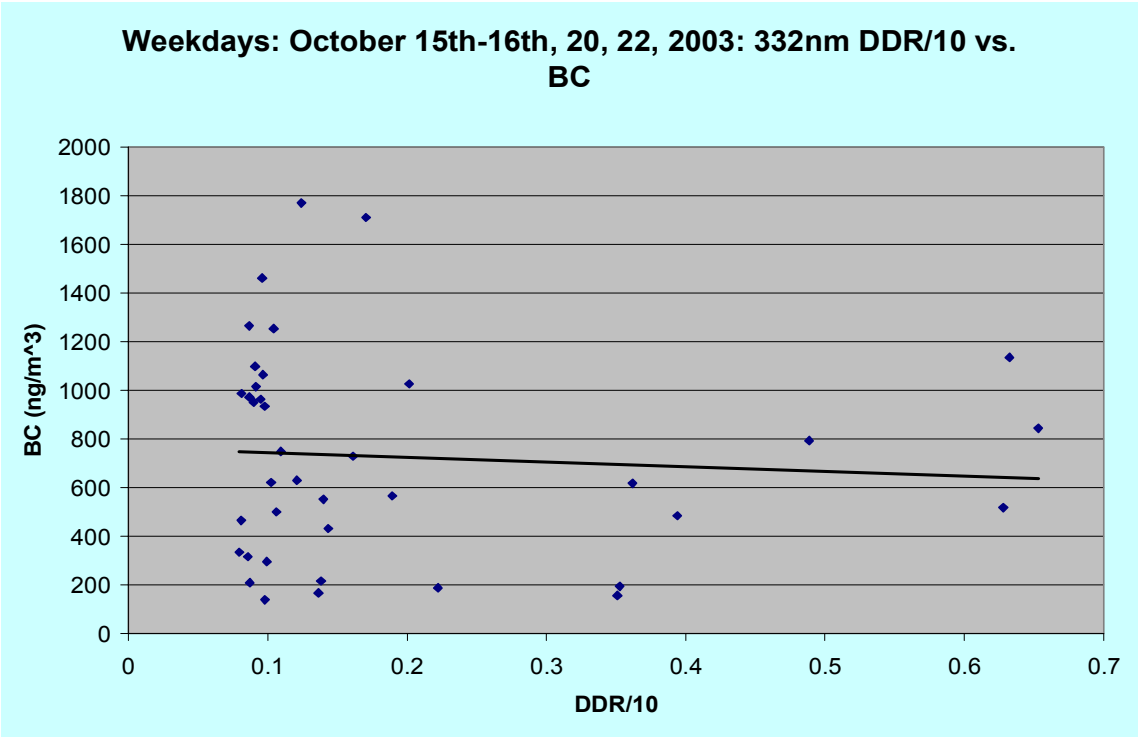

Figure 72. October 2003 Weekdays 332nm DDR/10 vs. BC Concentrations (ng/m^3)

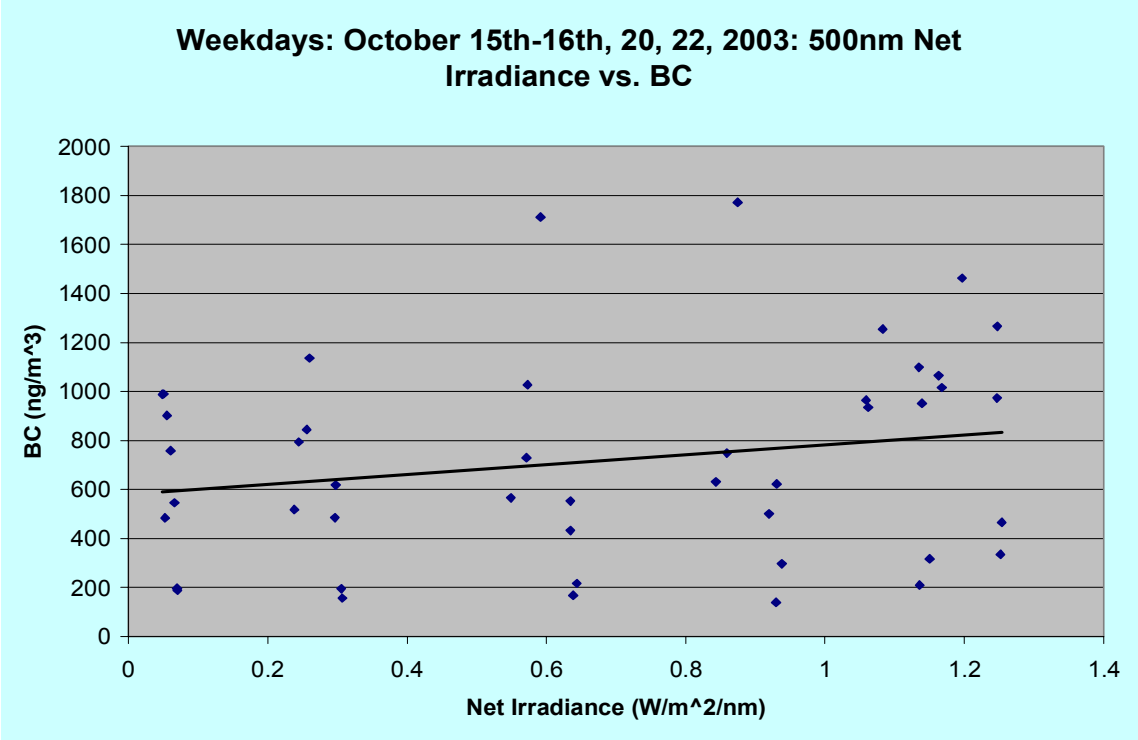

Figure 73. October 2003 Weekdays 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

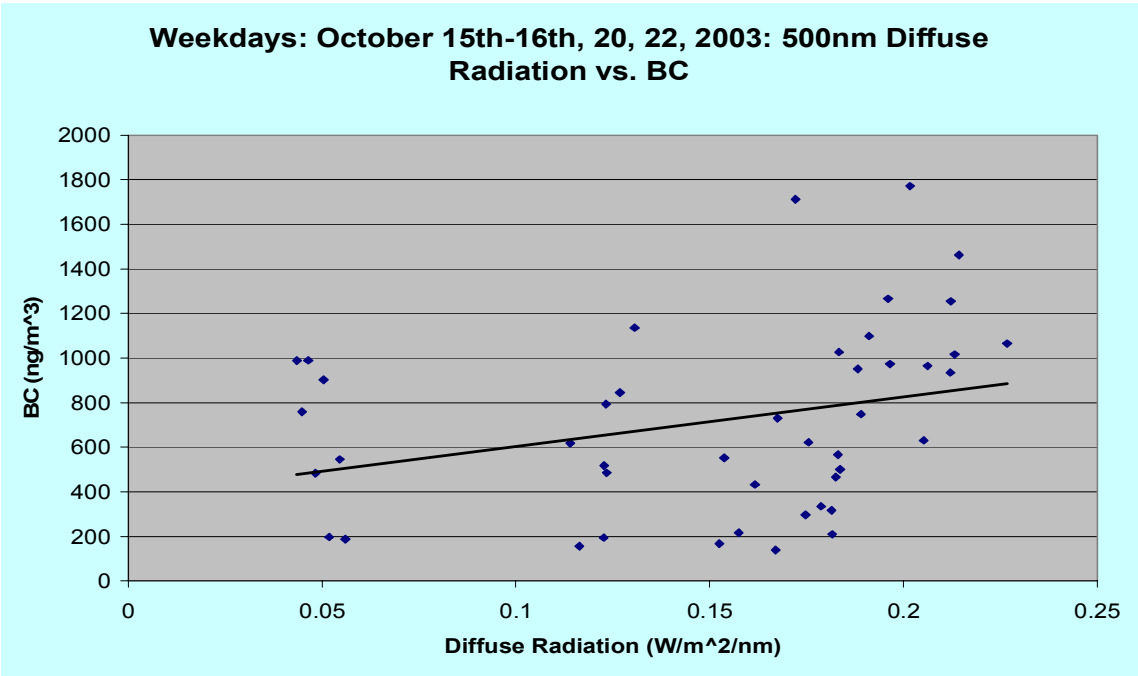

Figure 74. October 2003 Weekdays 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

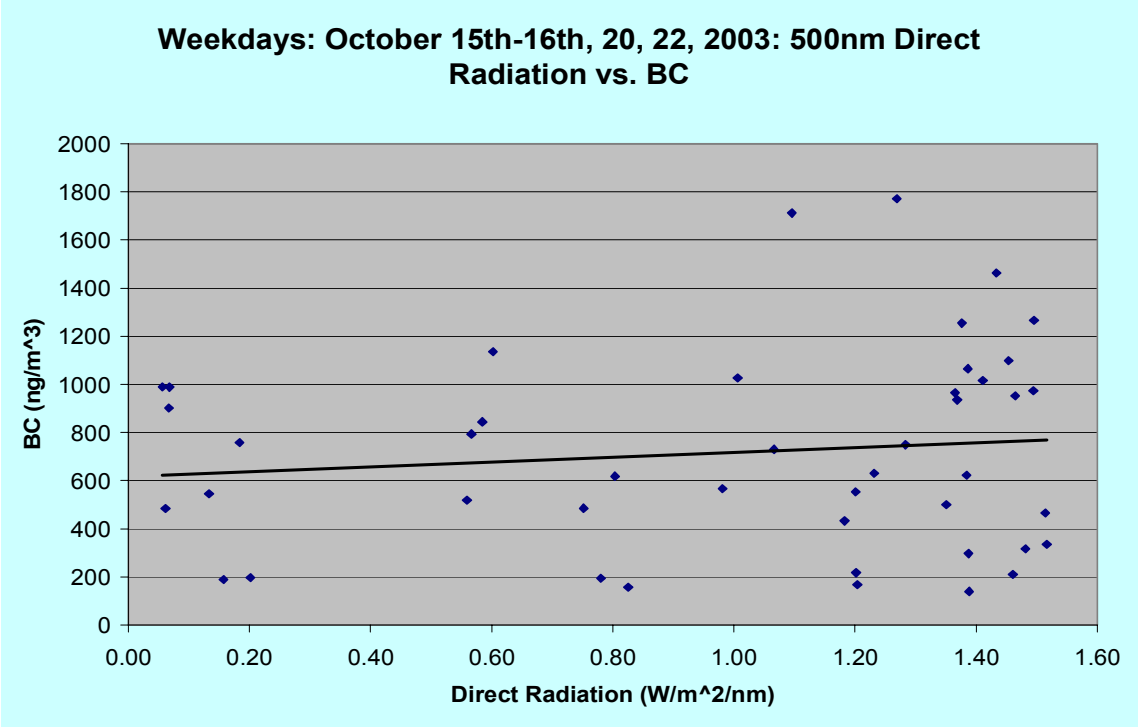

Figure 75. October 2003 Weekdays 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

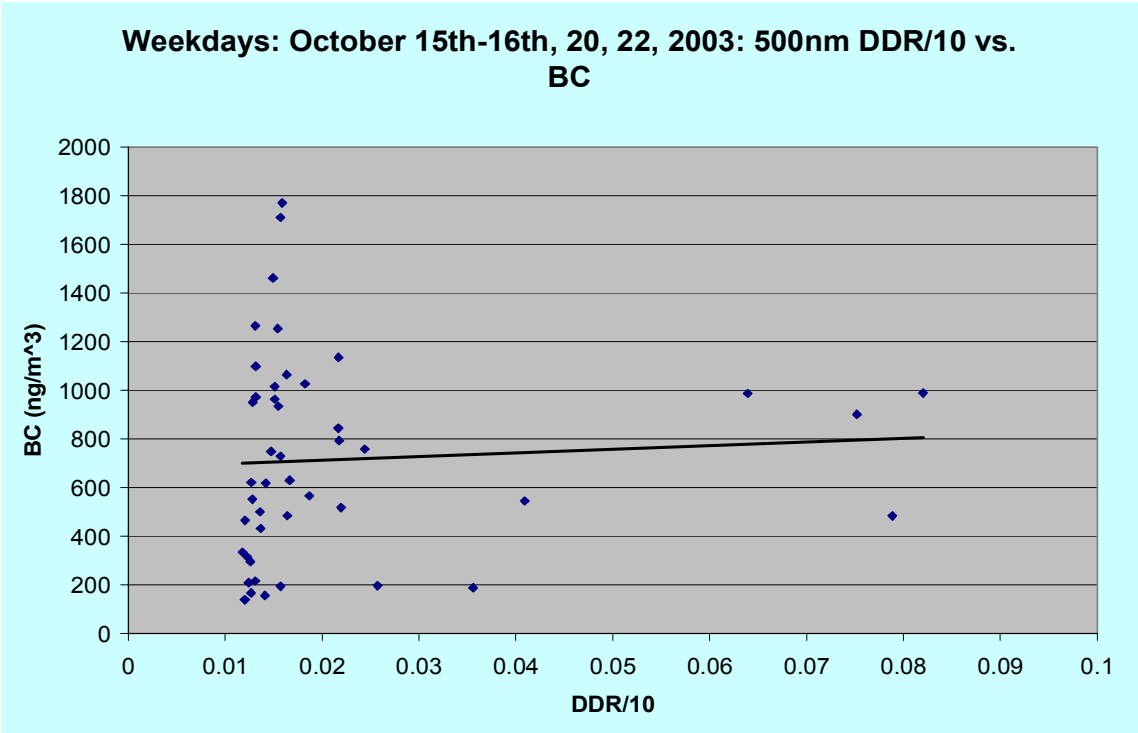

Figure 76. October 2003 Weekdays 500nm DDR/10 vs. BC Concentrations (ng/m^3)

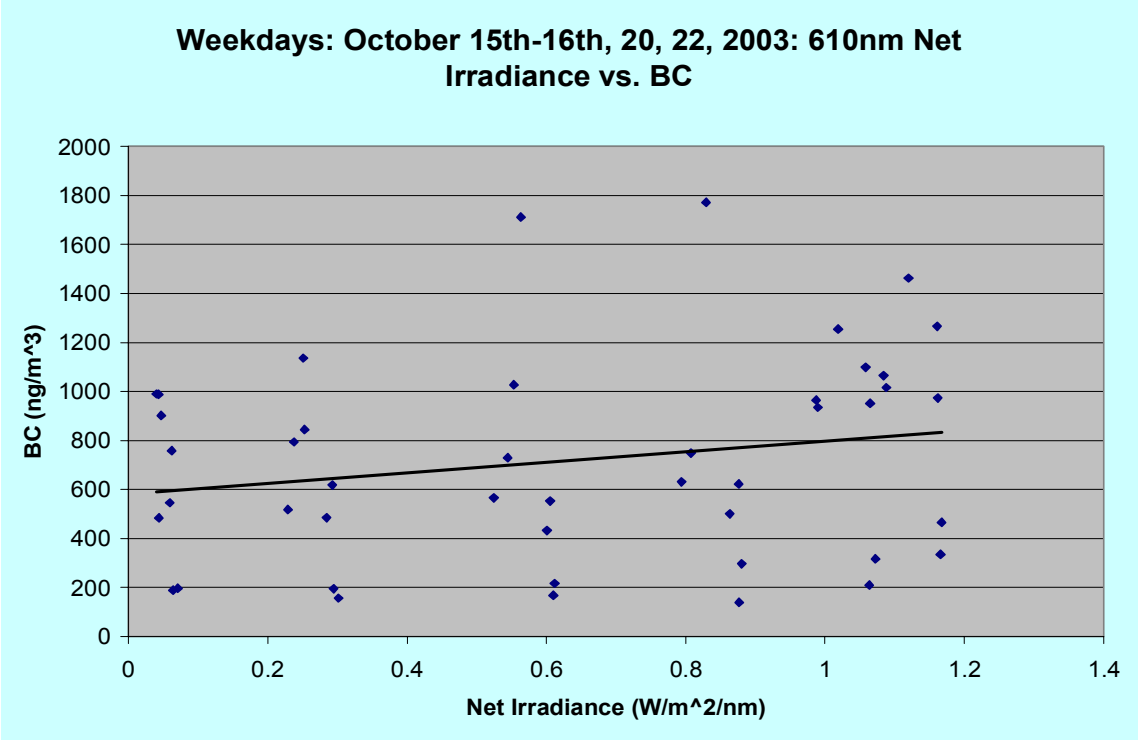

Figure 77. October 2003 Weekdays 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

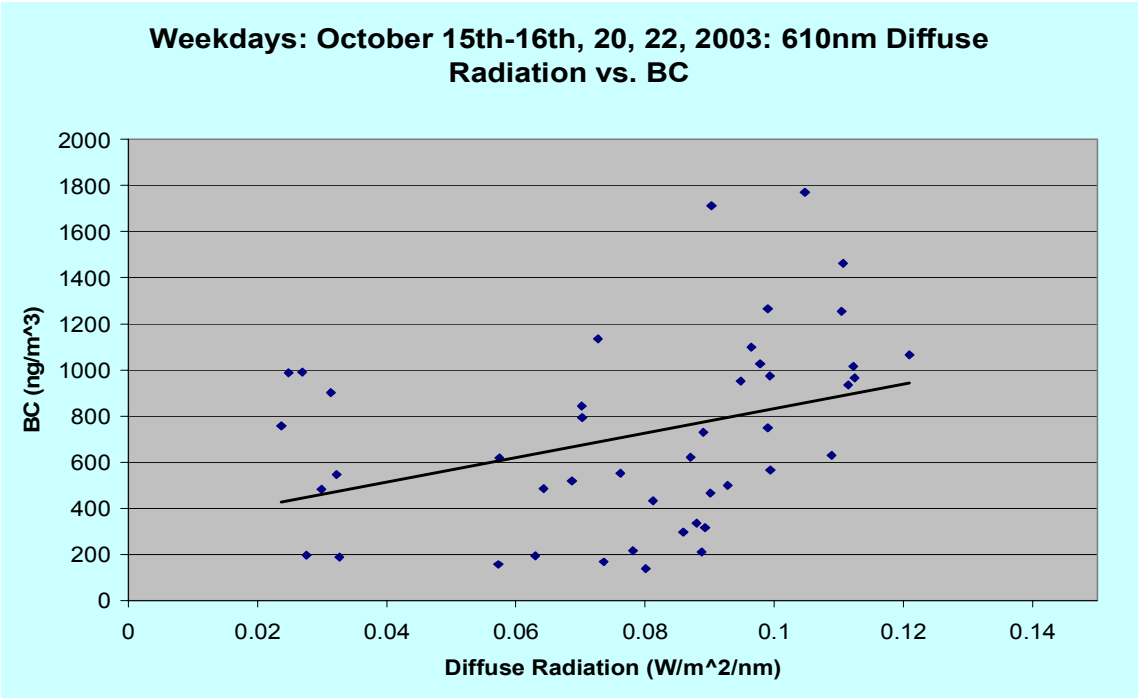

Figure 78. October 2003 Weekdays 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

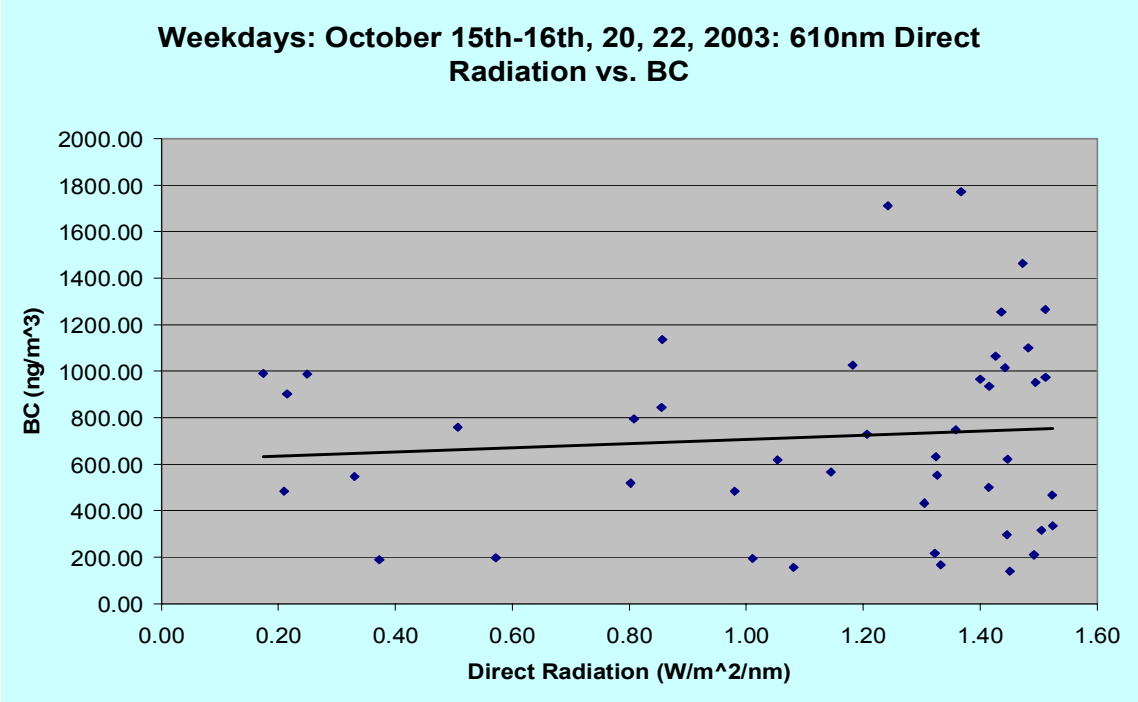

Figure 79. October 2003 Weekdays 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

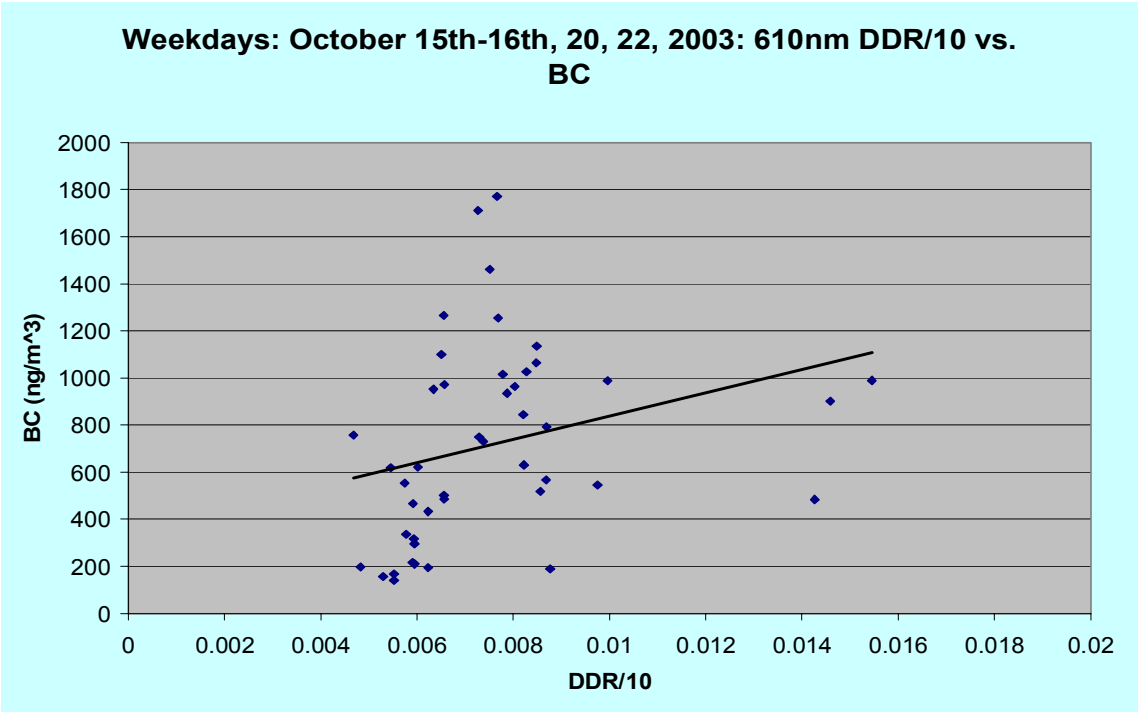

Figure 80. October 2003 Weekdays 610nm DDR/10 vs. BC Concentrations (ng/m^3)

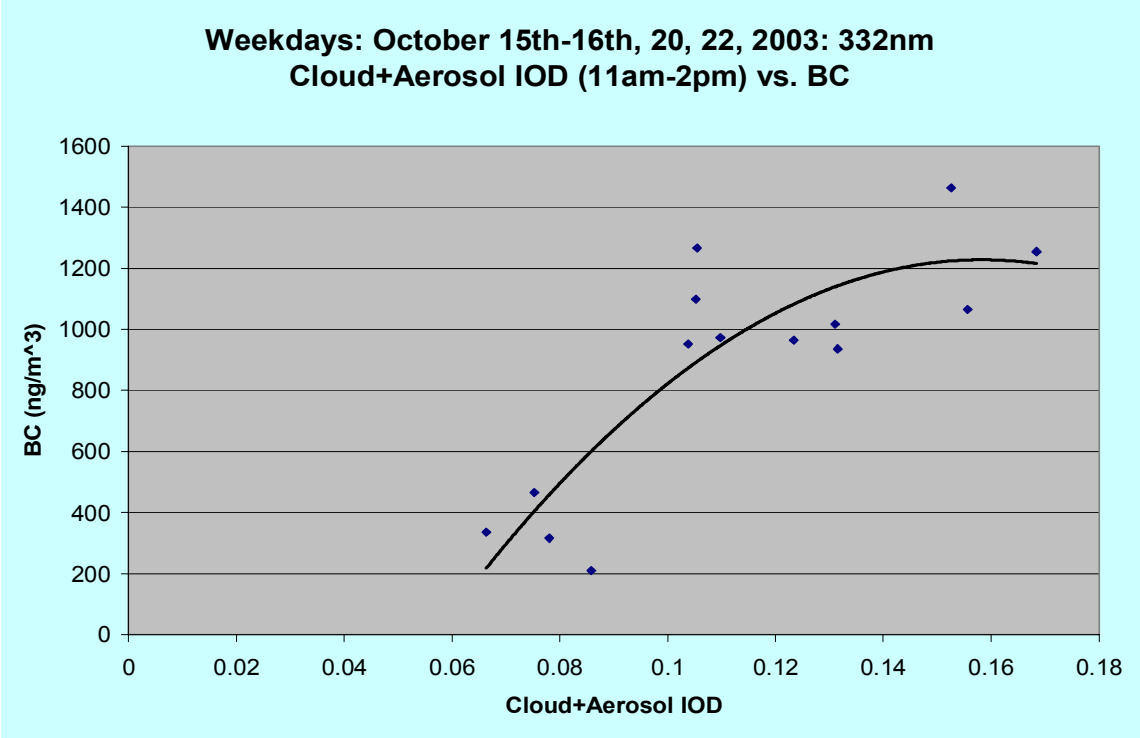

Figure 81. October 2003 Weekdays 332nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

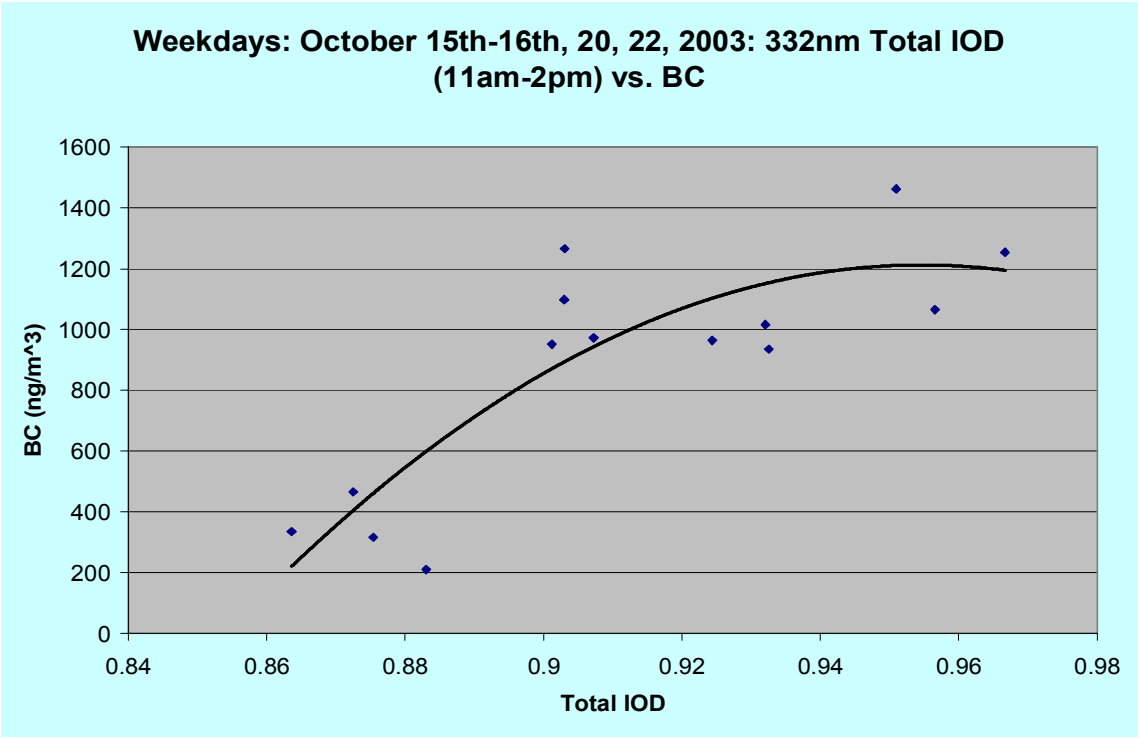

Figure 82. October 2003 Weekdays 332nm Total IOD vs. BC Concentrations (ng/m^3)

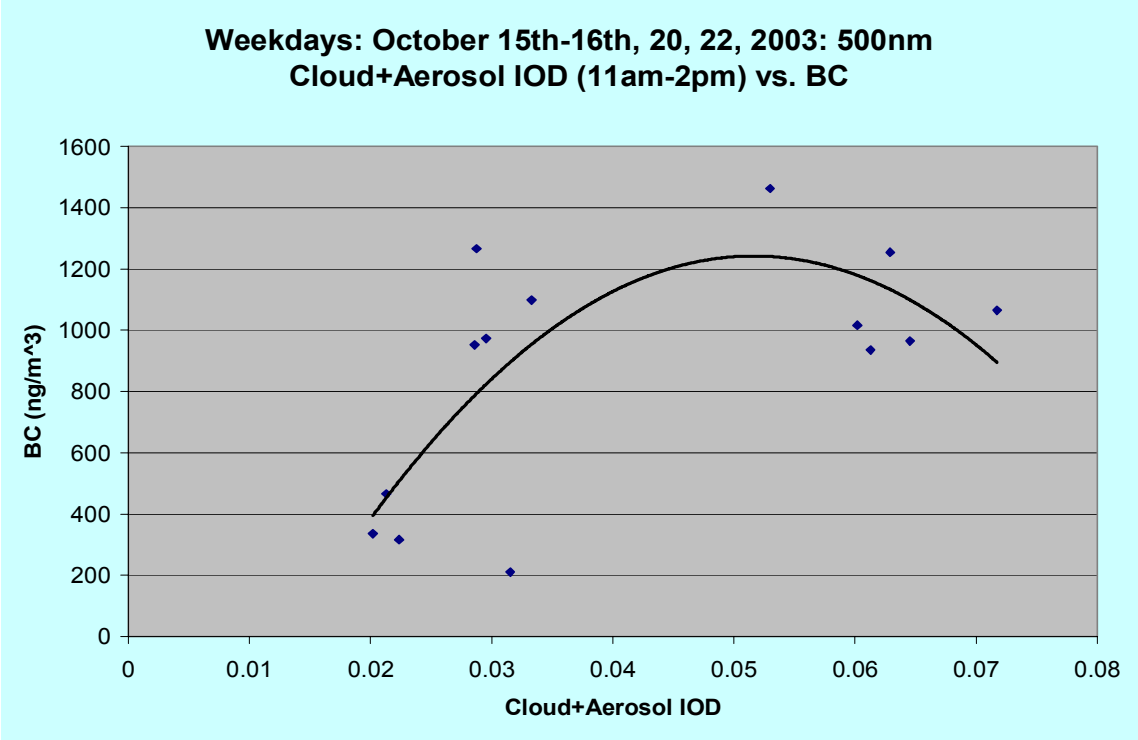

Figure 83. October 2003 Weekdays 500nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

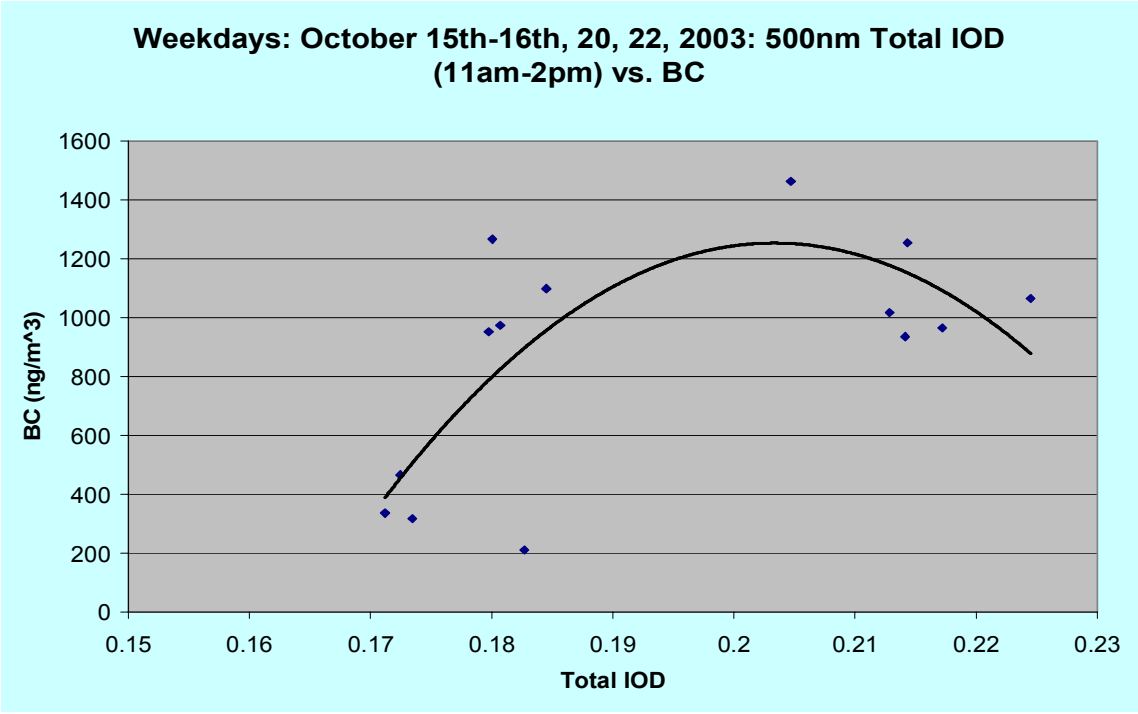

Figure 84. October 2003 Weekdays 500nm Total IOD vs. BC Concentrations (ng/m^3)

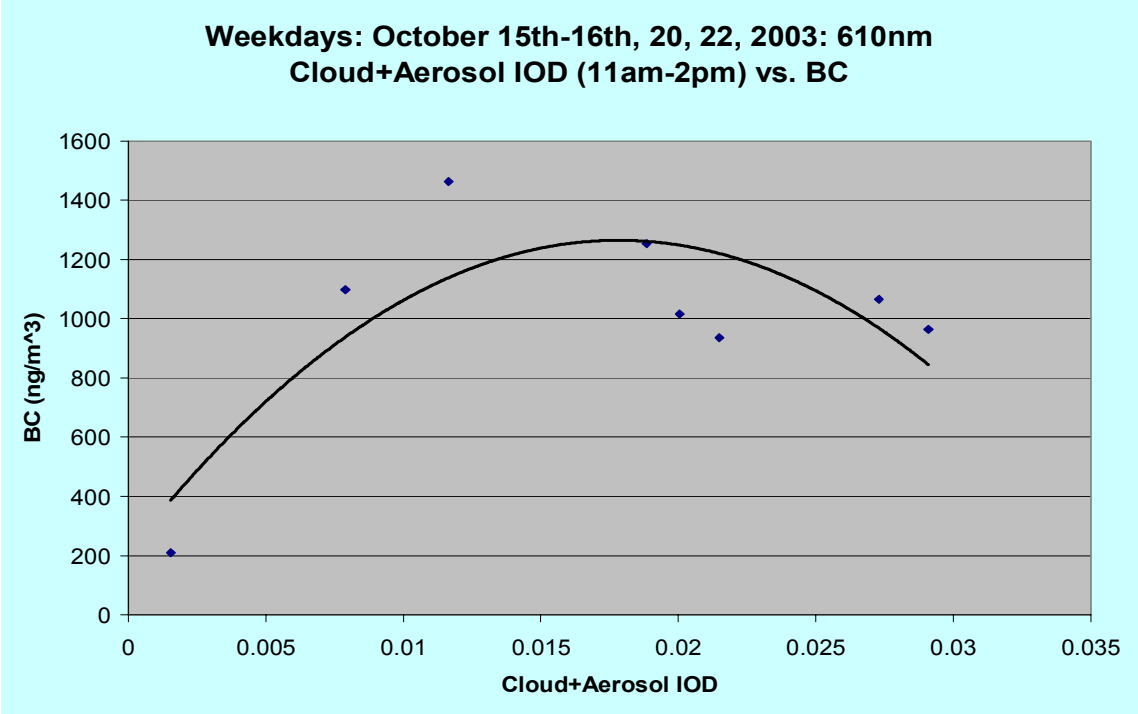

Figure 85. October 2003 Weekdays 610nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

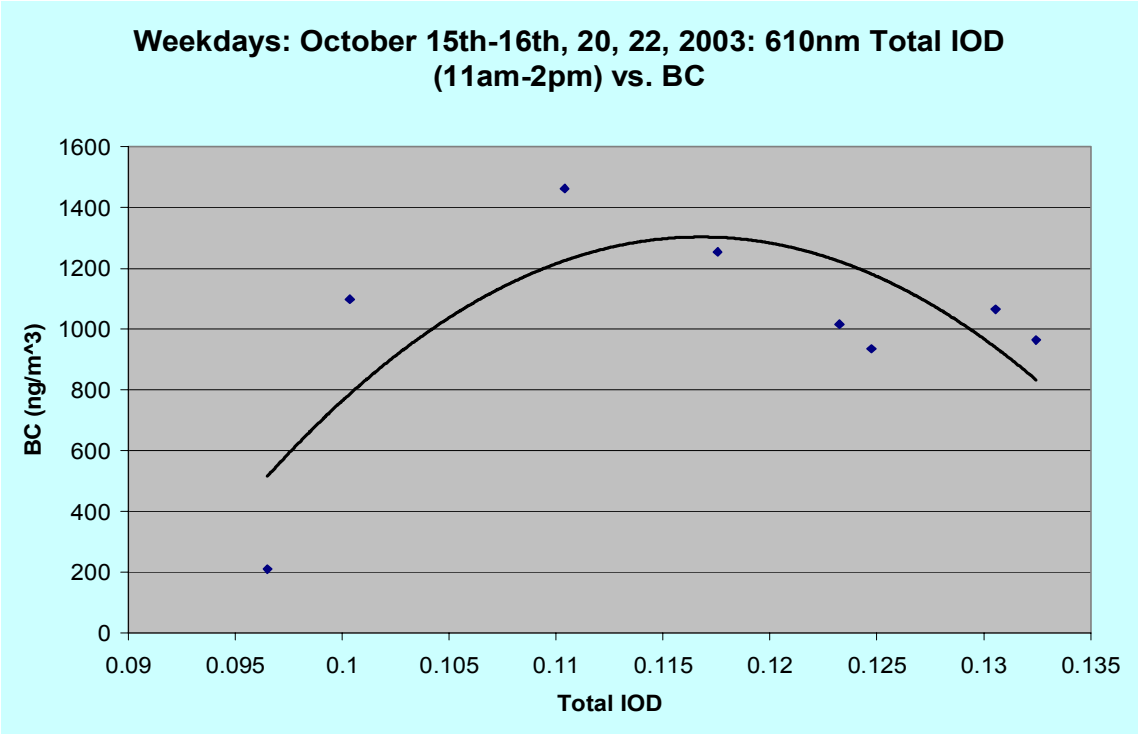

Figure 86. October 2003 Weekdays 610nm Total IOD vs. BC Concentrations (ng/m^3)

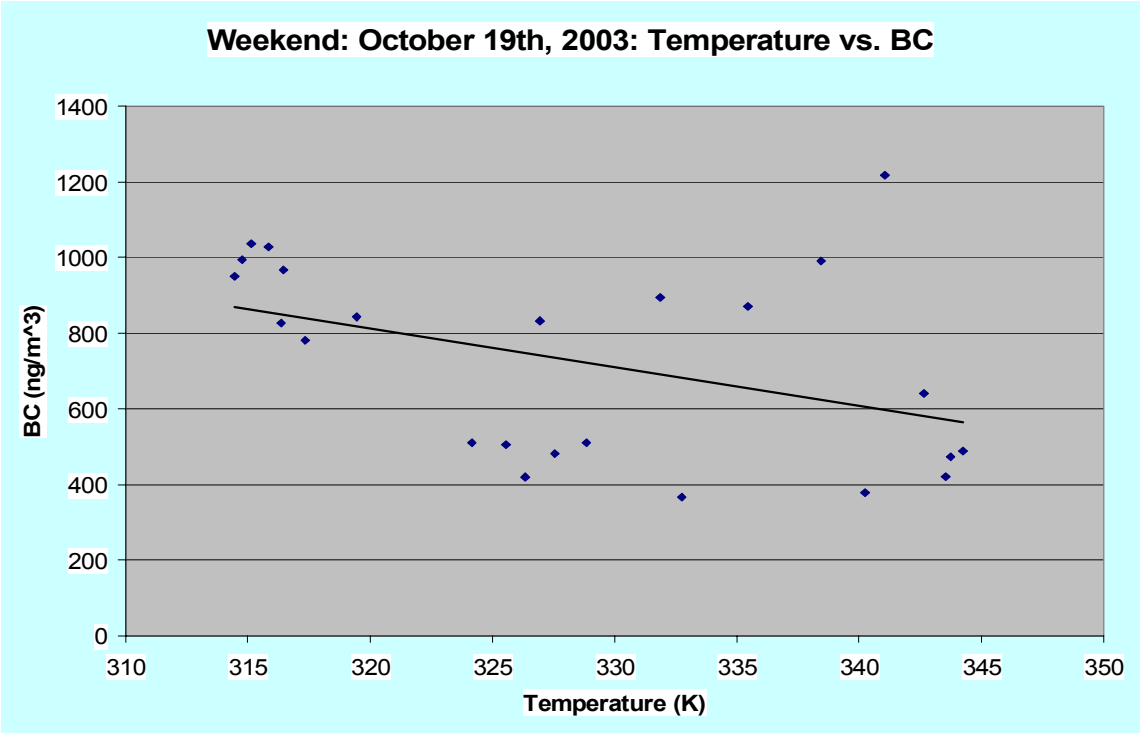

Figure 87. October 2003 Weekend Temperature (K) vs. BC Concentrations (ng/m^3)

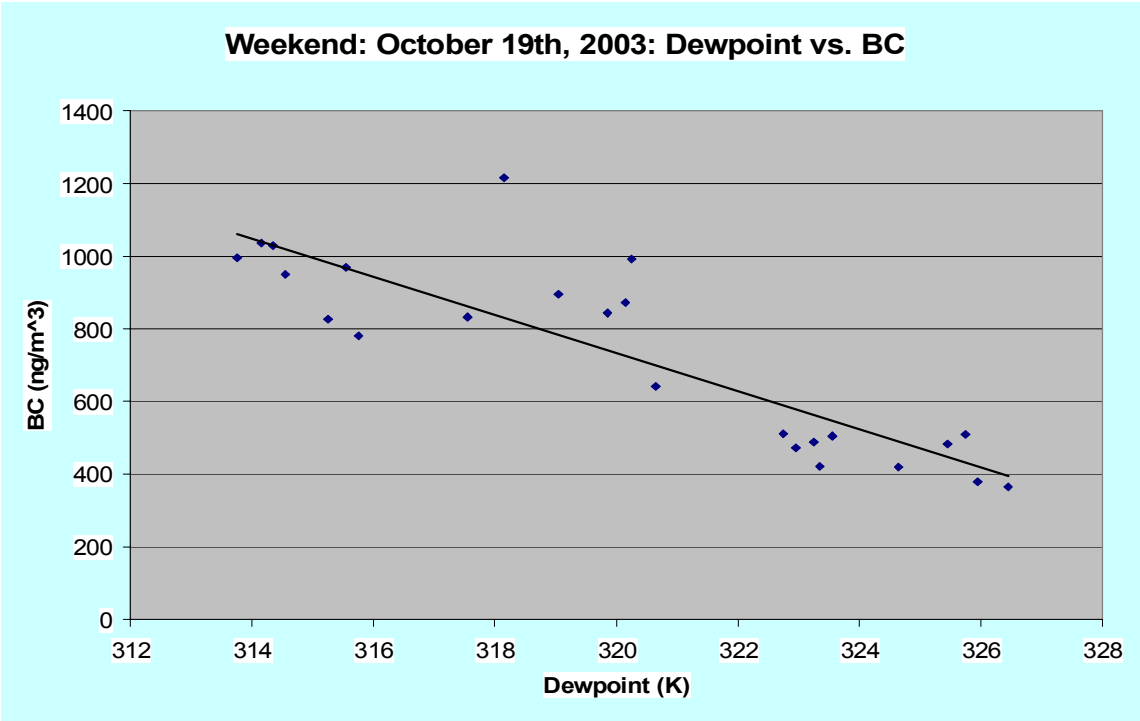

Figure 88. October 2003 Weekend Dewpoint (K) vs. BC Concentrations (ng/m^3)

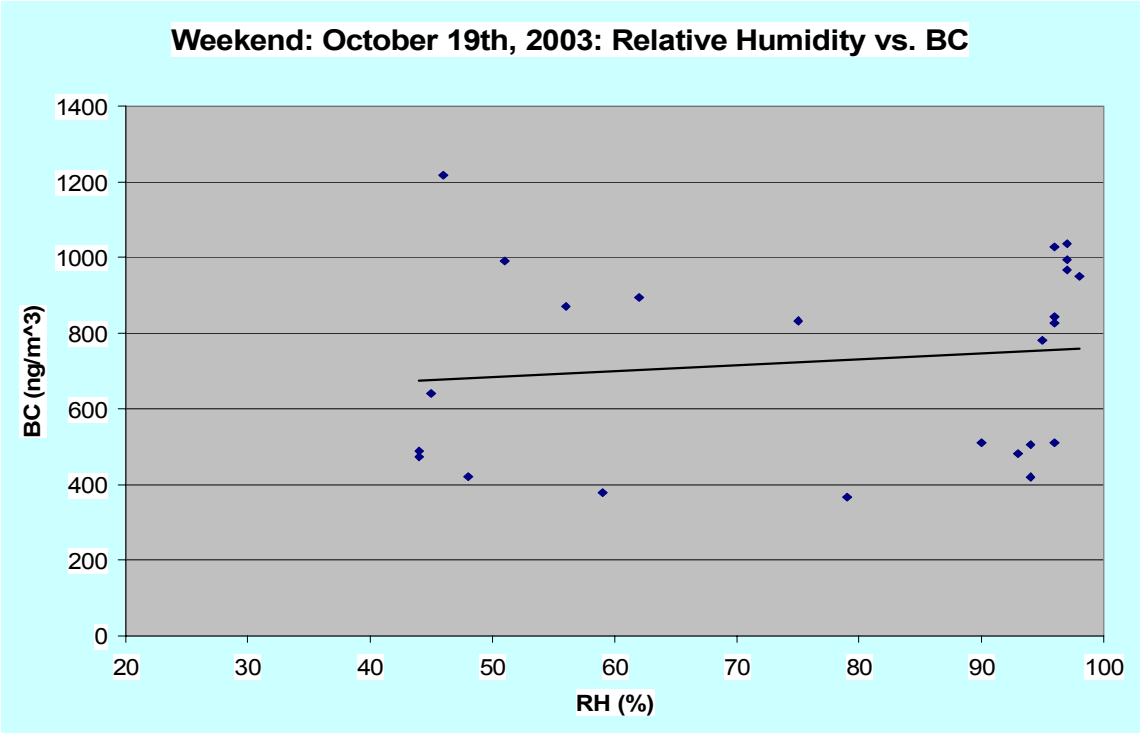

Figure 89. October 2003 Weekend Relative Humidity (%) vs. BC Concentrations (ng/m^3)

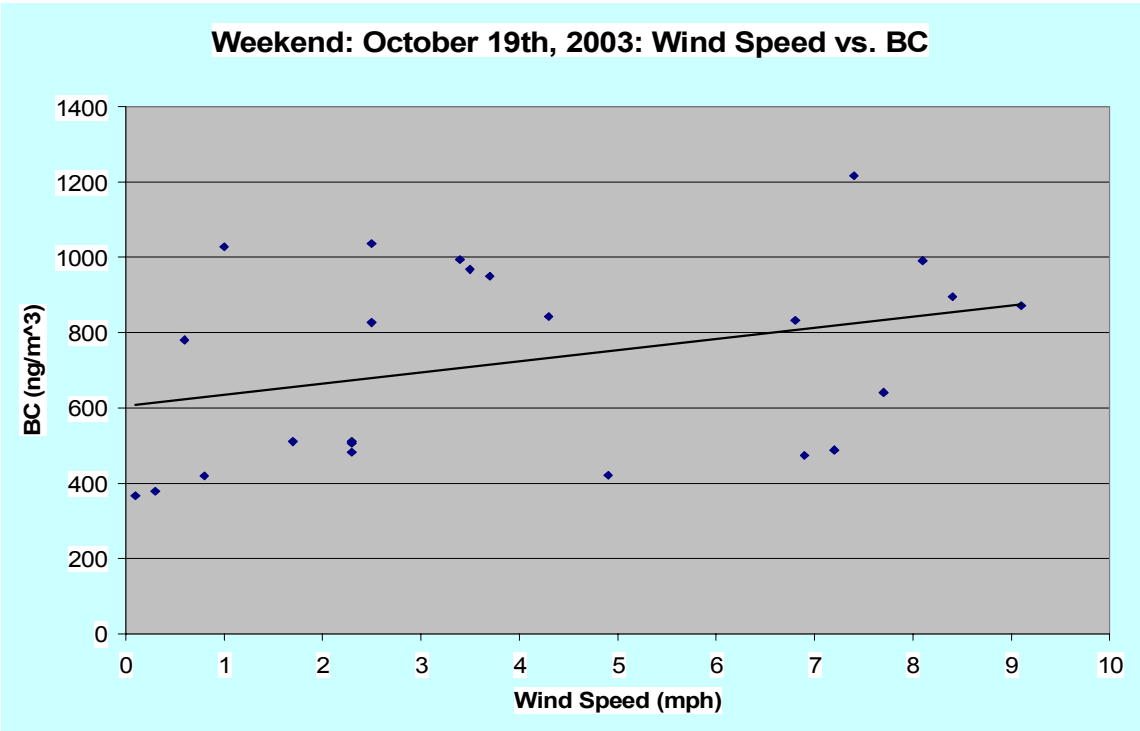

Figure 90. October 2003 Weekend Wind Speed (mph) vs. BC Concentrations (ng/m^3)

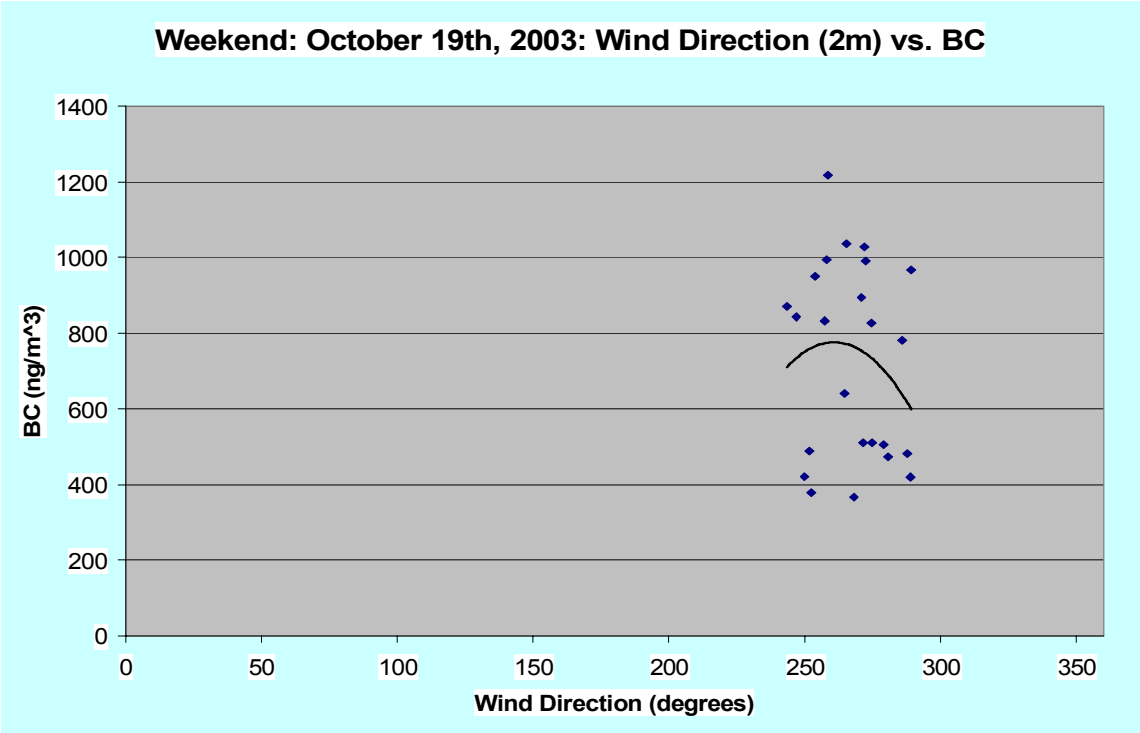

Figure 91. October 2003 Weekend Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

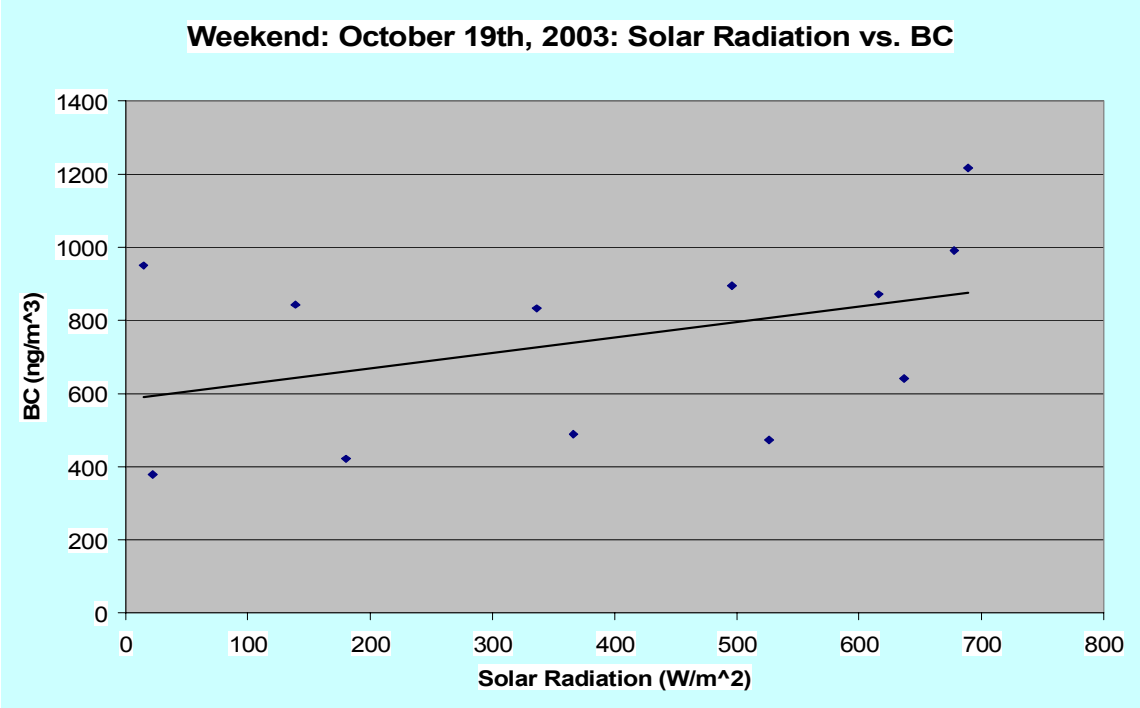

Figure 92. October 2003 Weekend Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

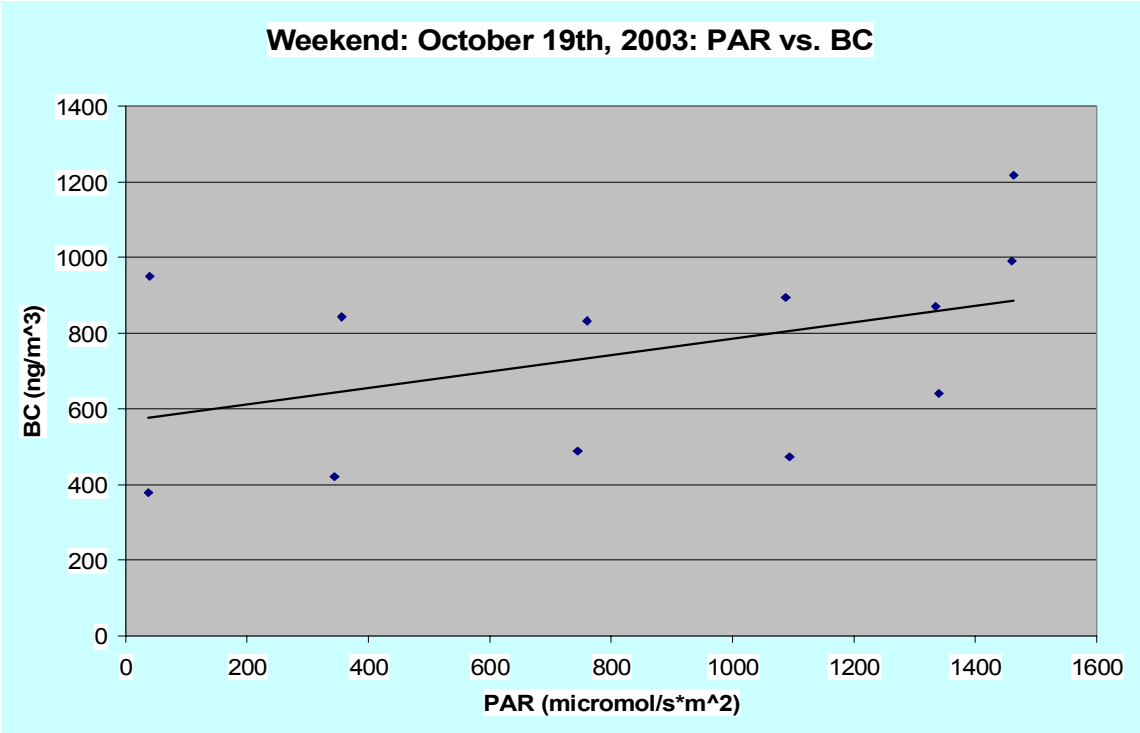

Figure 93. October 2003 Weekend PAR (micromol/s*m^2) vs. BC Concentrations (ng/m^3)

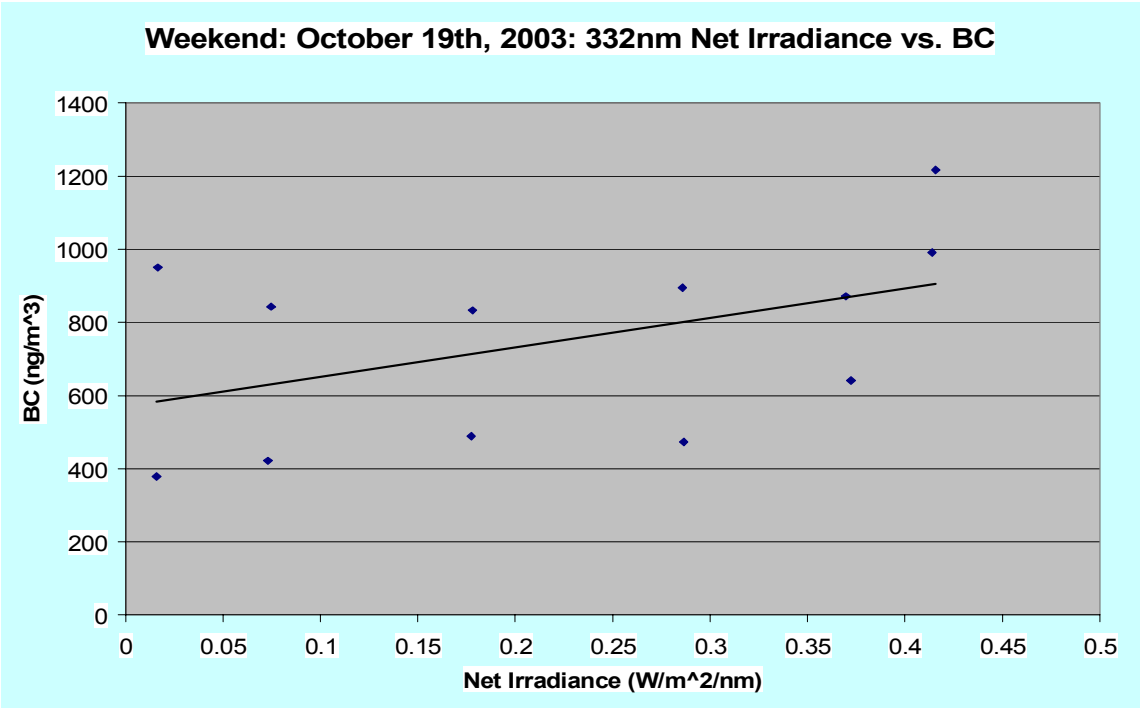

Figure 94. October 2003 Weekend 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

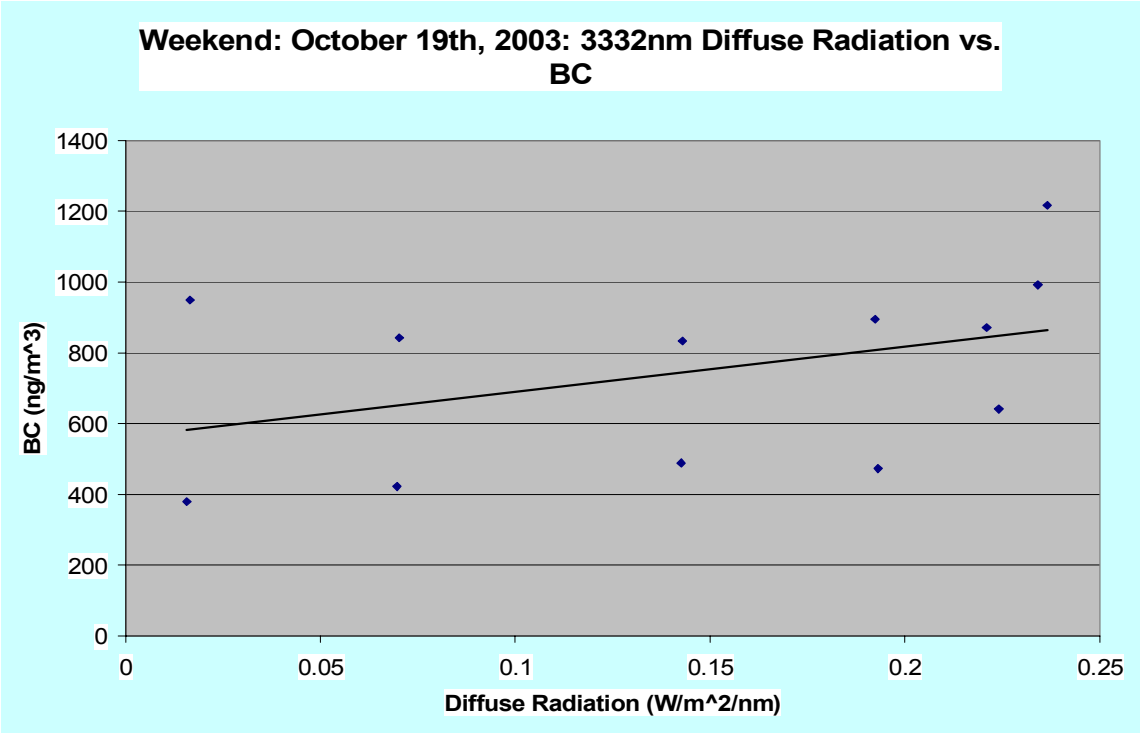

Figure 95. October 2003 Weekend 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

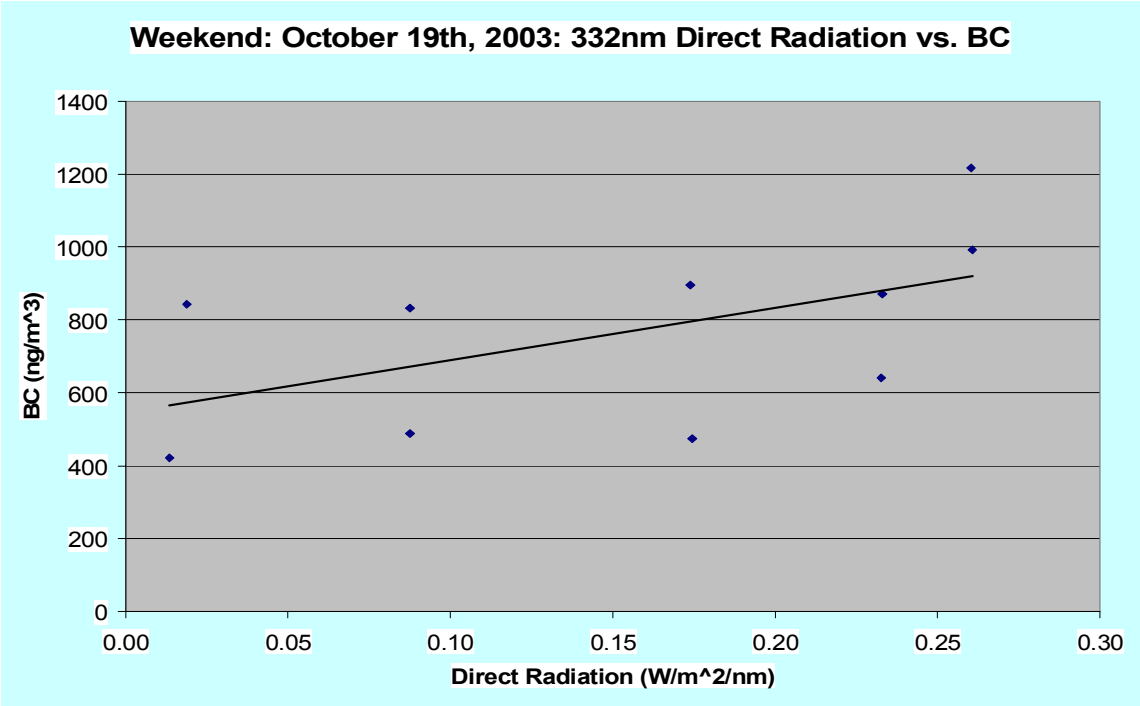

Figure 96. October 2003 Weekend 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

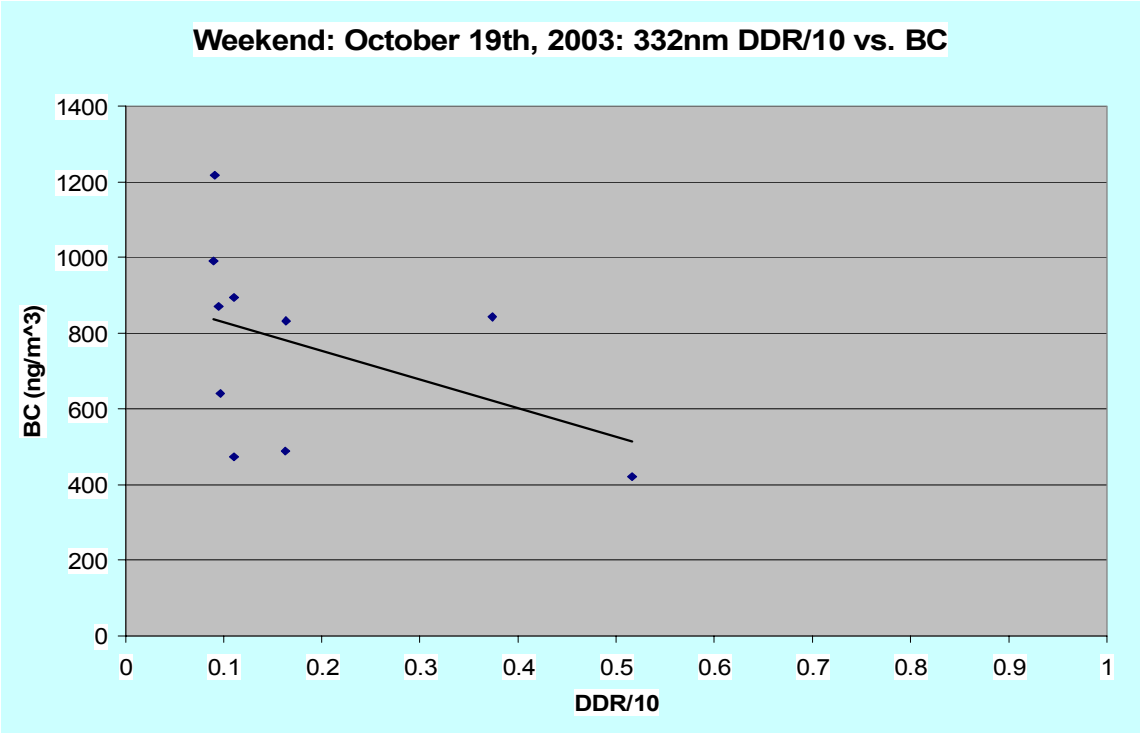

Figure 97. October 2003 Weekend 332nm DDR/10 vs. BC Concentrations (ng/m^3)

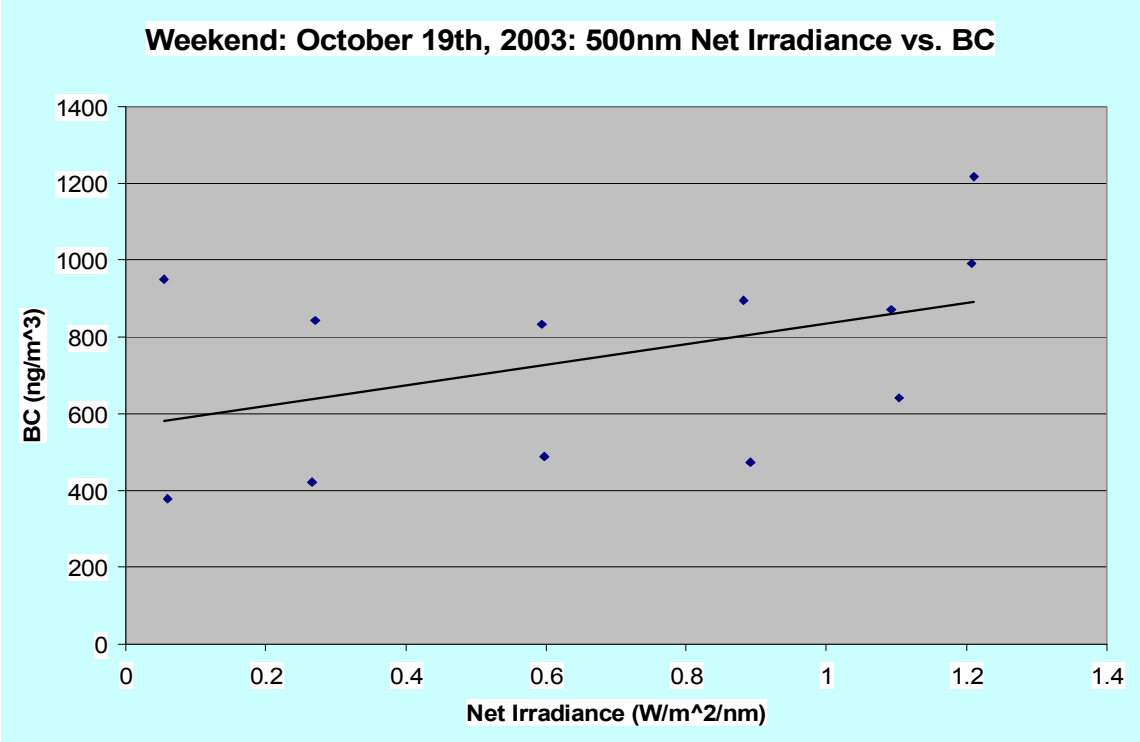

Figure 98. October 2003 Weekend 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

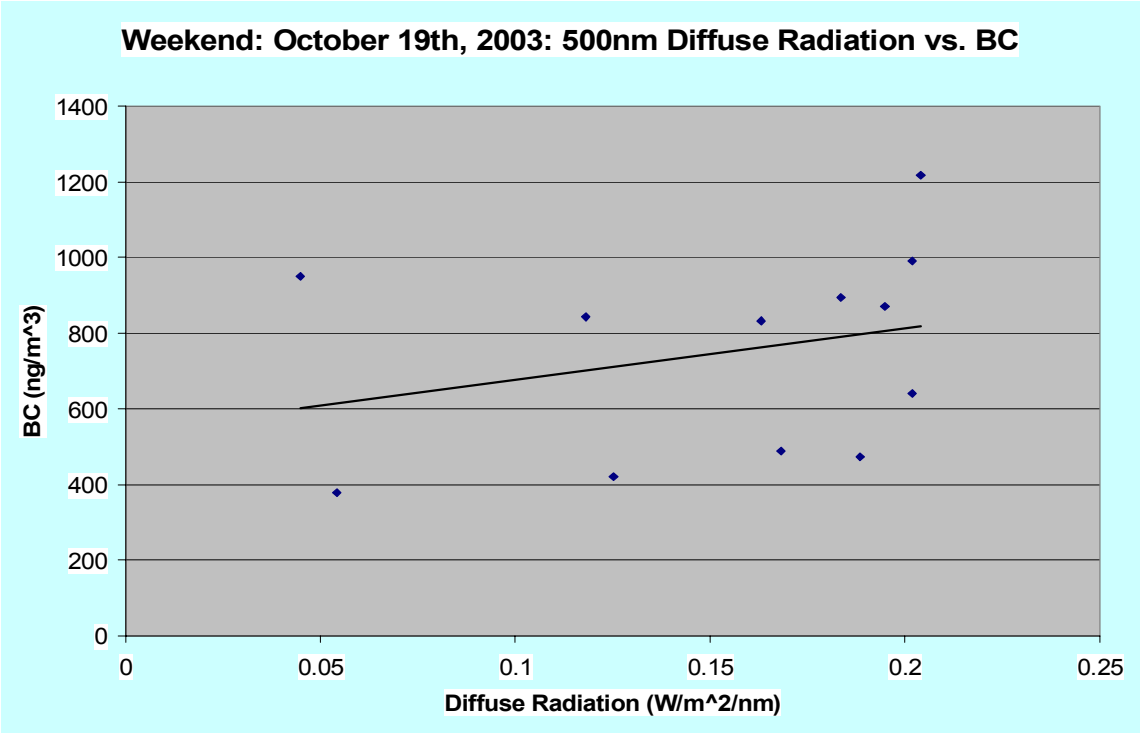

Figure 99. October 2003 Weekend 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

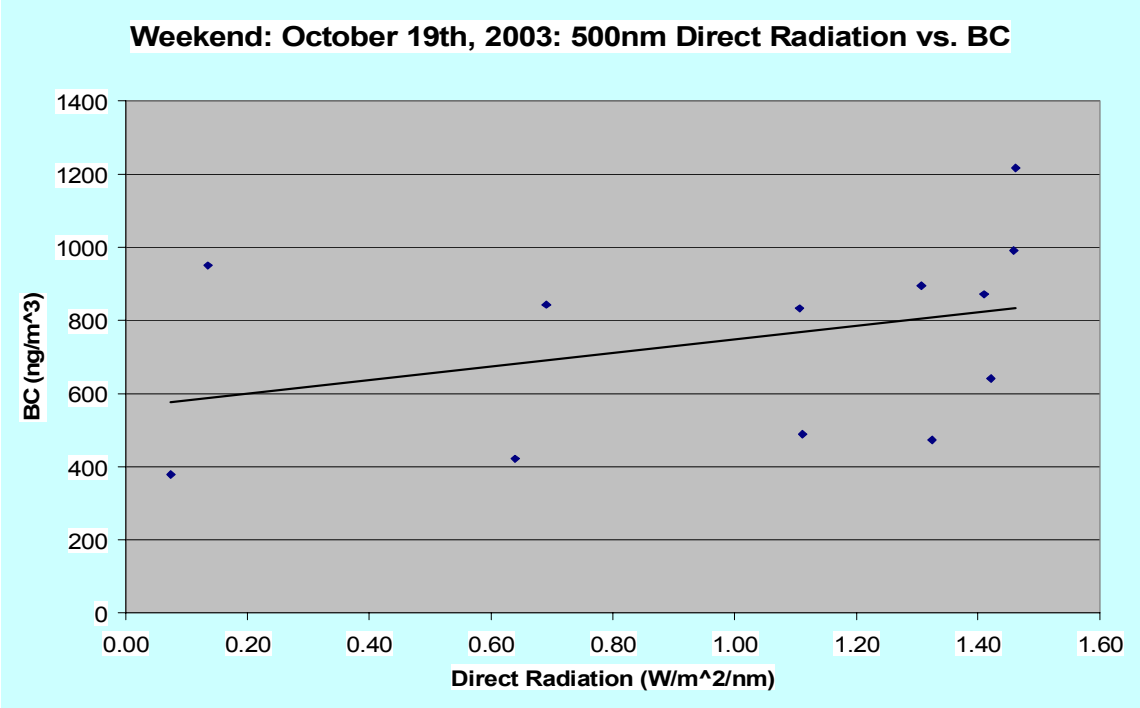

Figure 100. October 2003 Weekend 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

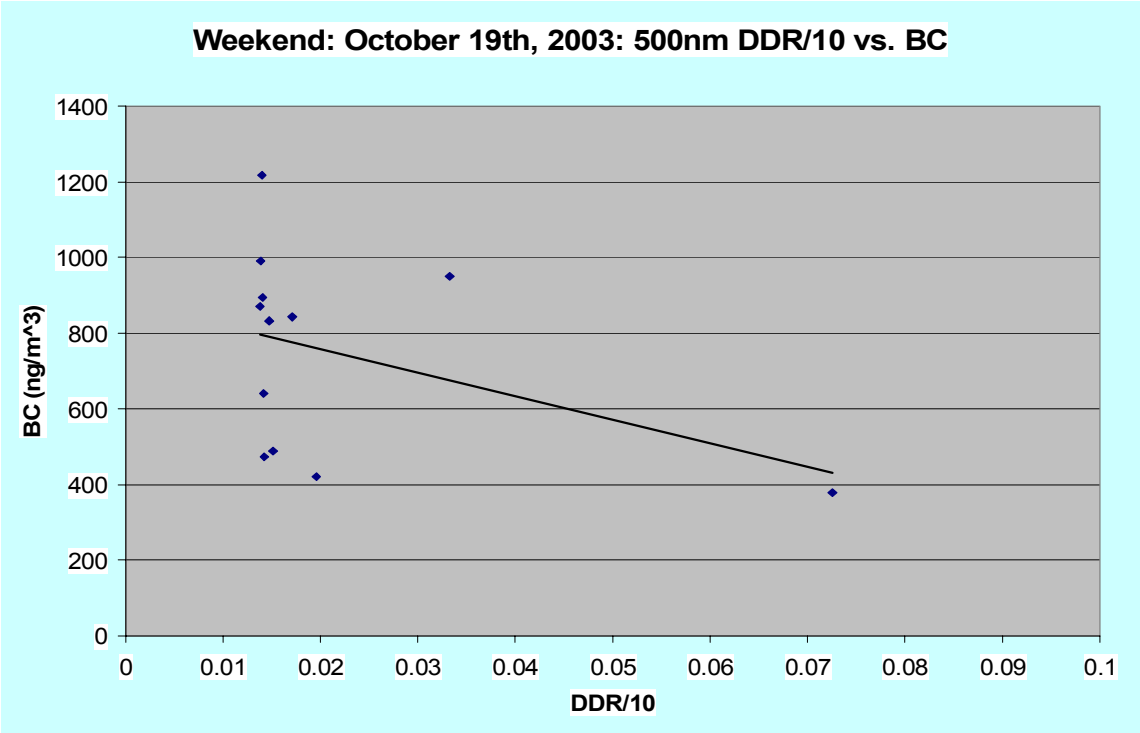

Figure 101. October 2003 Weekend 500nm DDR/10 vs. BC Concentrations (ng/m^3)

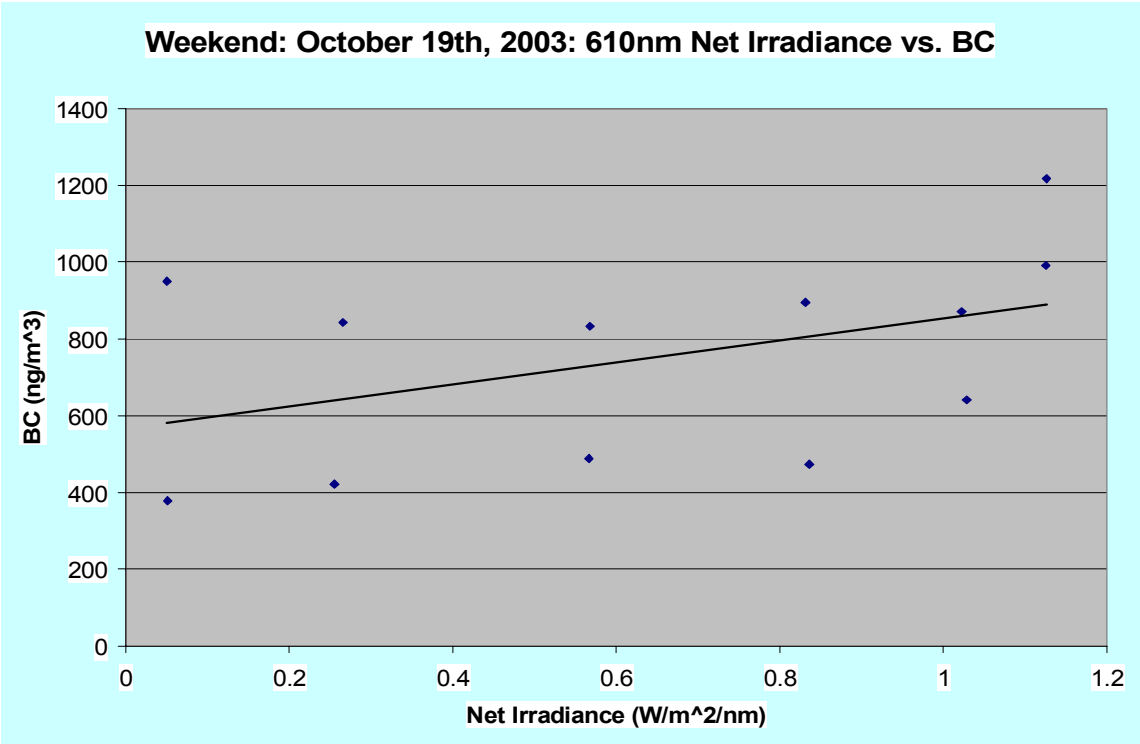

Figure 102. October 2003 Weekend 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

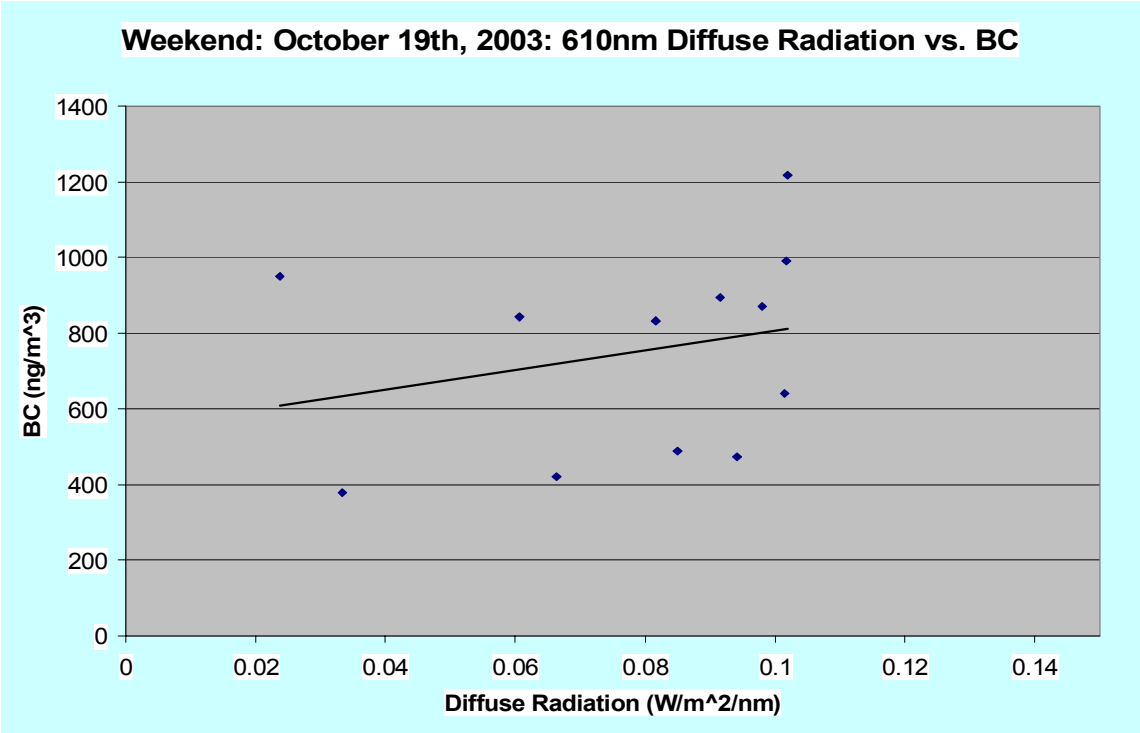

Figure 103. October 2003 Weekend 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

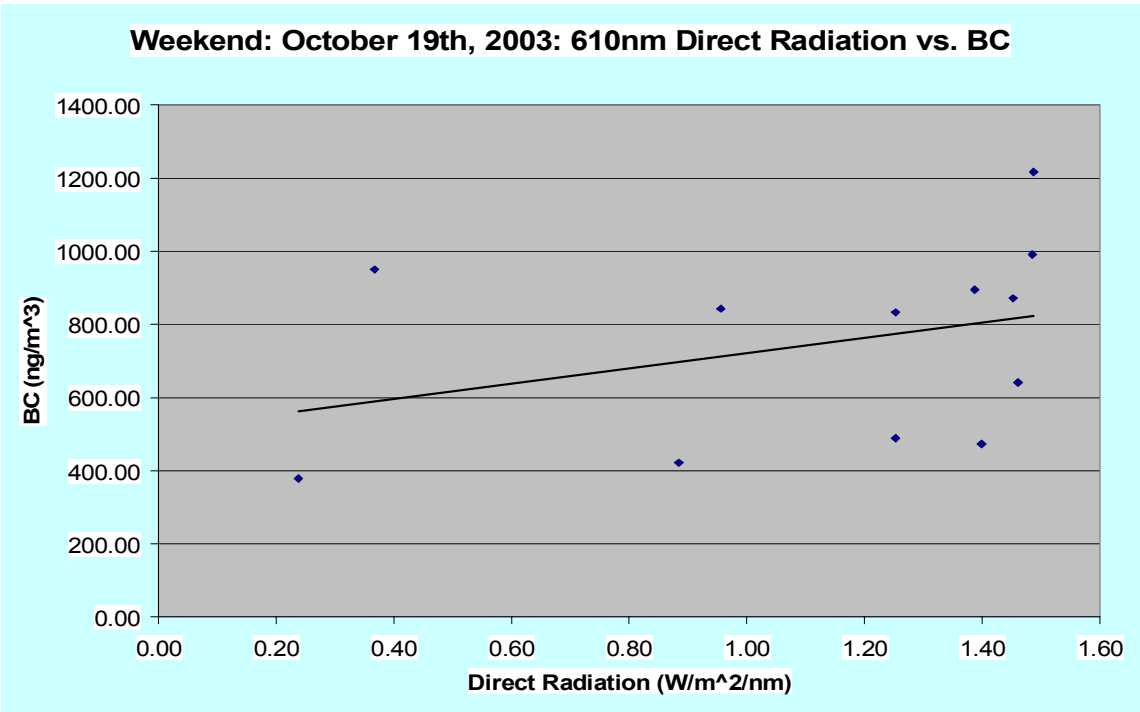

Figure 104. October 2003 Weekend 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

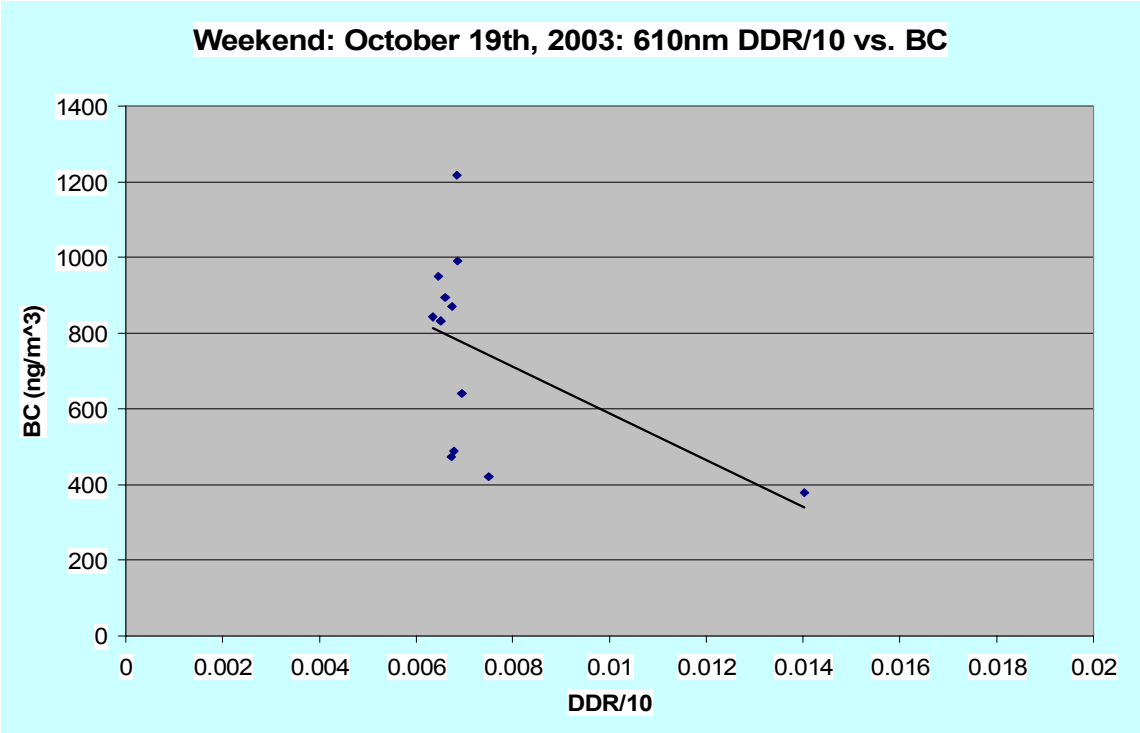

Figure 105. October 2003 Weekend 610nm DDR/10 vs. BC Concentrations (ng/m^3)

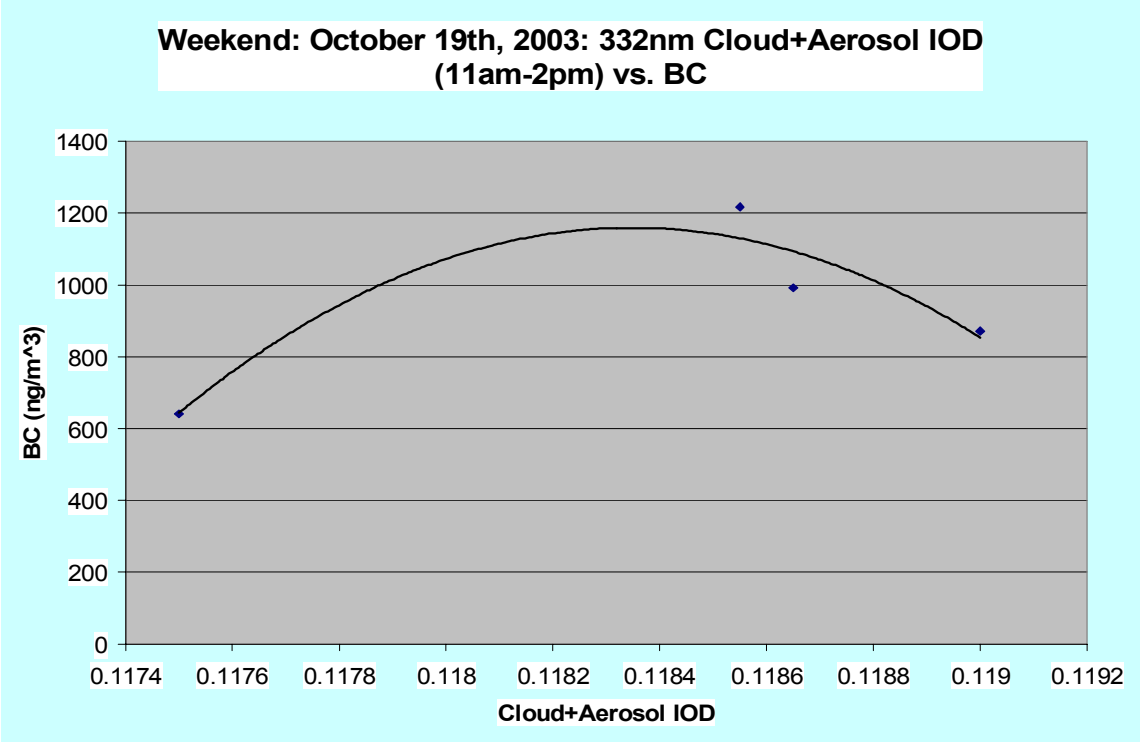

Figure 106. October 2003 Weekend 332nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

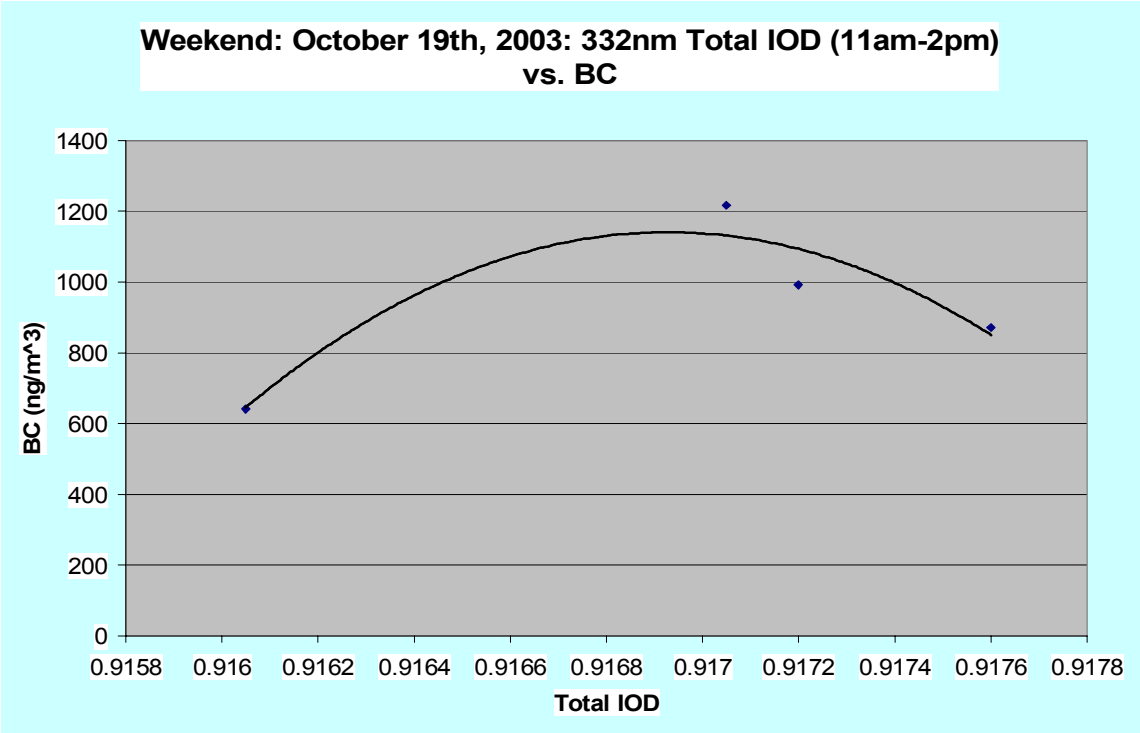

Figure 107. October 2003 Weekend 332nm Total IOD vs. BC Concentrations (ng/m^3)

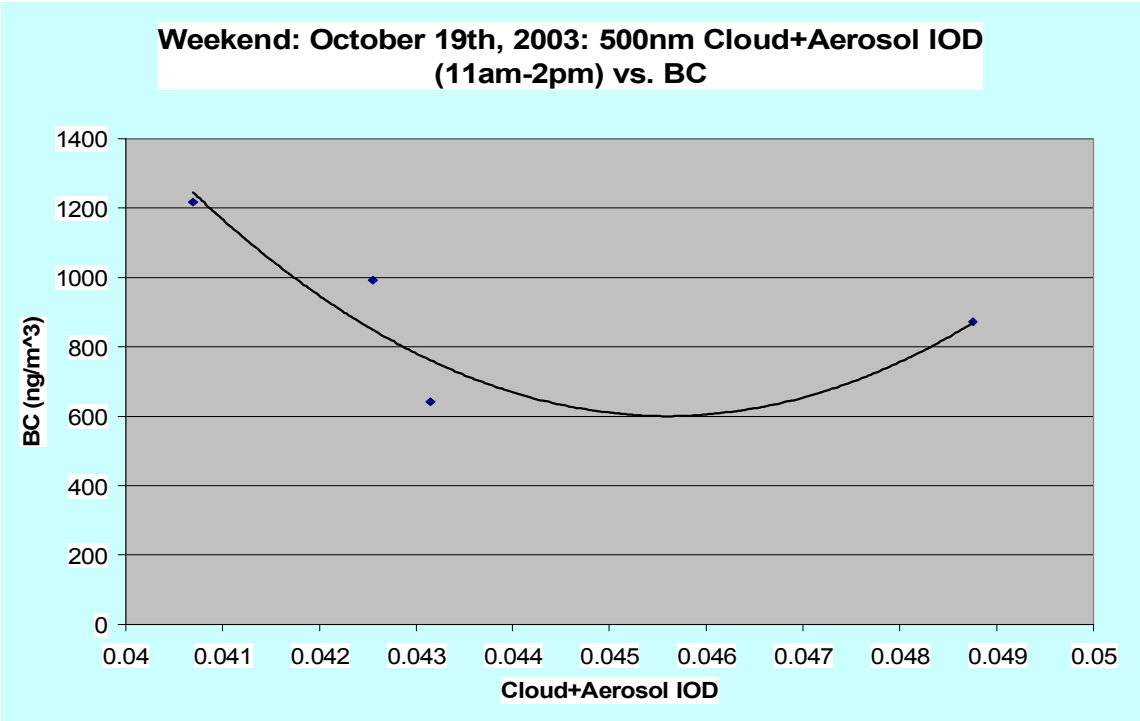

Figure 108. October 2003 Weekend 500nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

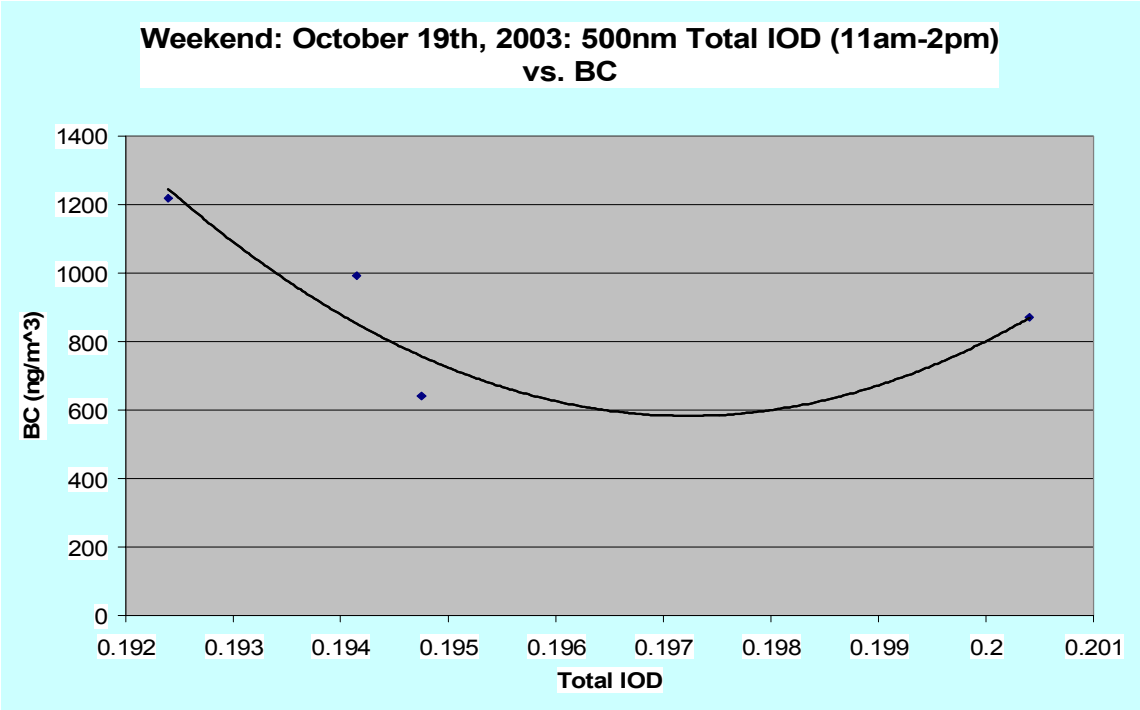

Figure 109. October 2003 Weekend 500nm Total IOD vs. BC Concentrations (ng/m^3)

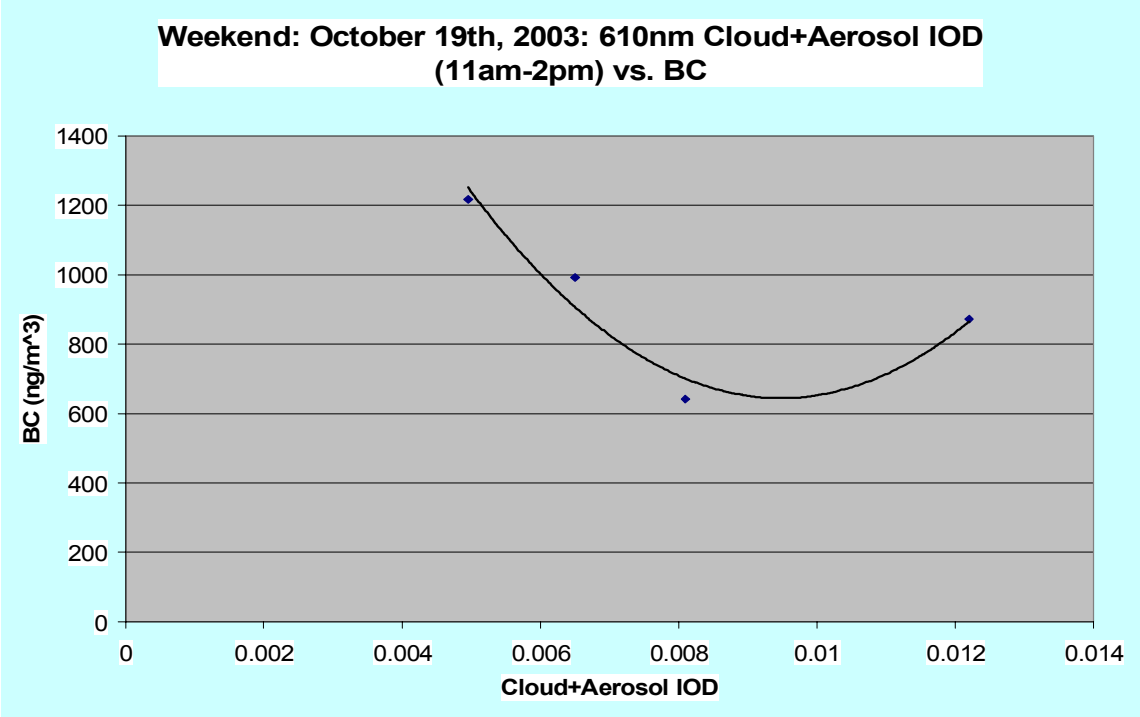

Figure 110. October 2003 Weekend 610nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

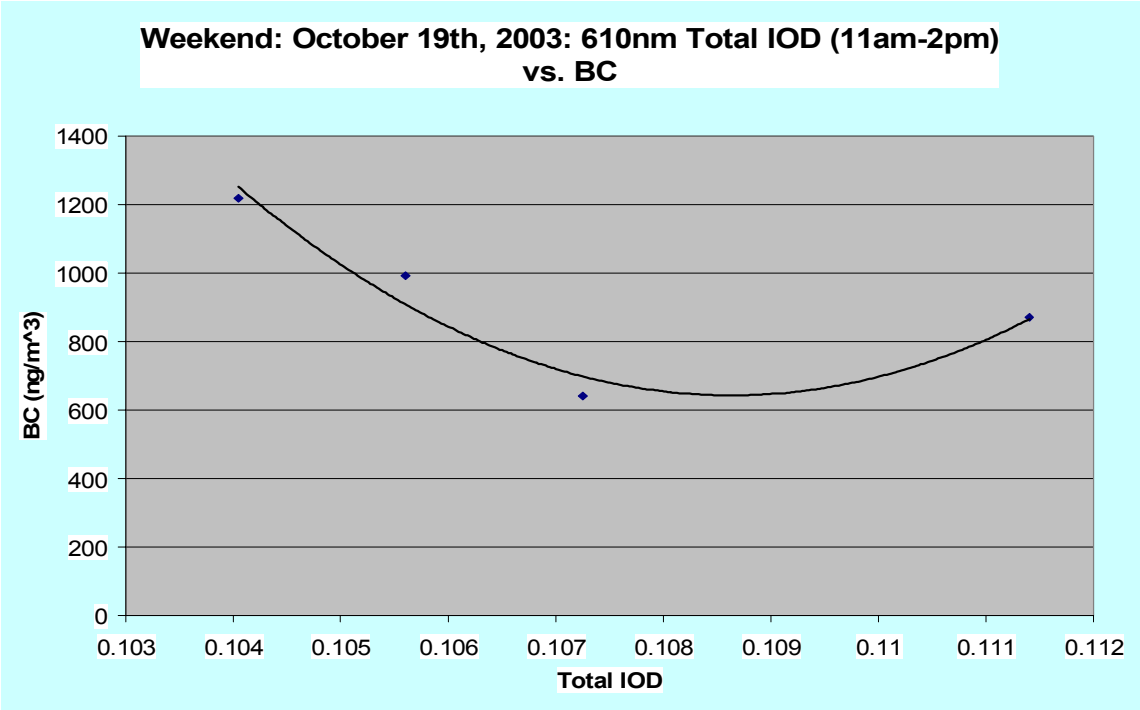

Figure 111. October 2003 Weekend 610nm Total IOD vs. BC Concentrations (ng/m^3)

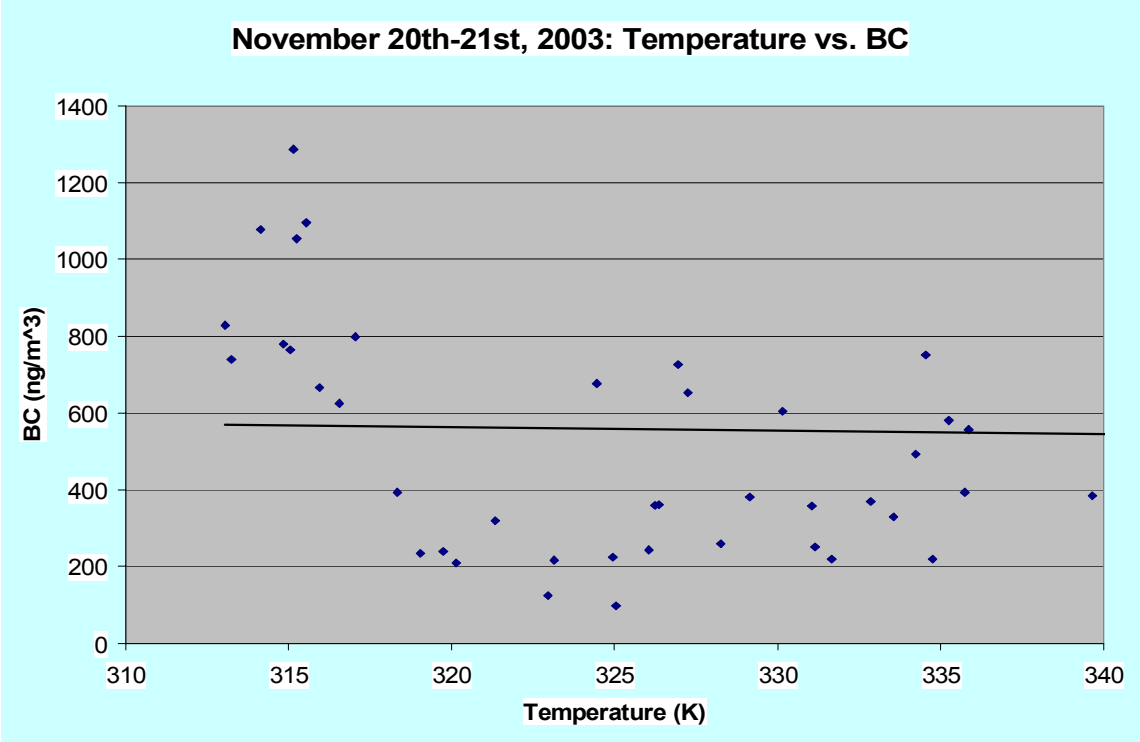

Figure 112. November 2003 Weekdays Temperature (K) vs. BC Concentrations (ng/m^3)

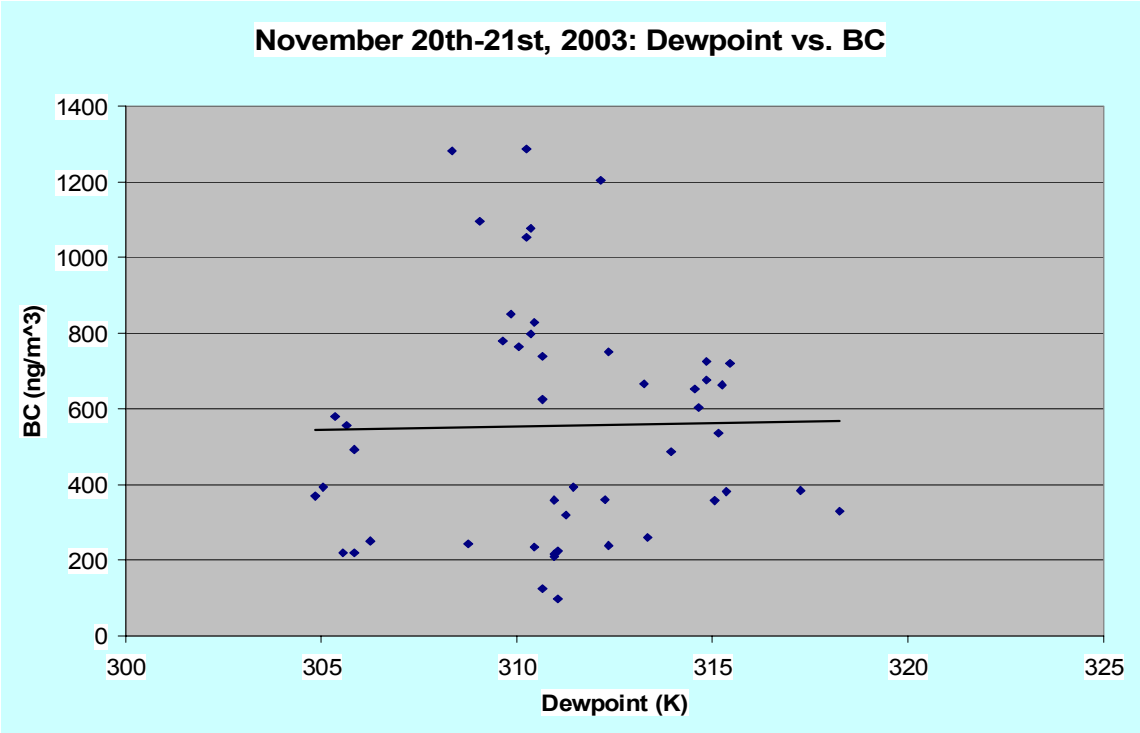

Figure 113. November 2003 Weekdays Dewpoint (K) vs. BC Concentrations (ng/m^3)

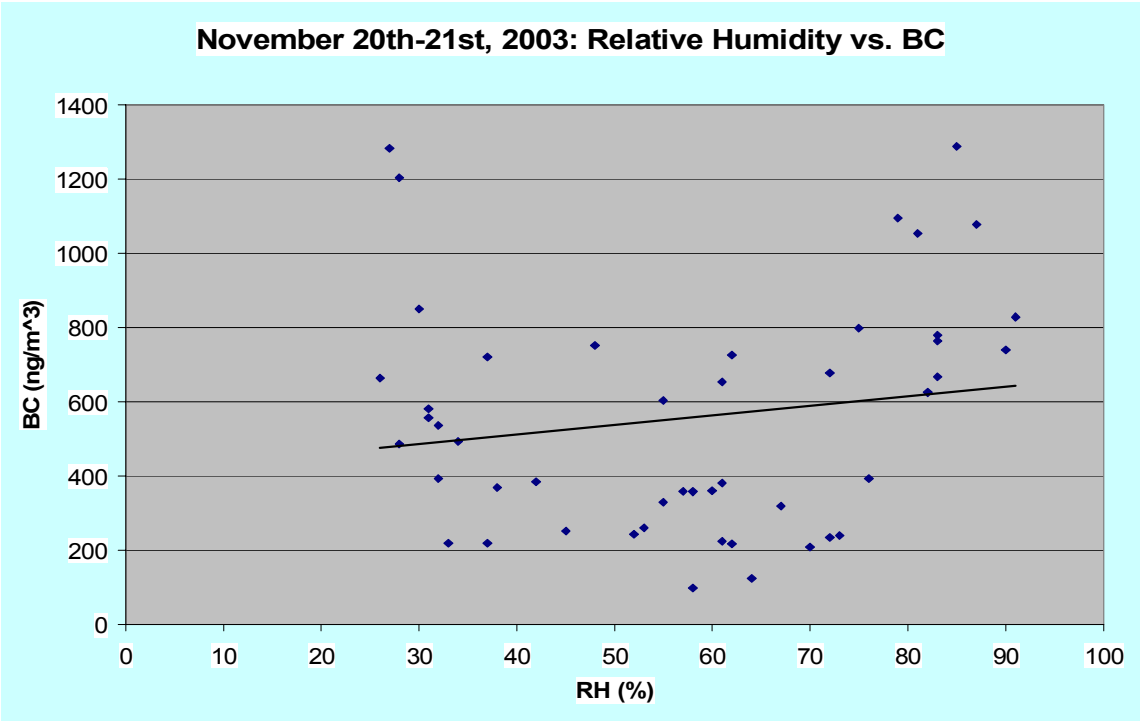

Figure 114. November 2003 Weekdays Relative Humidity (%) vs. BC Concentrations (ng/m^3)

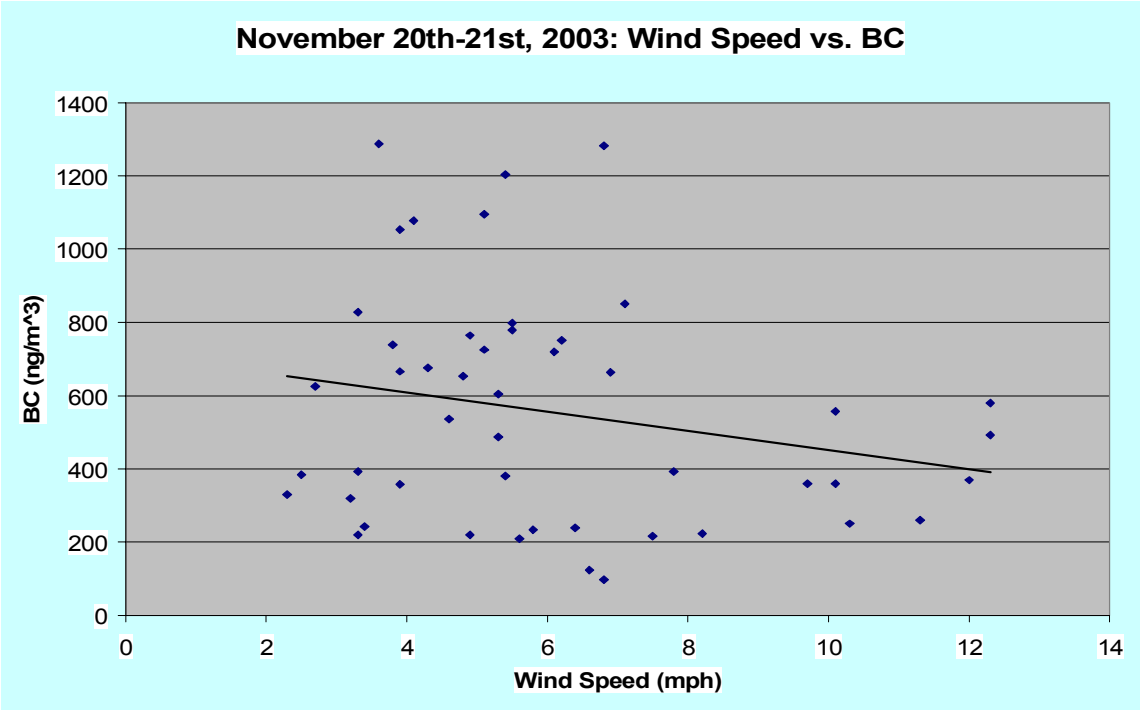

Figure 115. November 2003 Weekdays Wind Speed (mph) vs. BC Concentrations (ng/m^3)

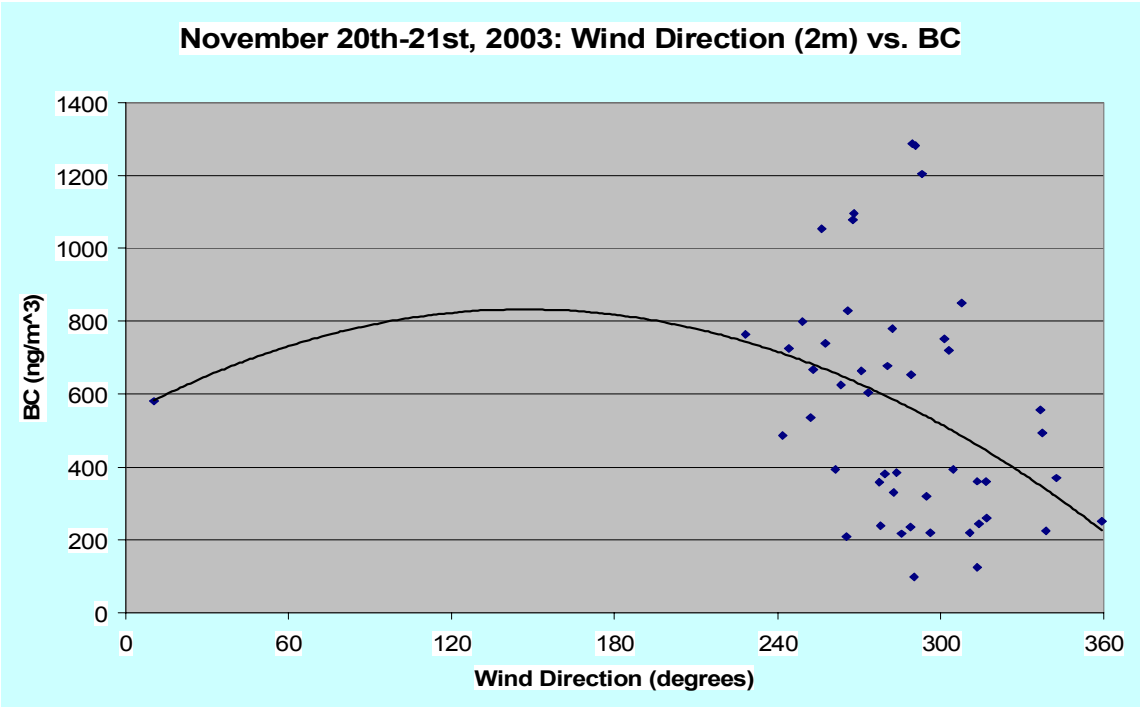

Figure 116. November 2003 Weekdays Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

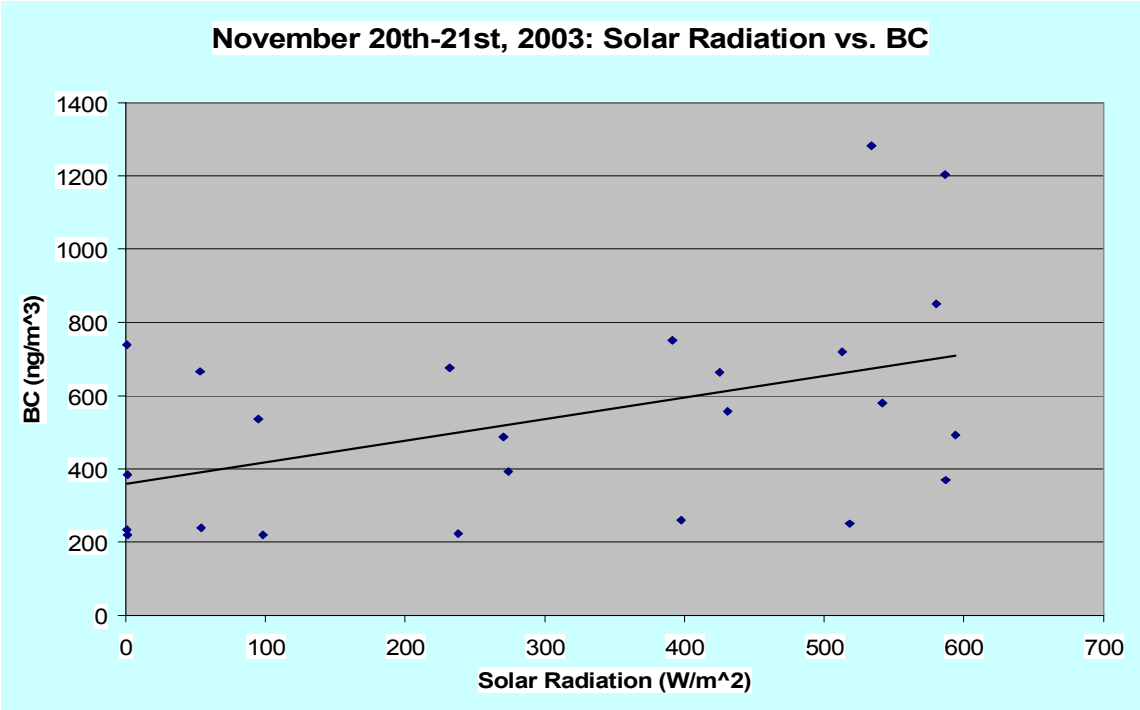

Figure 117. November 2003 Weekdays Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

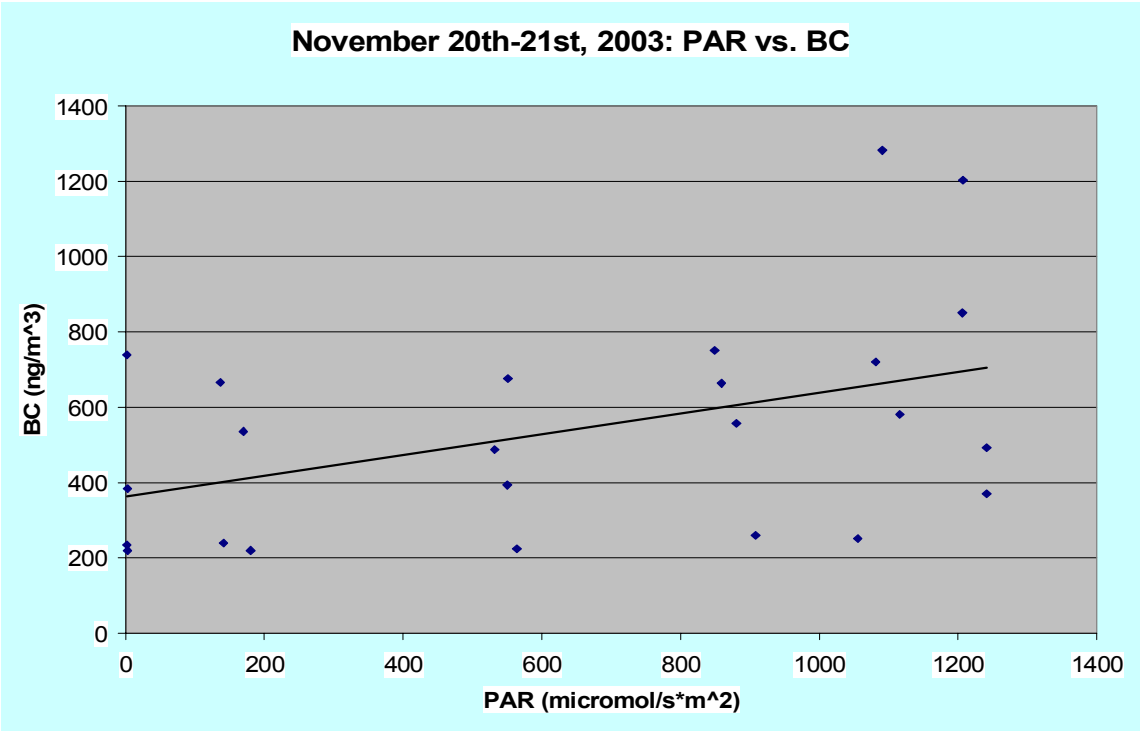

Figure 118. November 2003 Weekdays PAR (micromole/s*m^2) vs. BC Concentrations (ng/m^3)

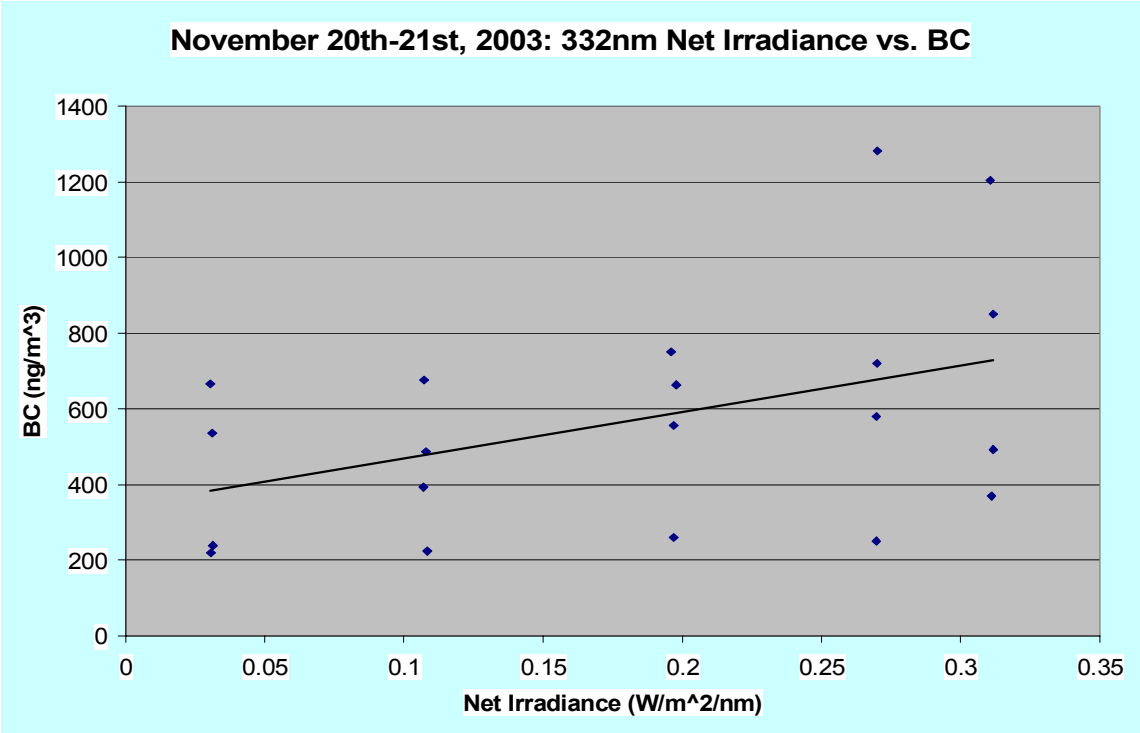

Figure 119. November 2003 Weekdays 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

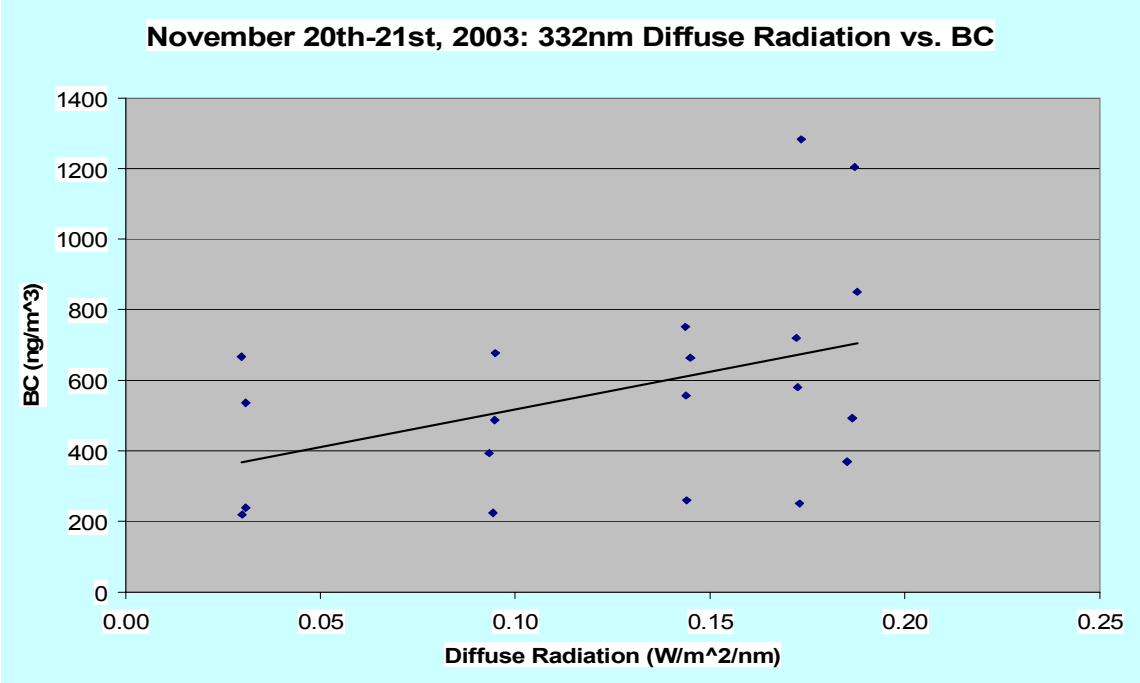

Figure 120. November 2003 Weekdays 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

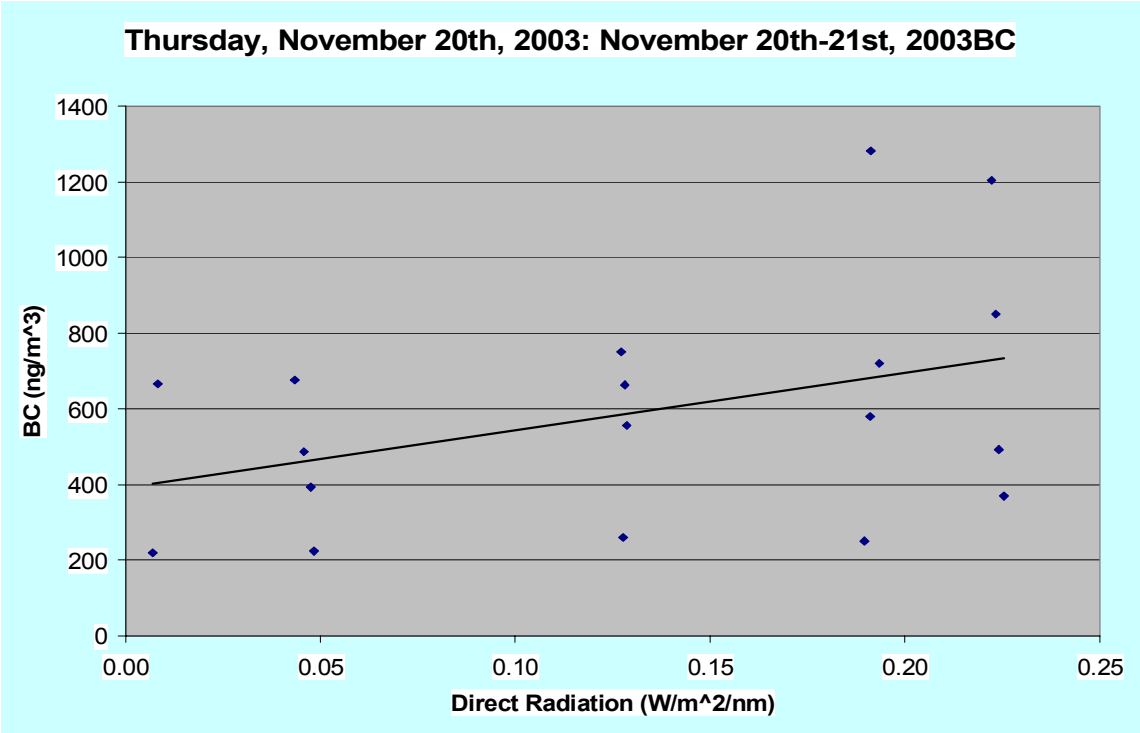

Figure 121. November 2003 Weekdays 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

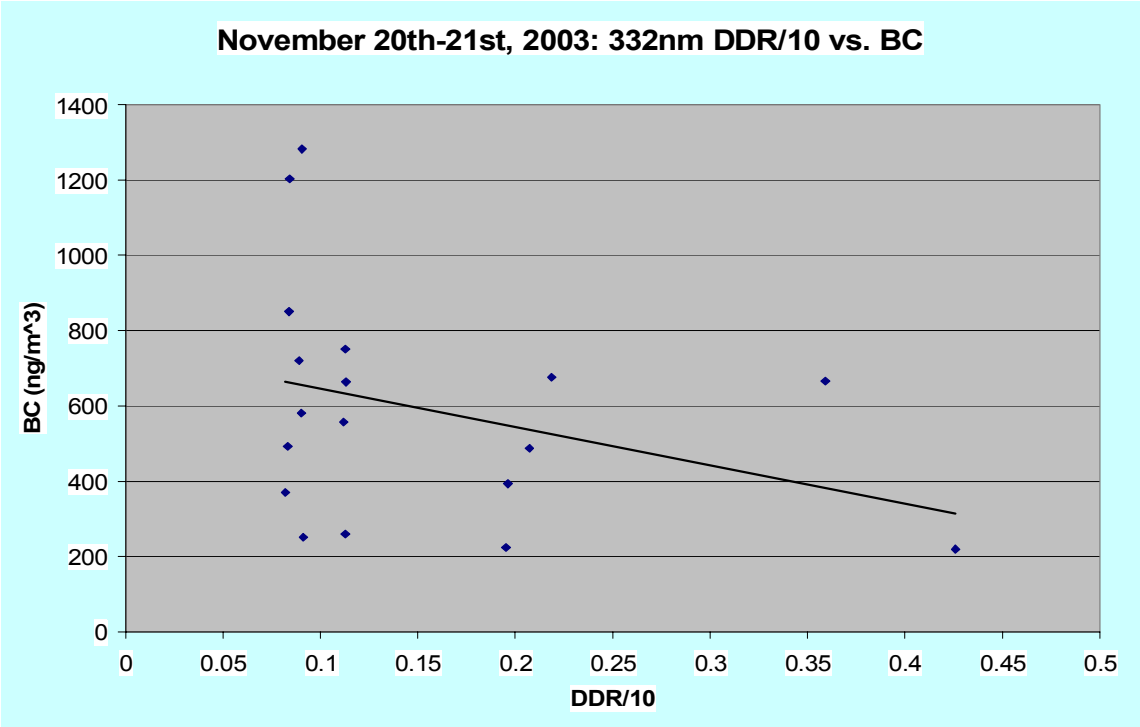

Figure 122. November 2003 Weekdays 332nm DDR/10 vs. BC Concentrations (ng/m^3)

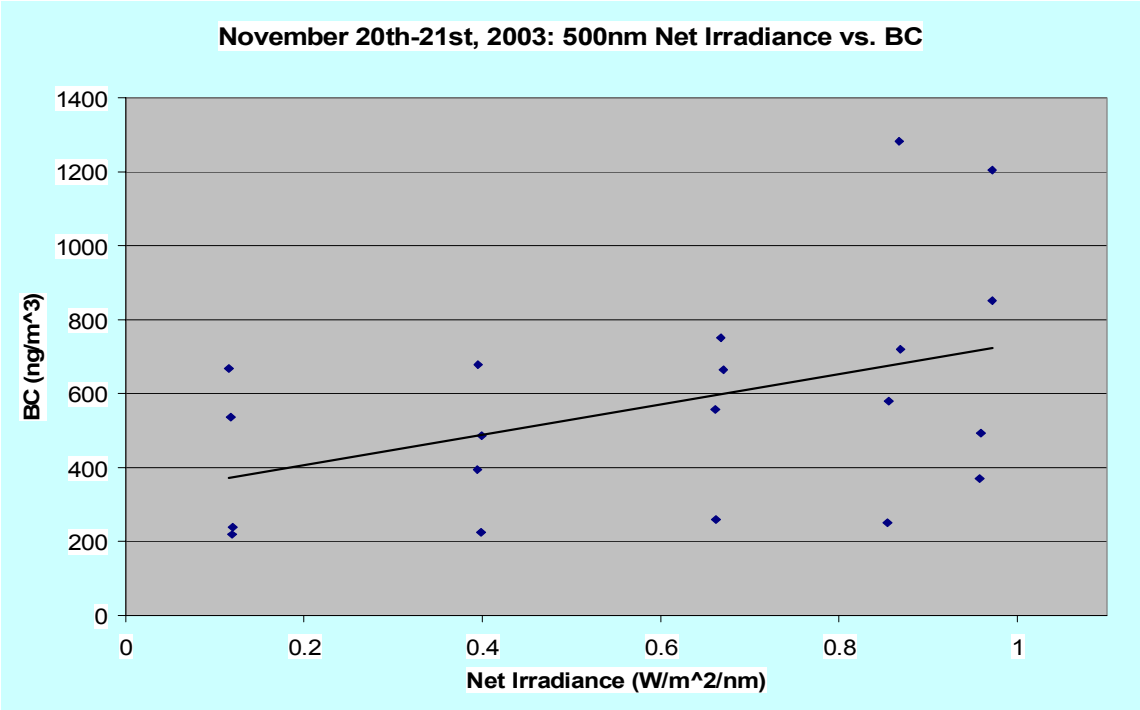

Figure 123. November 2003 Weekdays 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

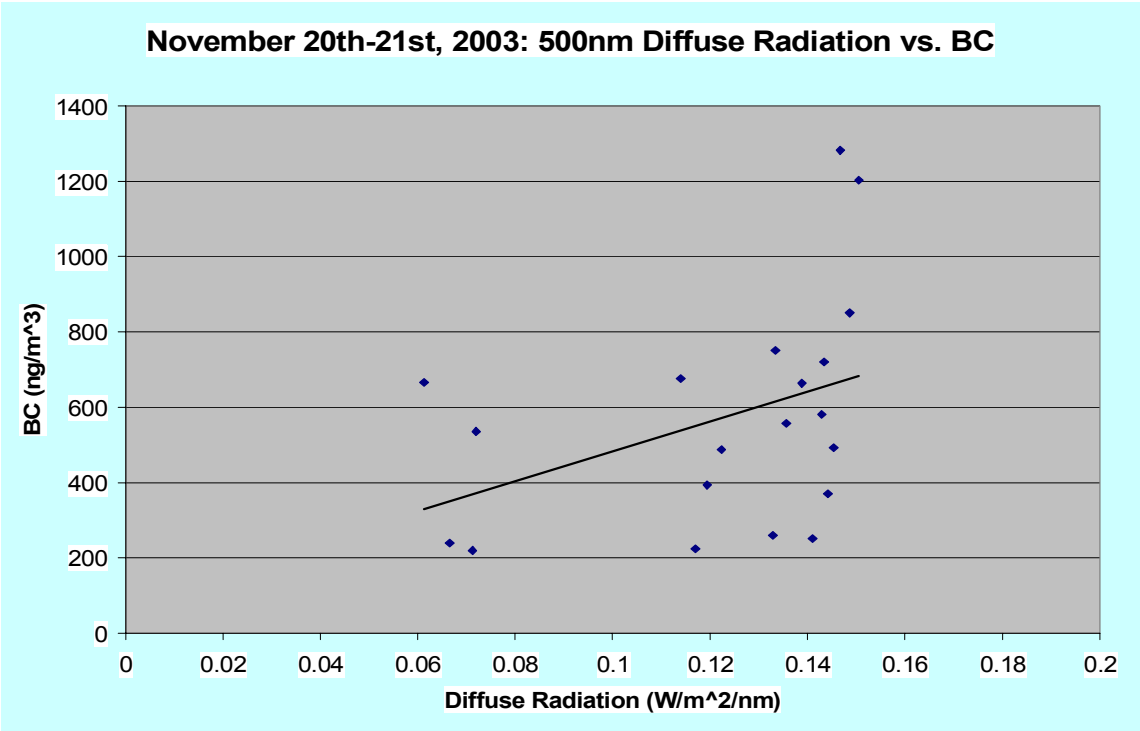

Figure 124. November 2003 Weekdays 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

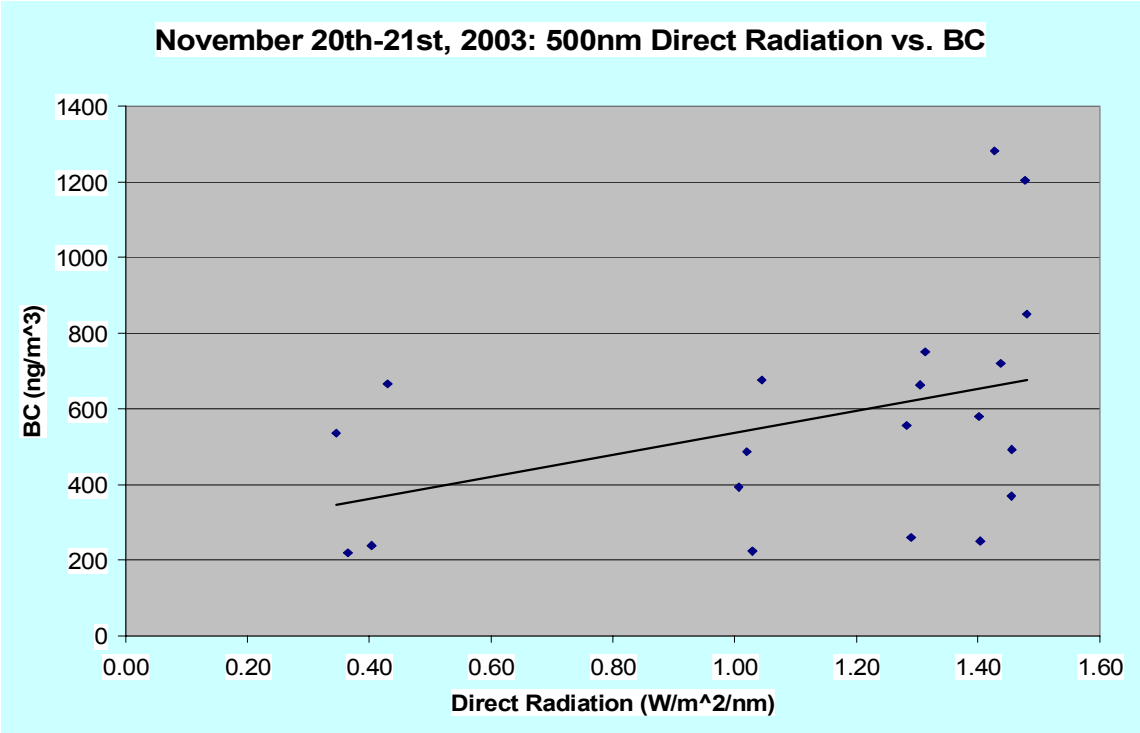

Figure 125. November 2003 Weekdays 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

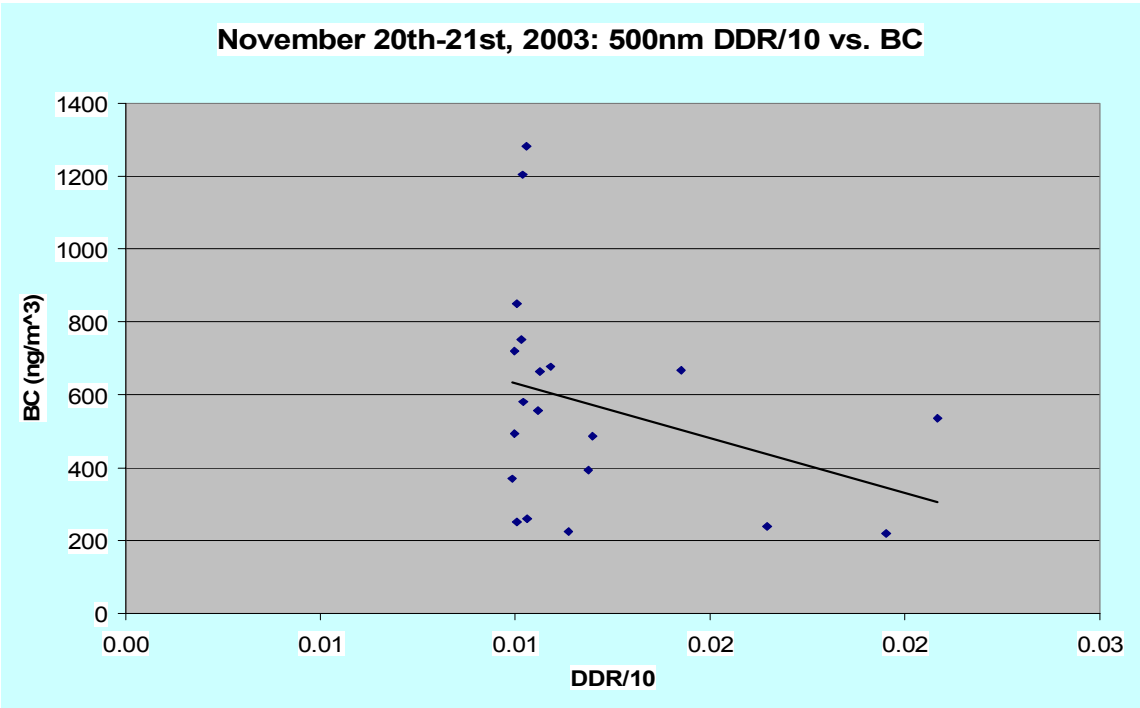

Figure 126. November 2003 Weekdays 500nm DDR/10 vs. BC Concentrations (ng/m^3)

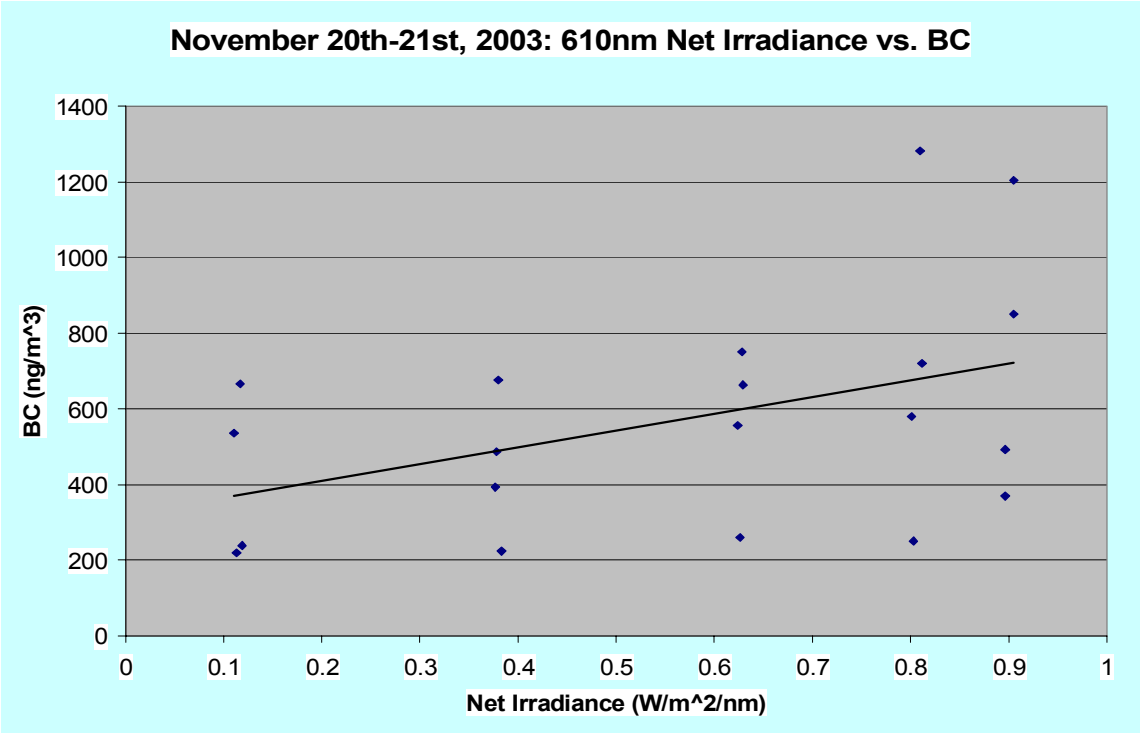

Figure 127. November 2003 Weekdays 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

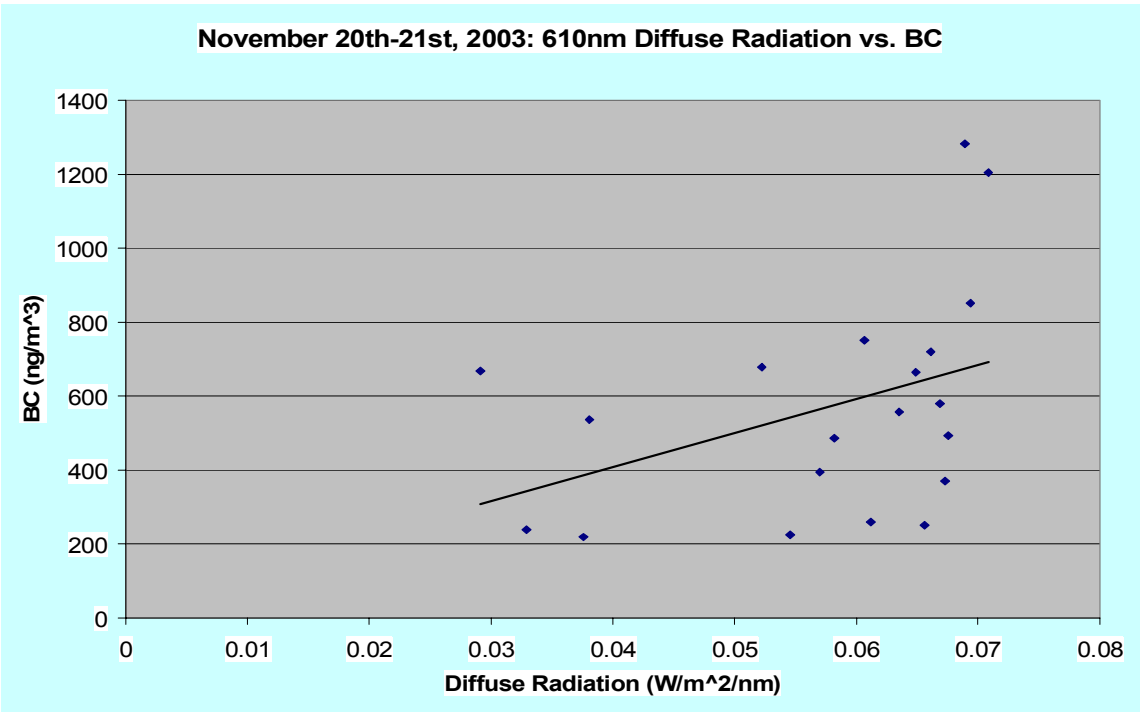

Figure 128. November 2003 Weekdays 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

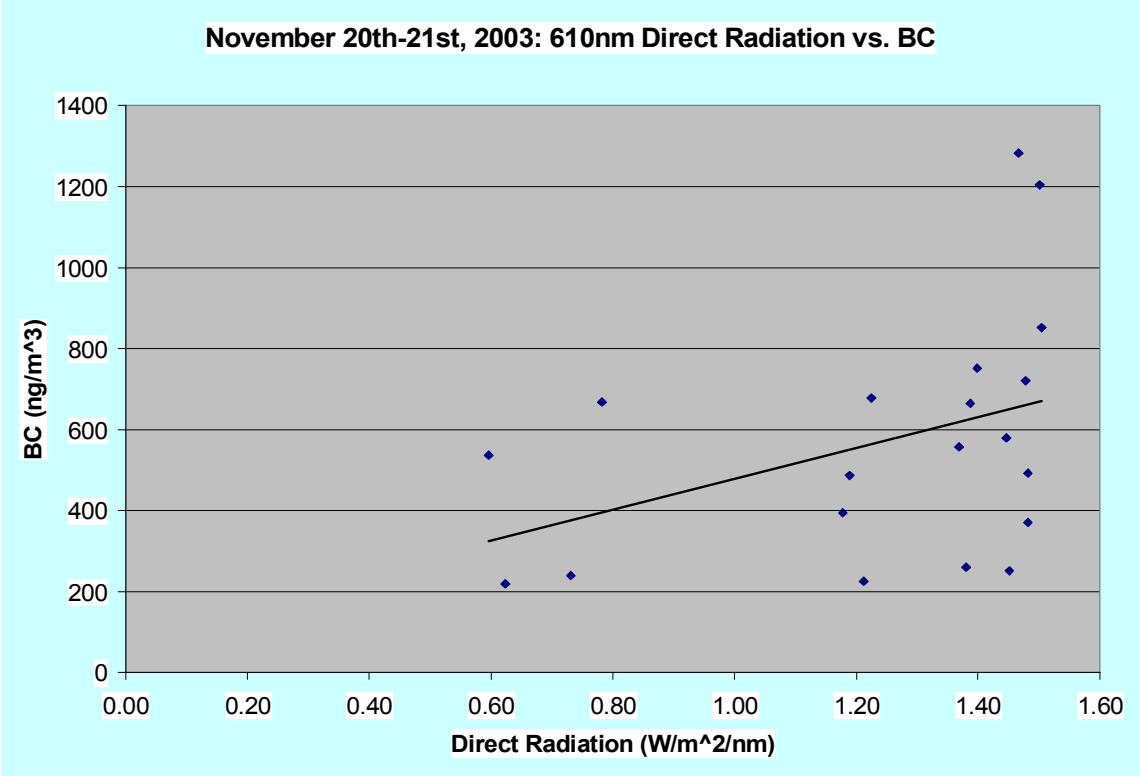

Figure 129. November 2003 Weekdays 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

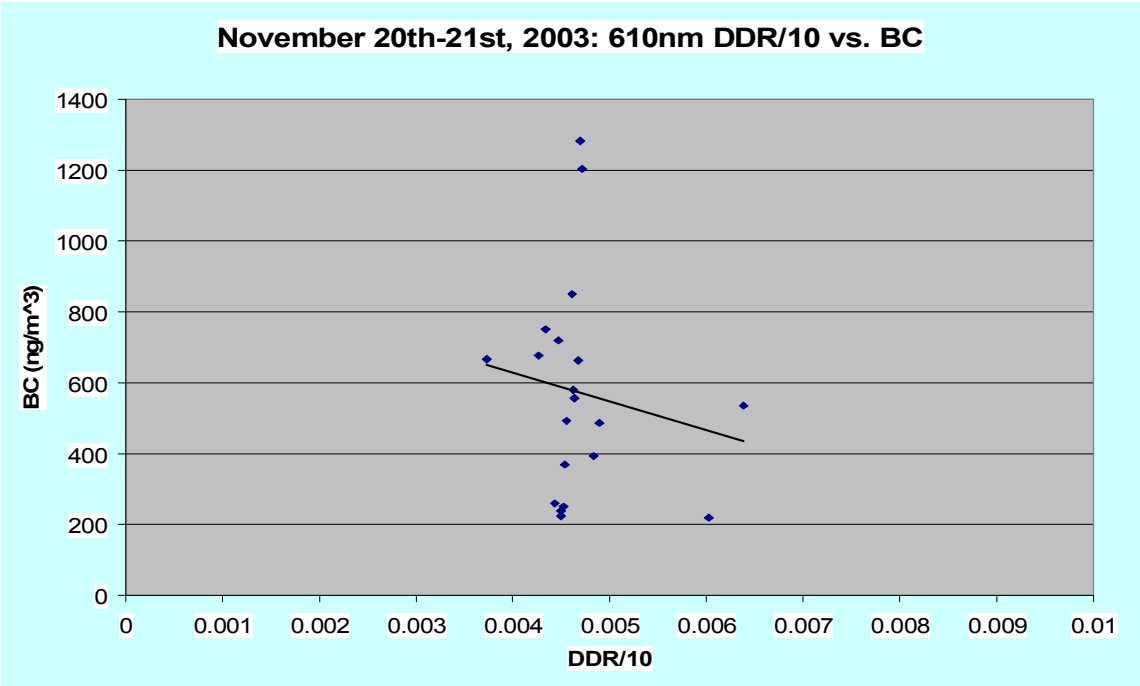

Figure 130. November 2003 Weekdays 610nm DDR/10 vs. BC Concentrations (ng/m^3)

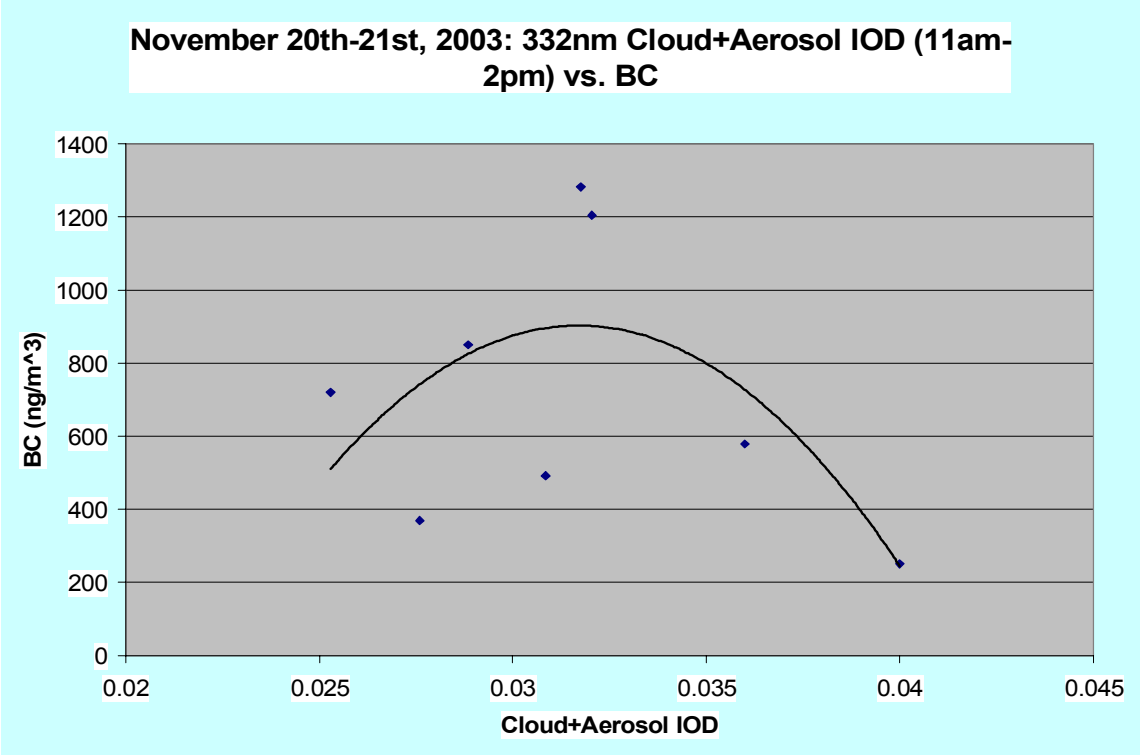

Figure 131. November 2003 Weekdays 332nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

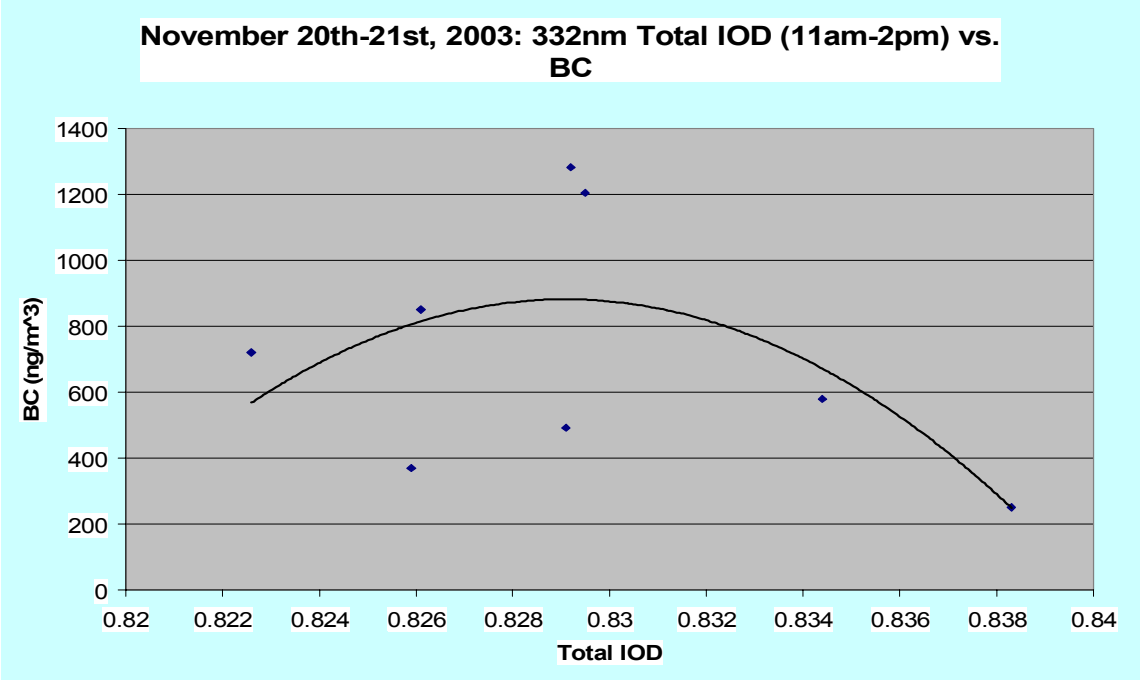

Figure 132. November 2003 Weekdays 332nm Total IOD vs. BC Concentrations (ng/m^3)

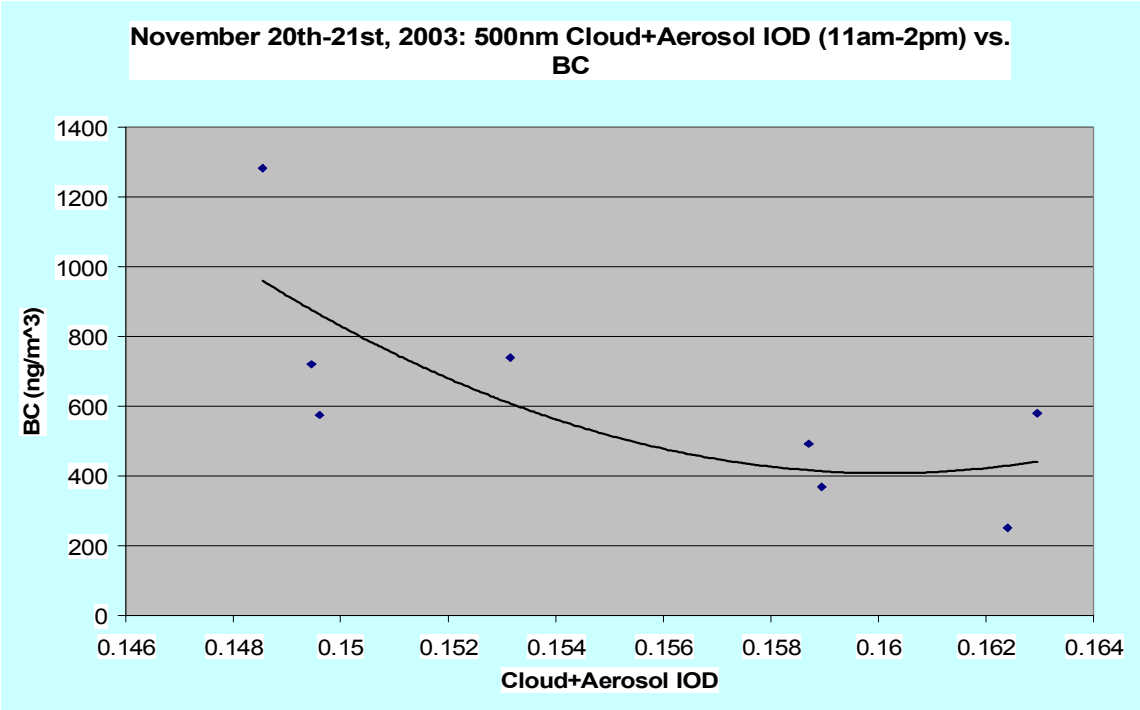

Figure 133. November 2003 Weekdays 500nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

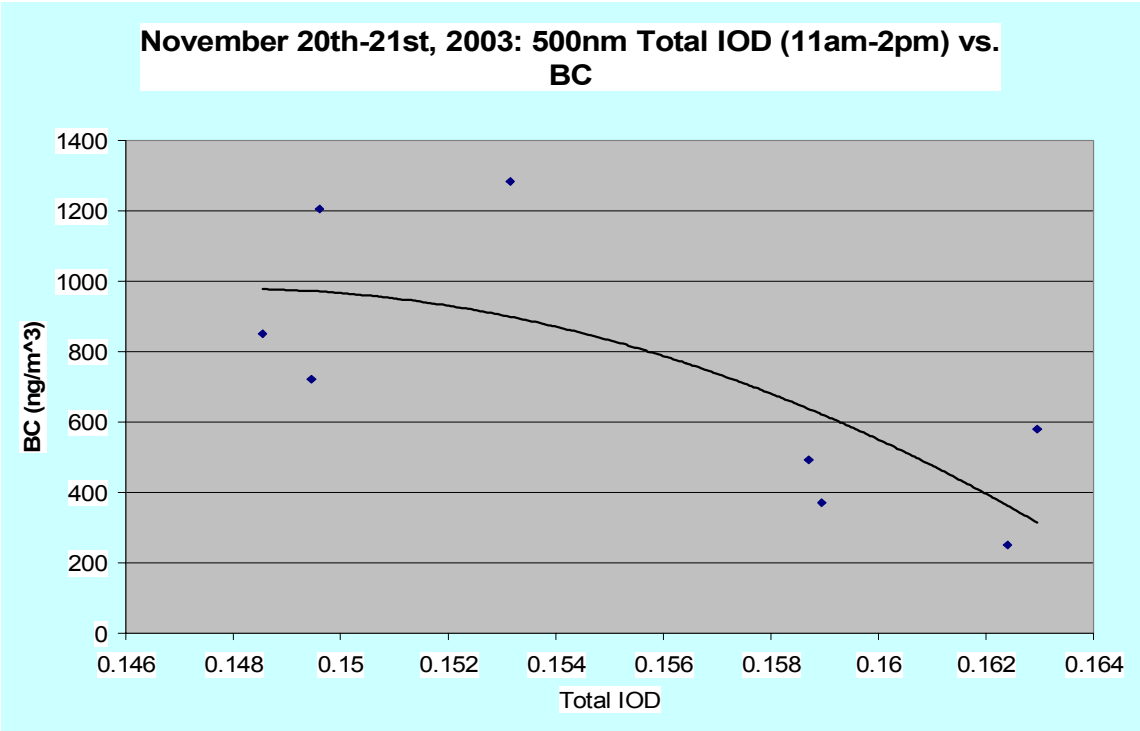

Figure 134. November 2003 Weekdays 500nm Total IOD vs. BC Concentrations (ng/m^3)

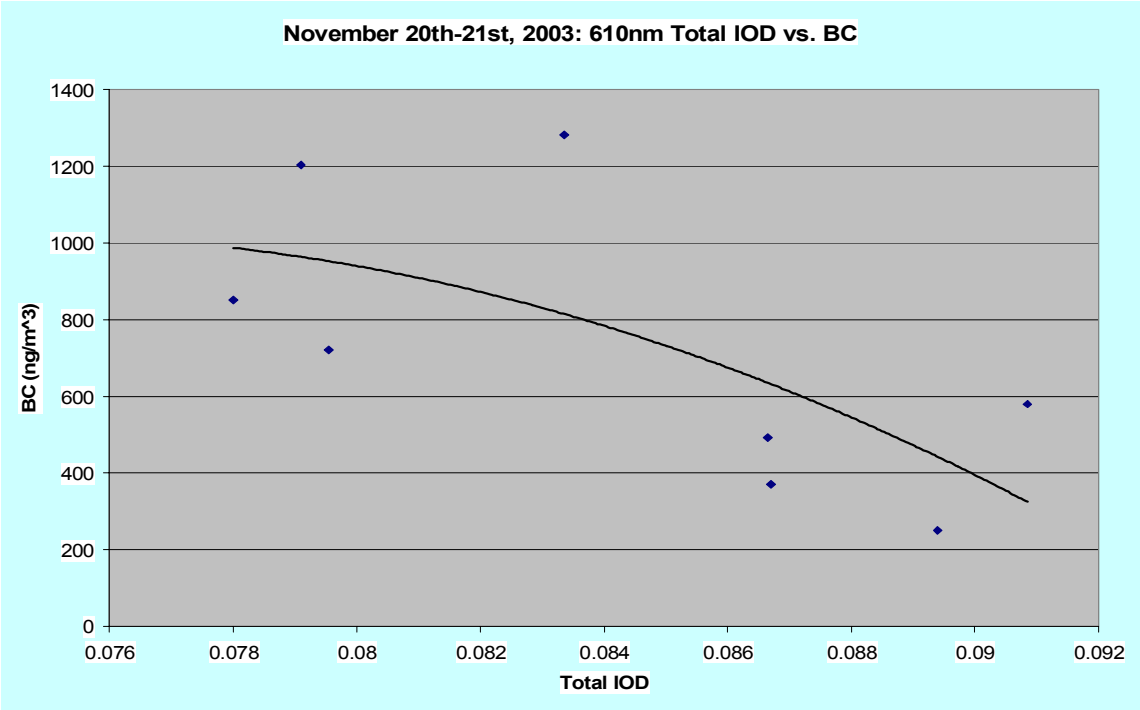

Figure 135. November 2003 Weekdays 610nm Total IOD vs. BC Concentrations (ng/m^3)

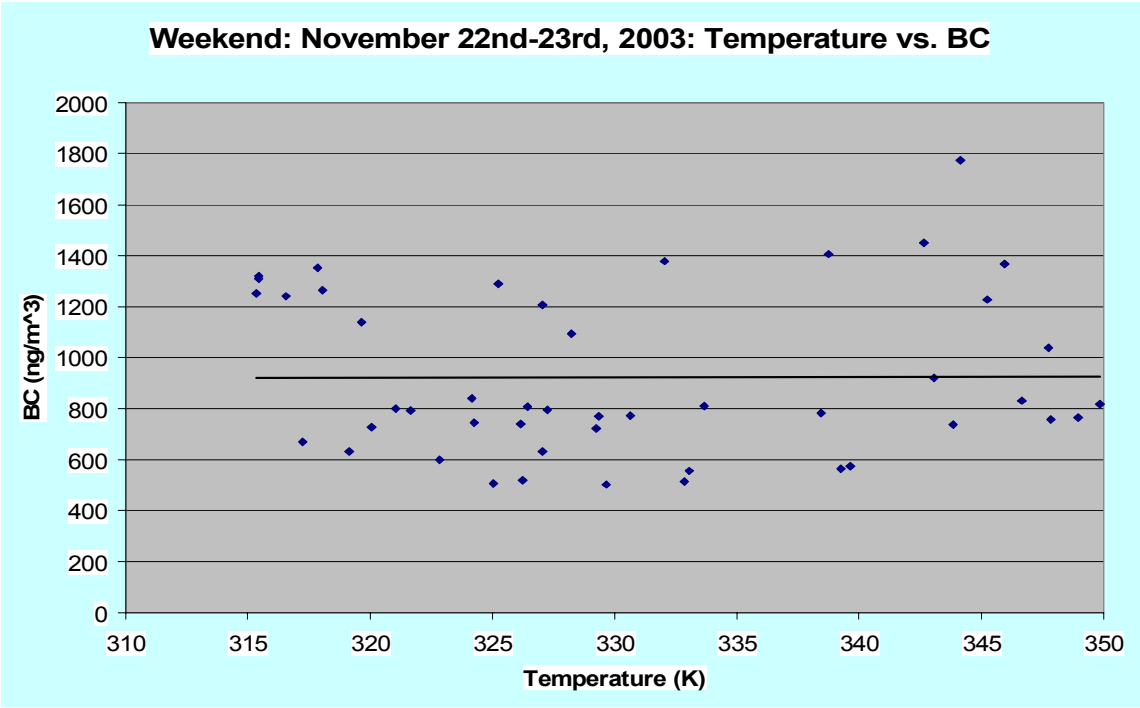

Figure 136. November 2003 Weekend Temperature (K) vs. BC Concentrations (ng/m^3)

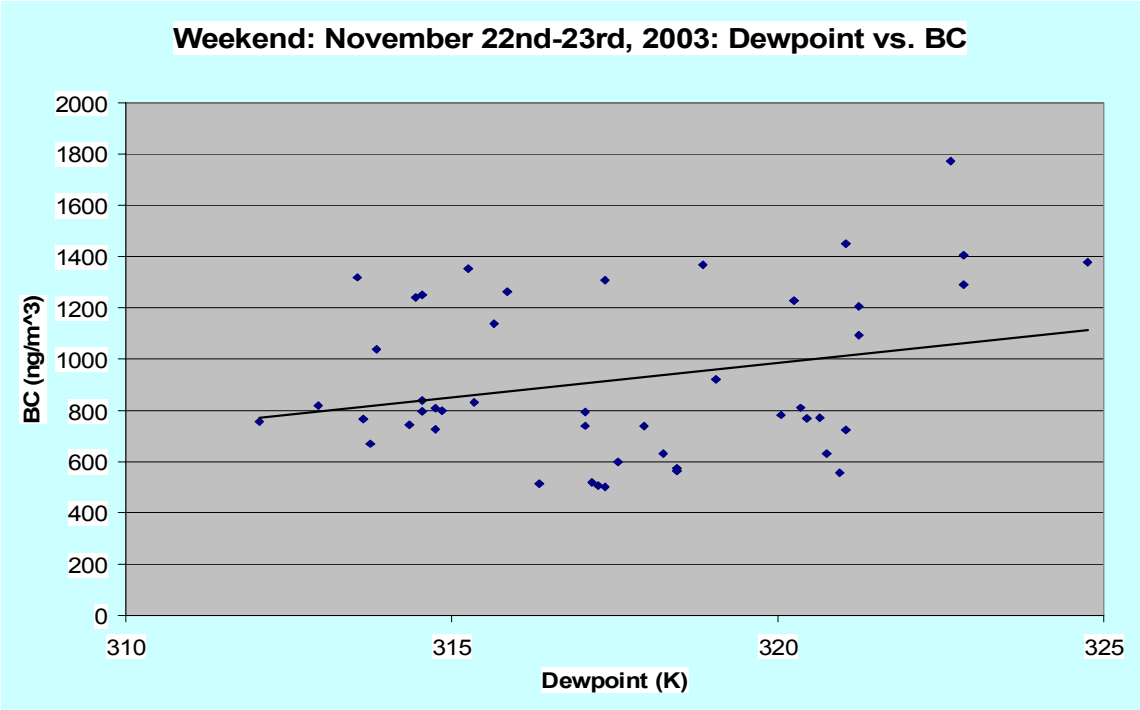

Figure 137. November 2003 Weekend Dewpoint (K) vs. BC Concentrations (ng/m^3)

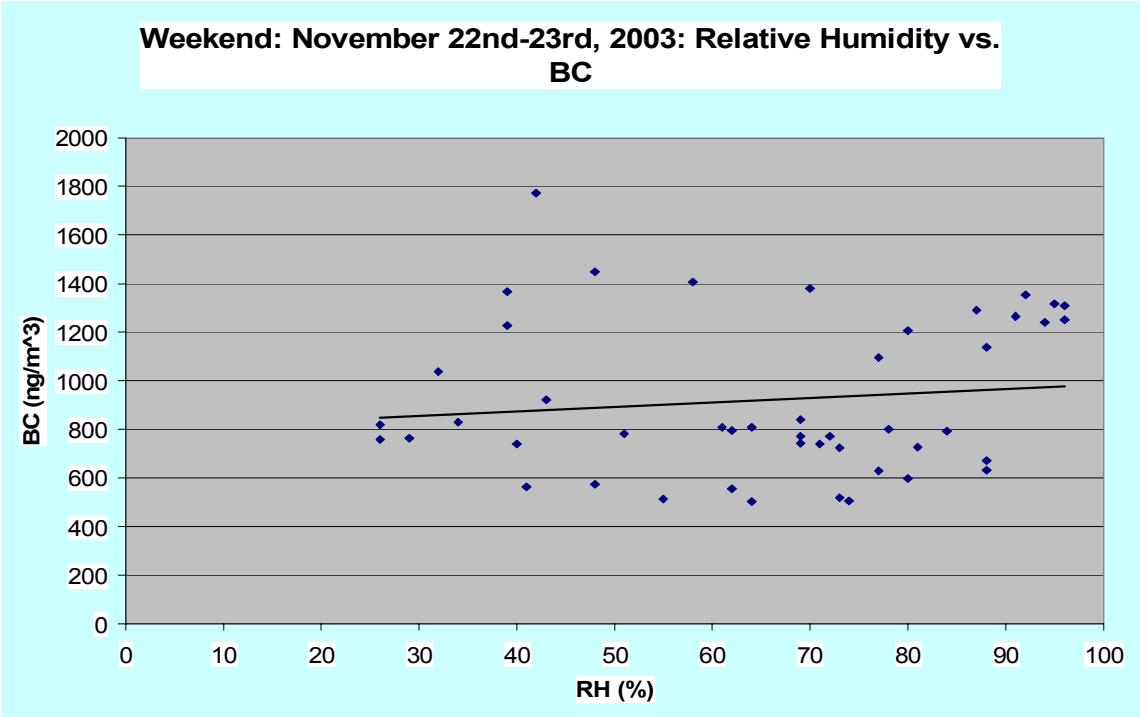

Figure 138. November 2003 Weekend Relative Humidity (%) vs. BC Concentrations (ng/m^3)

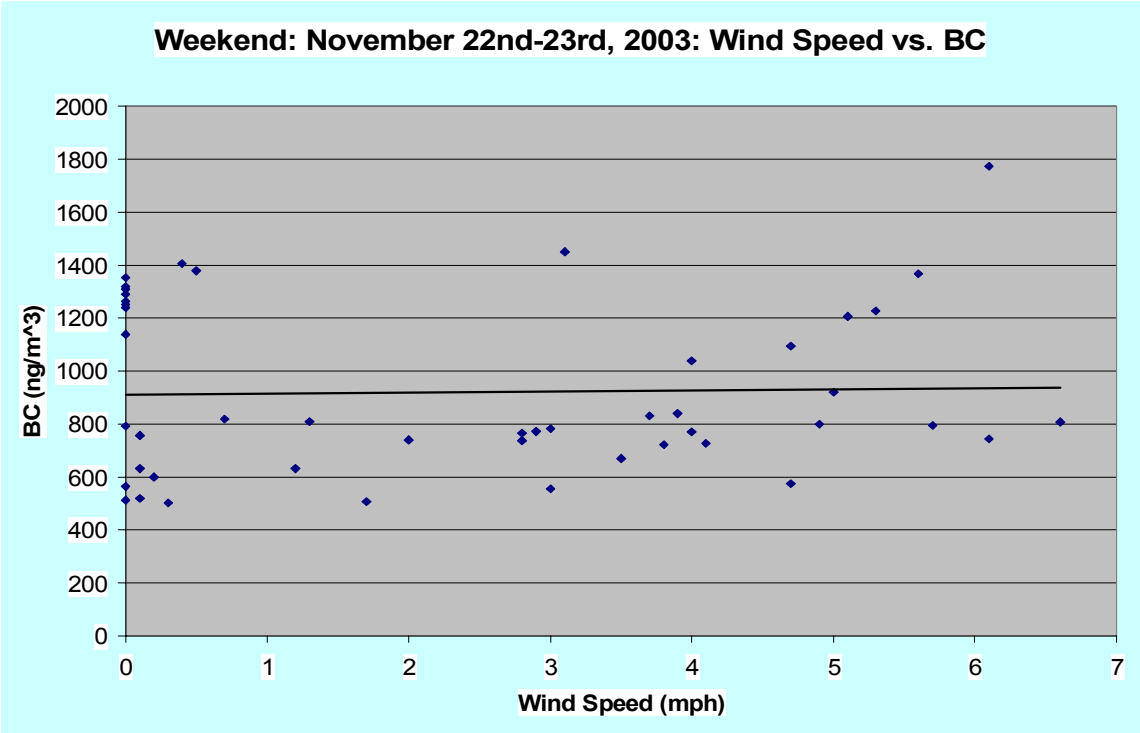

Figure 139. November 2003 Weekend Wind Speed (mph) vs. BC Concentrations (ng/m^3)

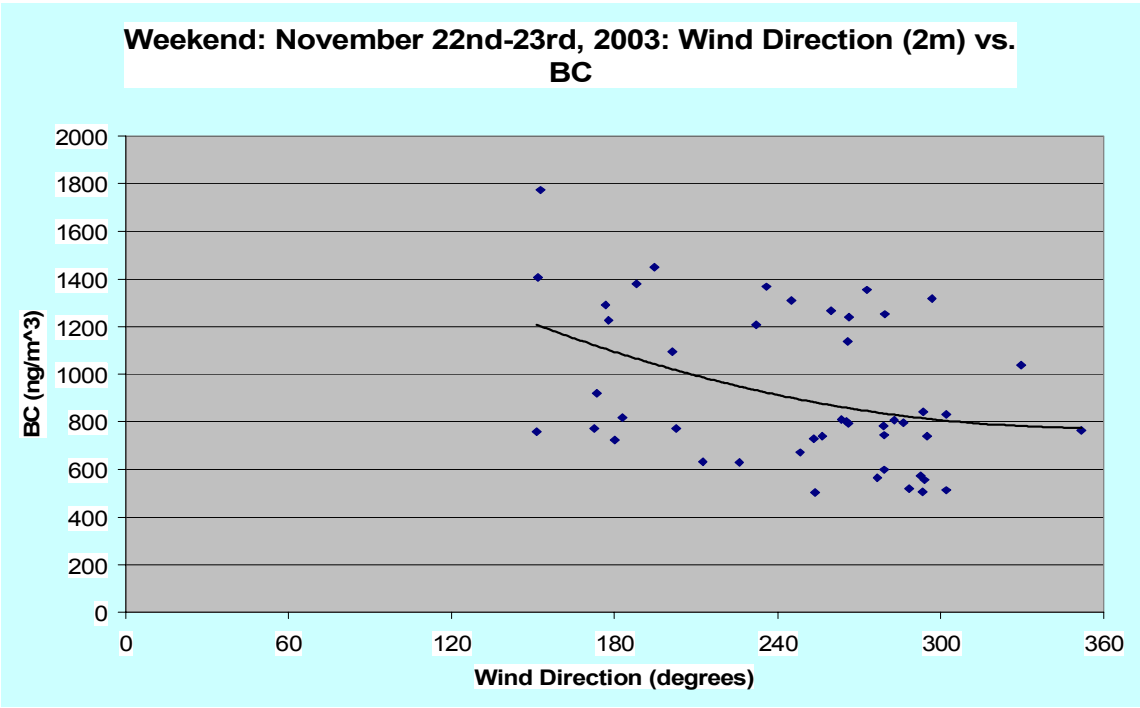

Figure 140. November 2003 Weekend Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

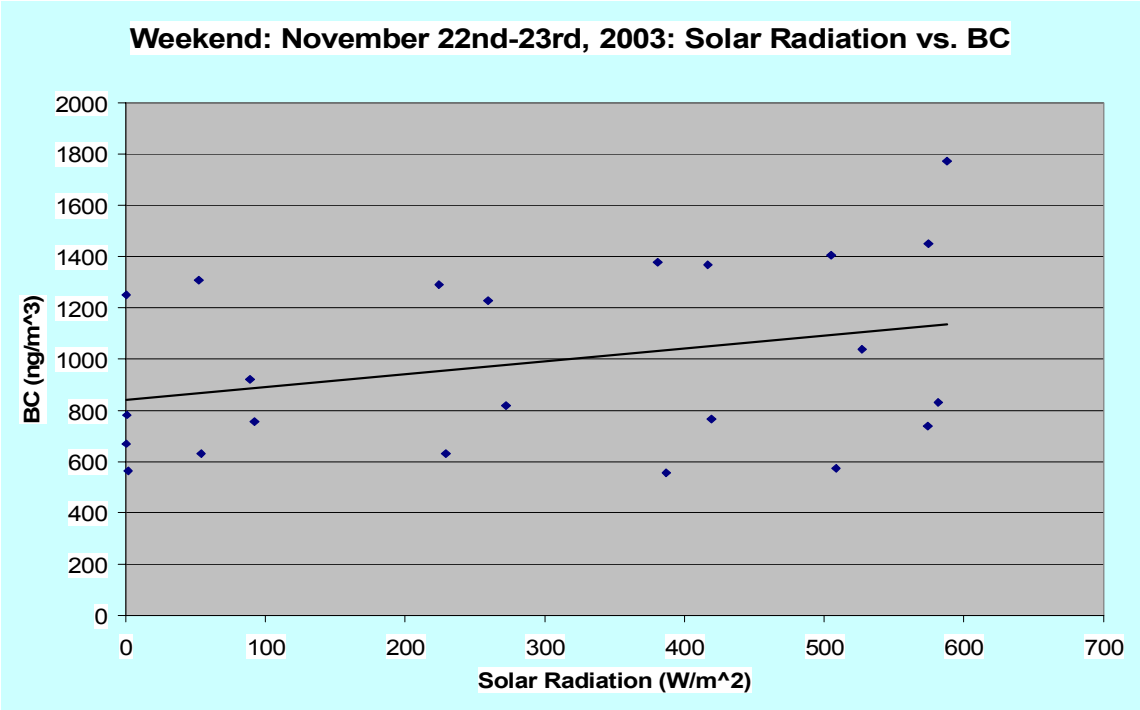

Figure 141. November 2003 Weekend Wind Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

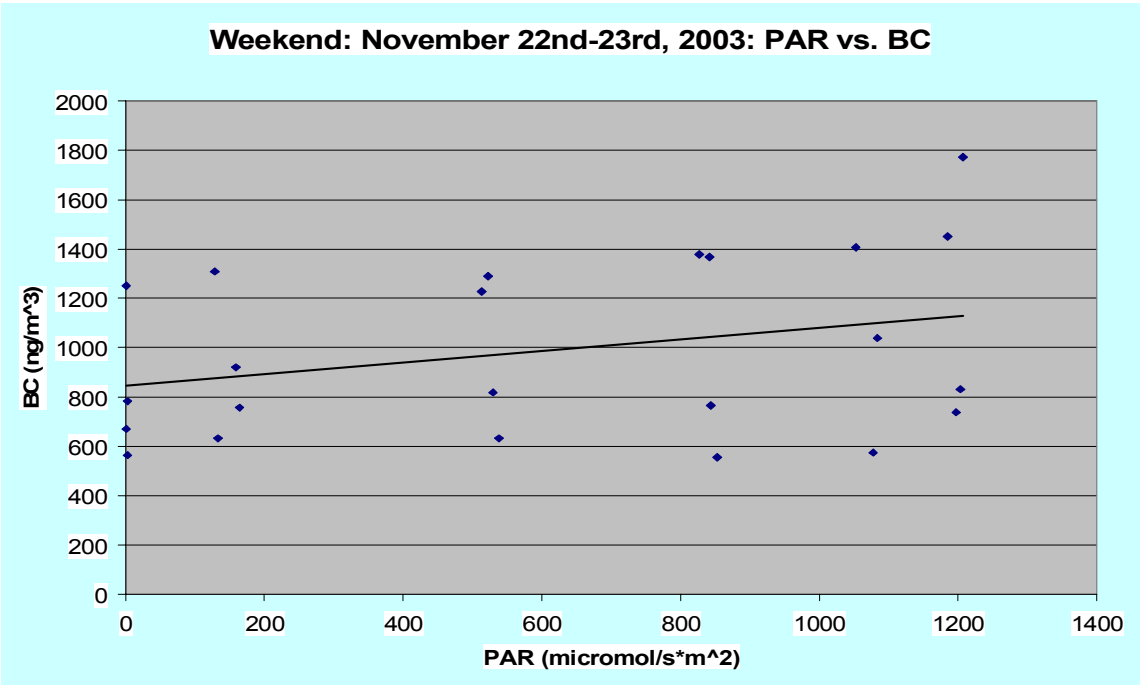

Figure 142. November 2003 Weekend PAR (micromole/s*m^2) vs. BC Concentrations (ng/m^3)

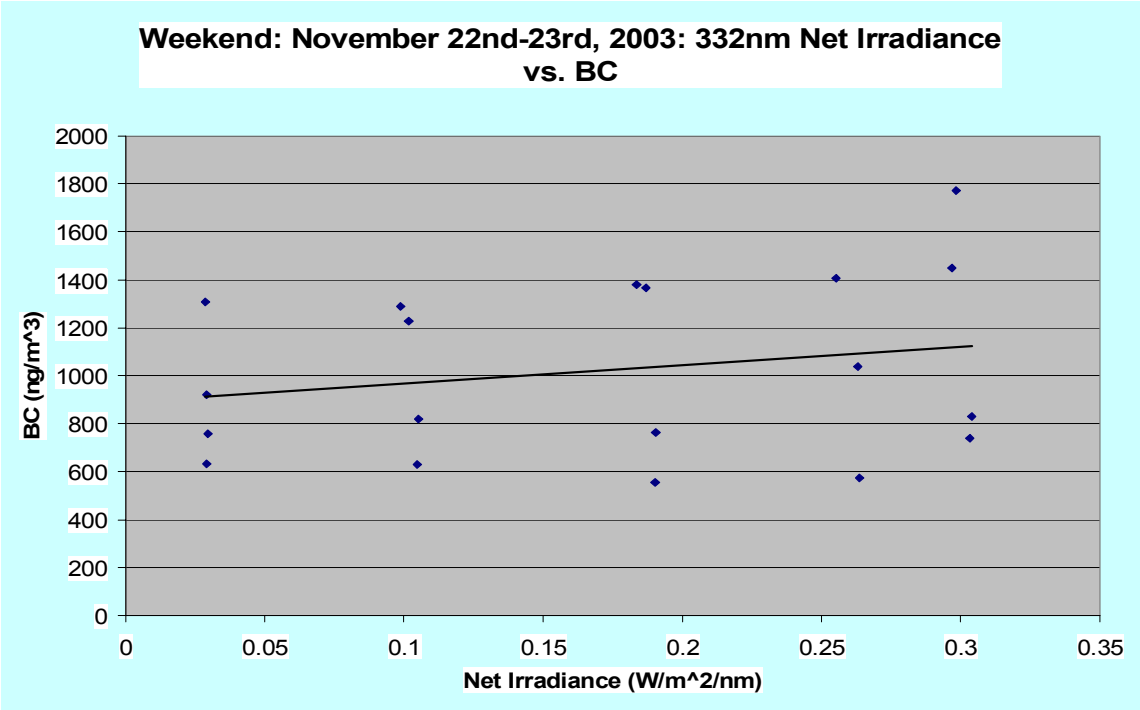

Figure 143. November 2003 Weekend 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

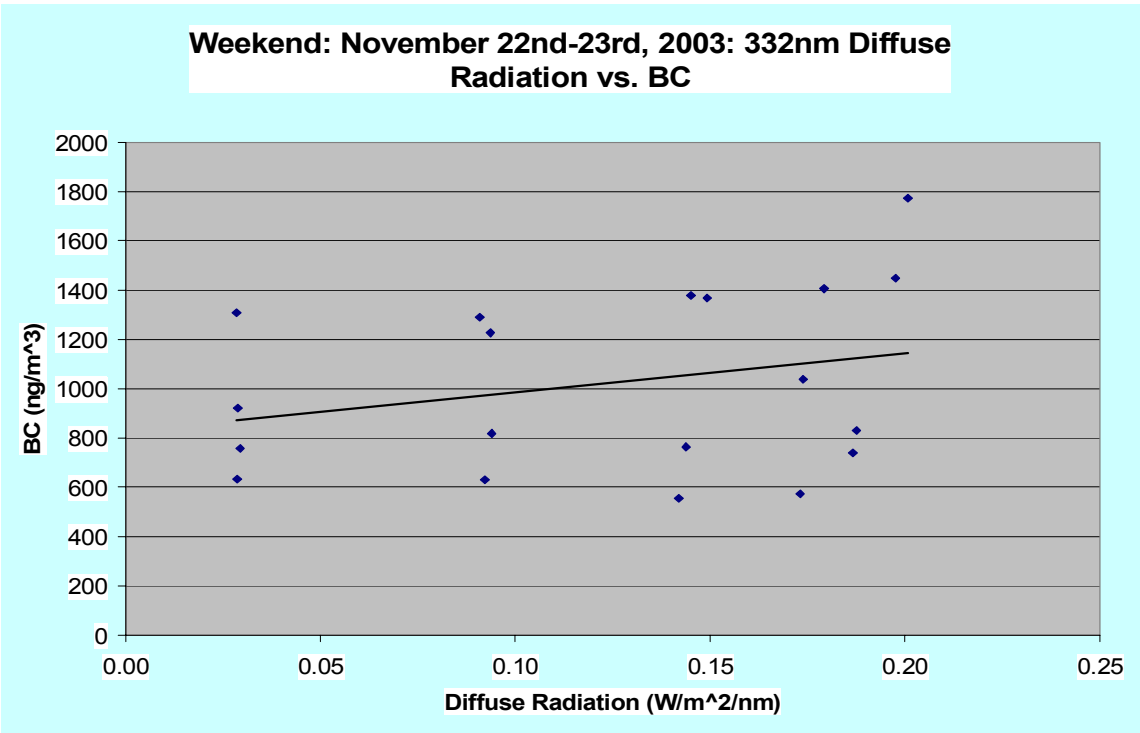

Figure 144. November 2003 Weekend 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

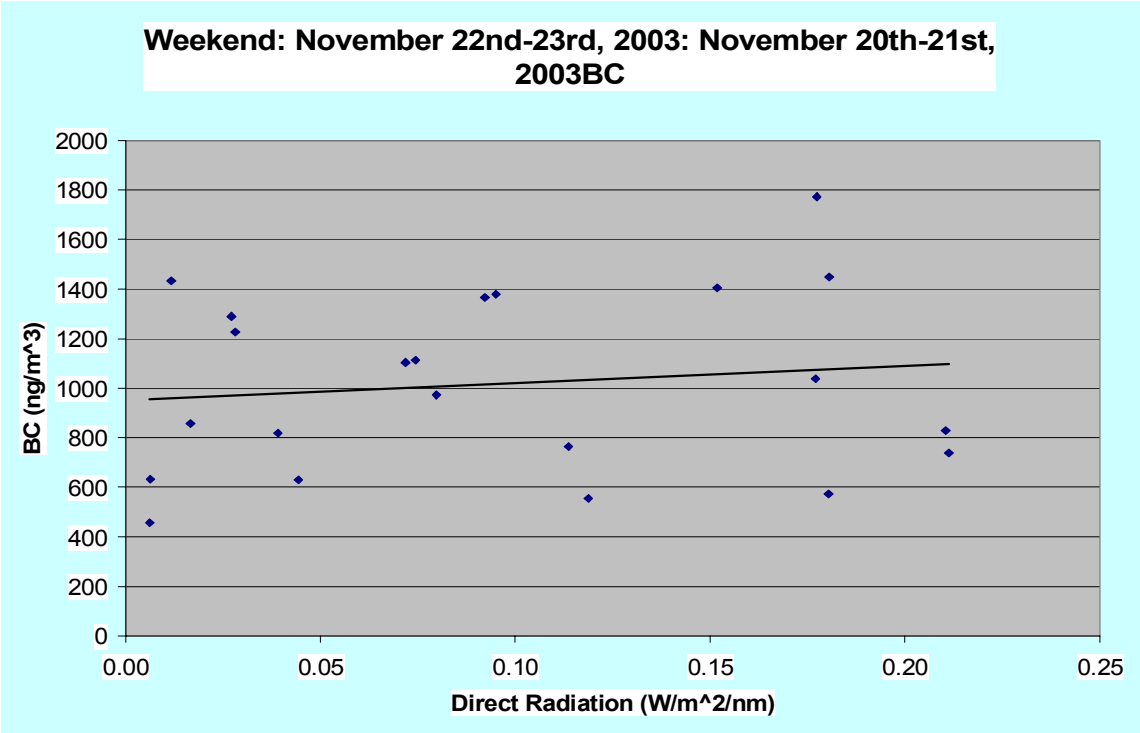

Figure 145. November 2003 Weekend 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

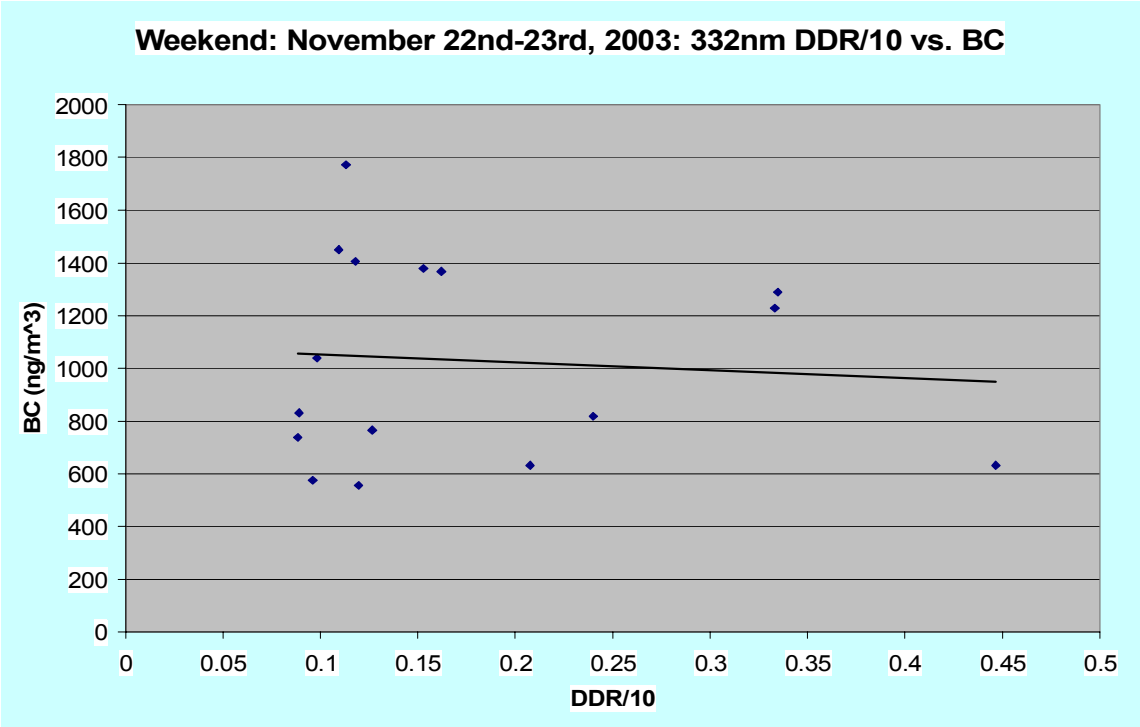

Figure 146. November 2003 Weekend 332nm DDR/10 vs. BC Concentrations (ng/m^3)

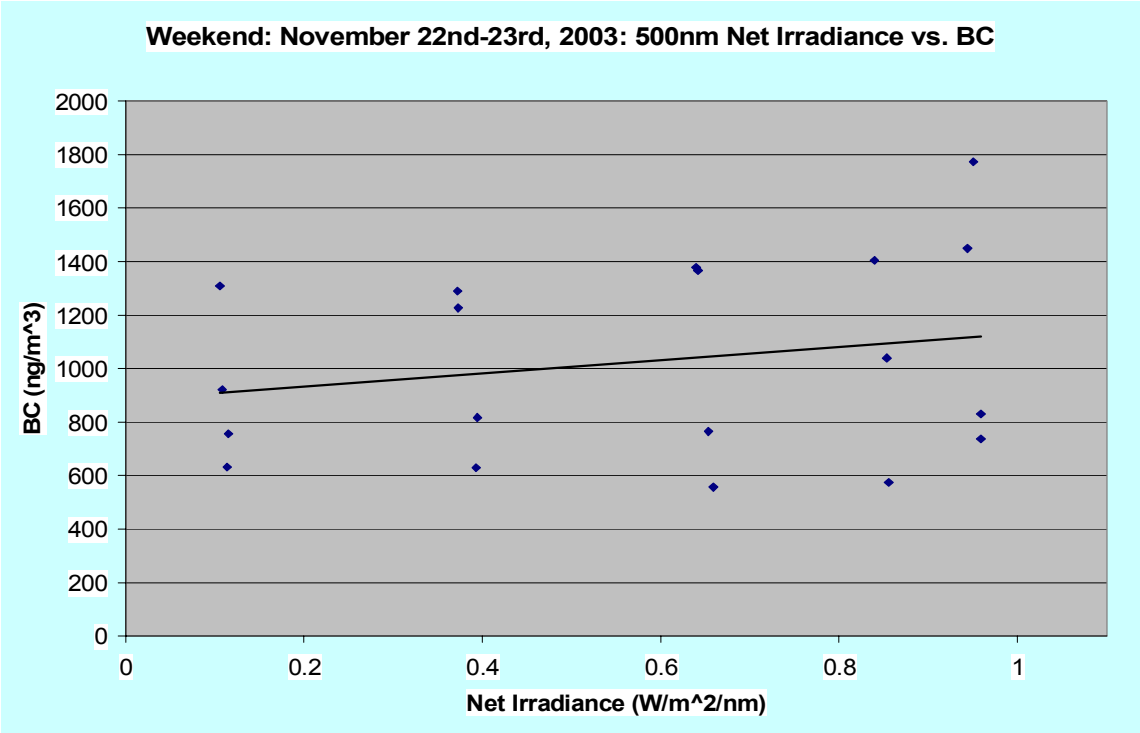

Figure 147. November 2003 Weekend 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

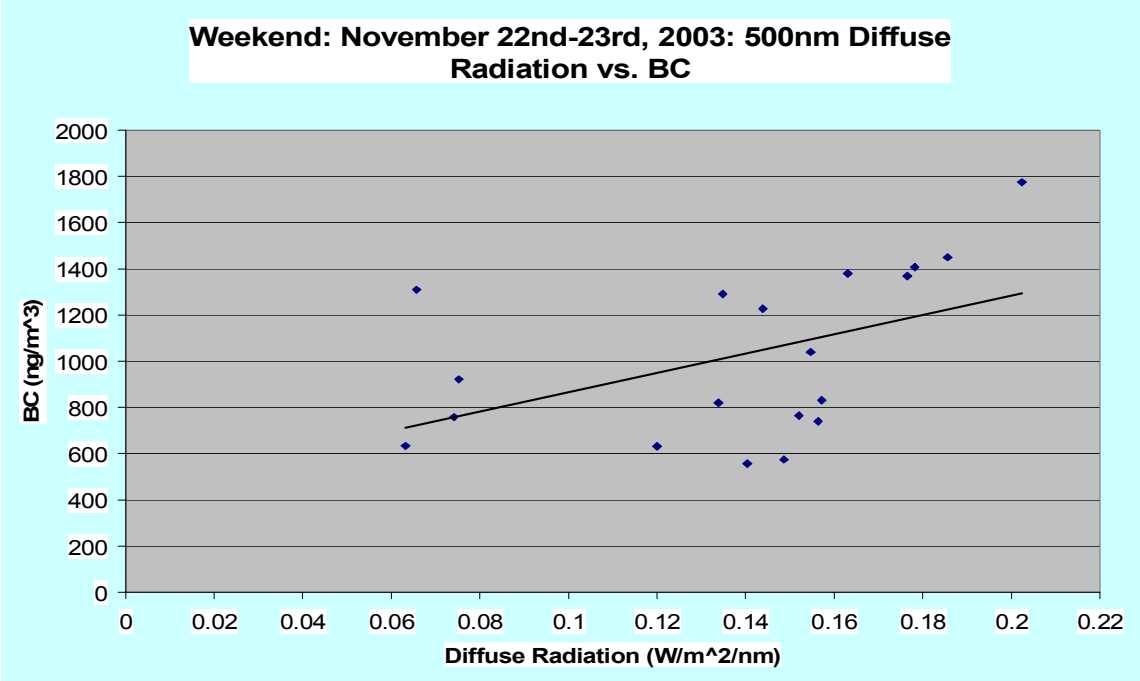

Figure 148. November 2003 Weekend 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

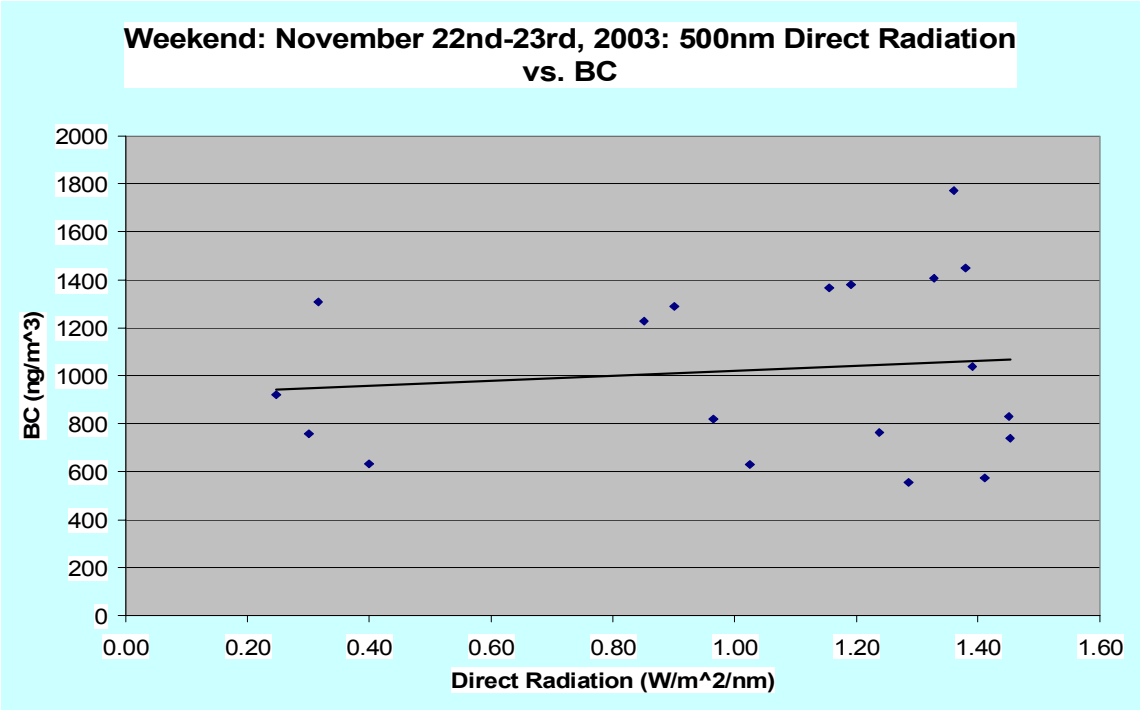

Figure 149. November 2003 Weekend 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

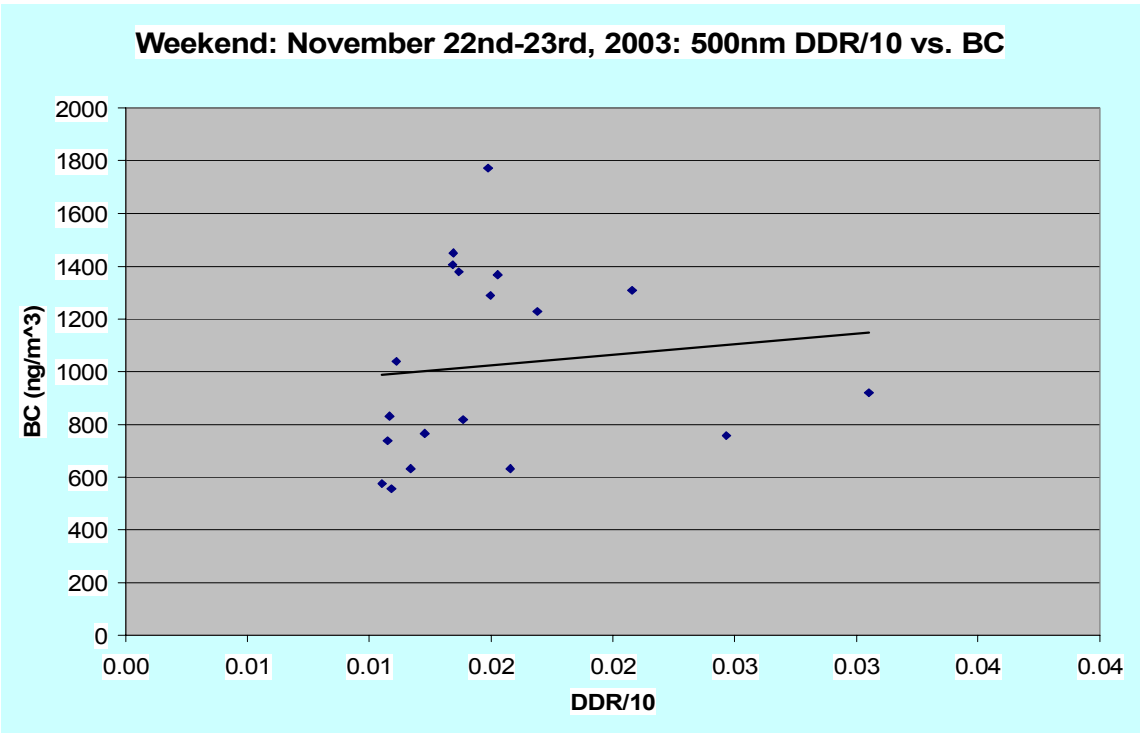

Figure 150. November 2003 Weekend 500nm DDR/10 vs. BC Concentrations (ng/m^3)

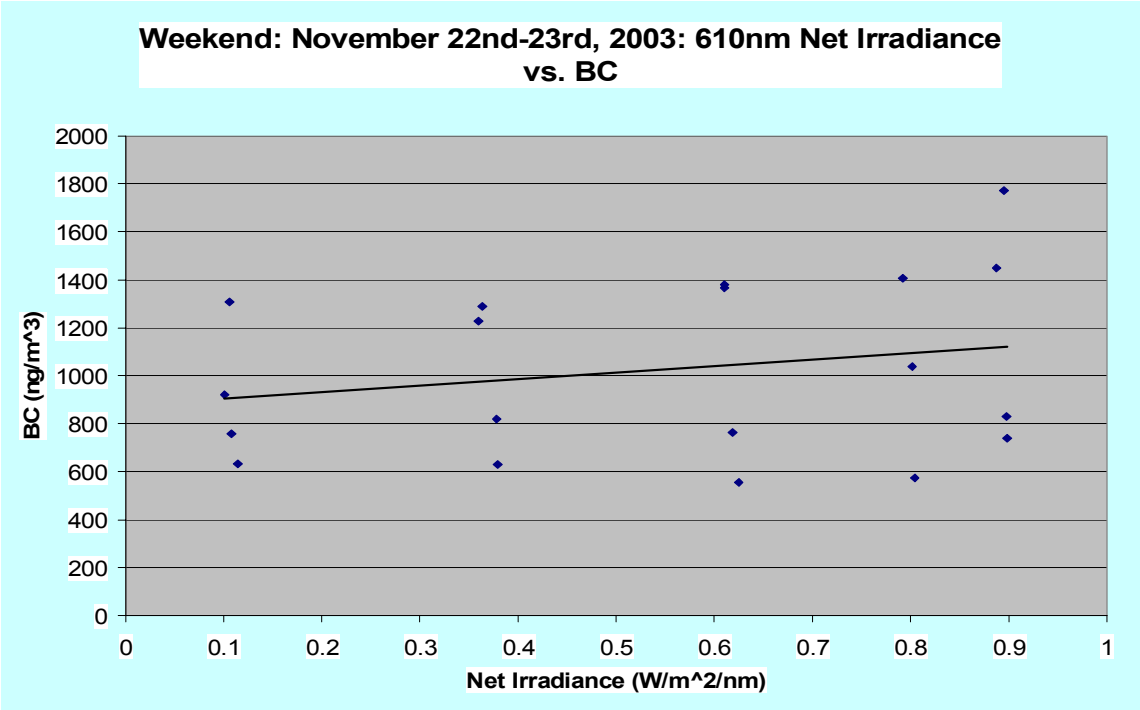

Figure 151. November 2003 Weekend 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

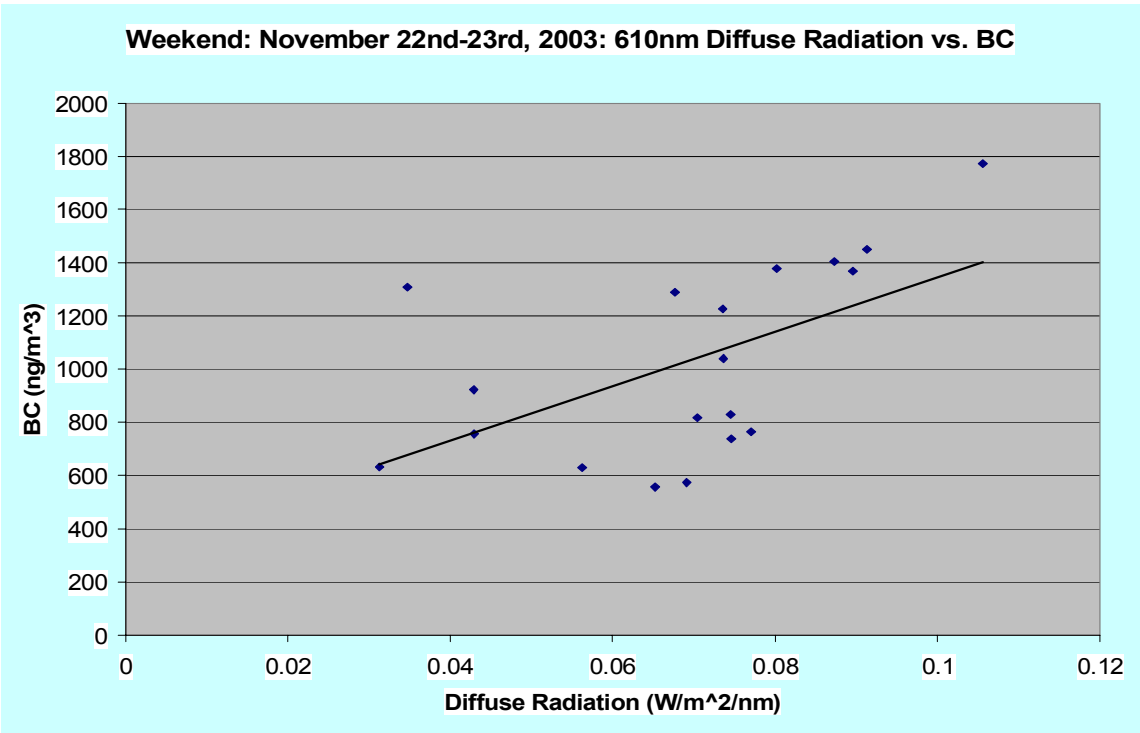

Figure 152. November 2003 Weekend 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

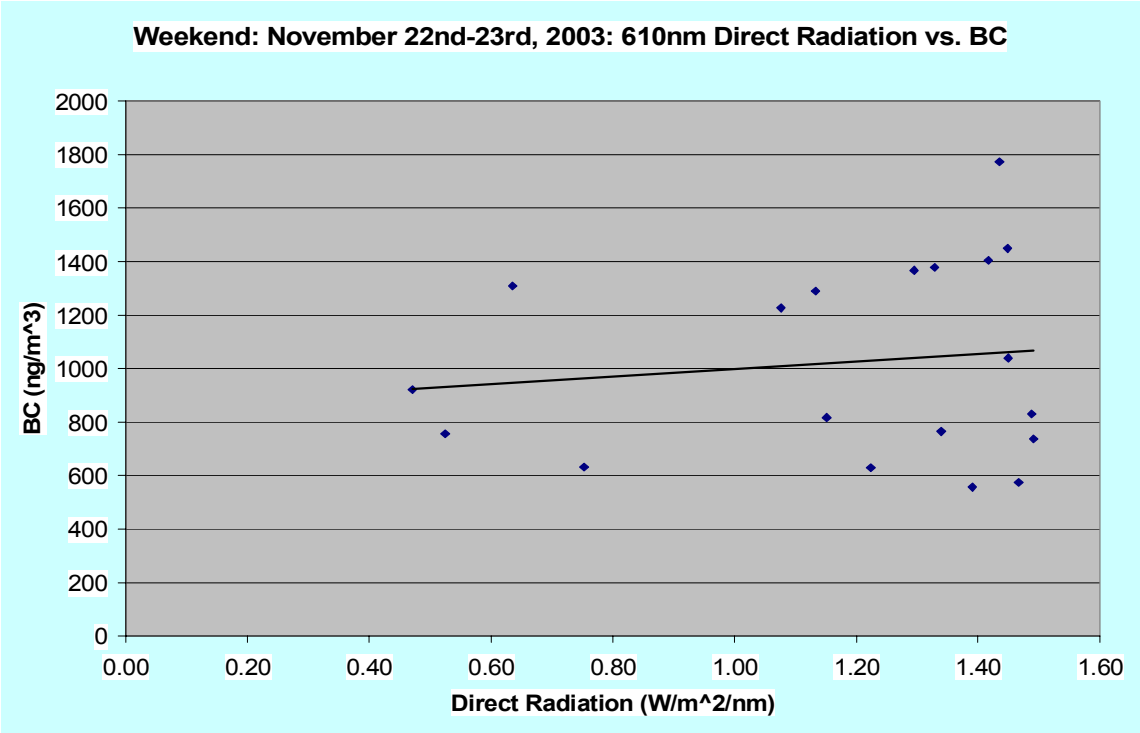

Figure 153. November 2003 Weekend 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

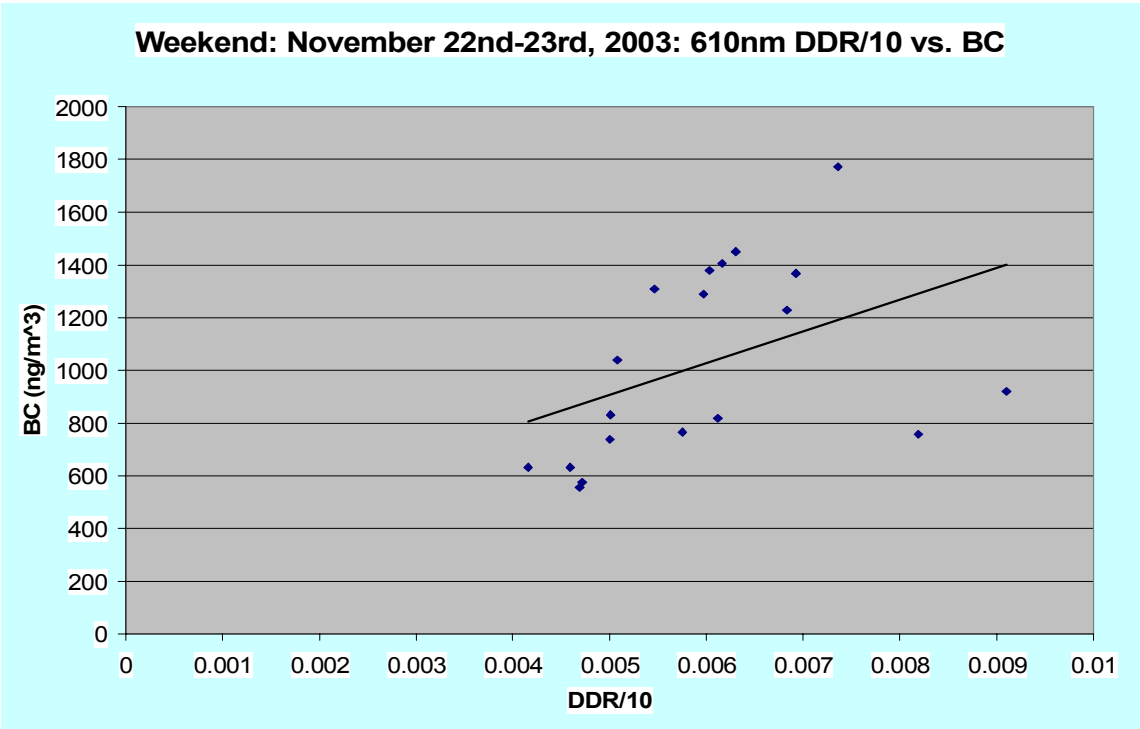

Figure 154. November 2003 Weekend 610nm DDR/10 vs. BC Concentrations (ng/m^3)

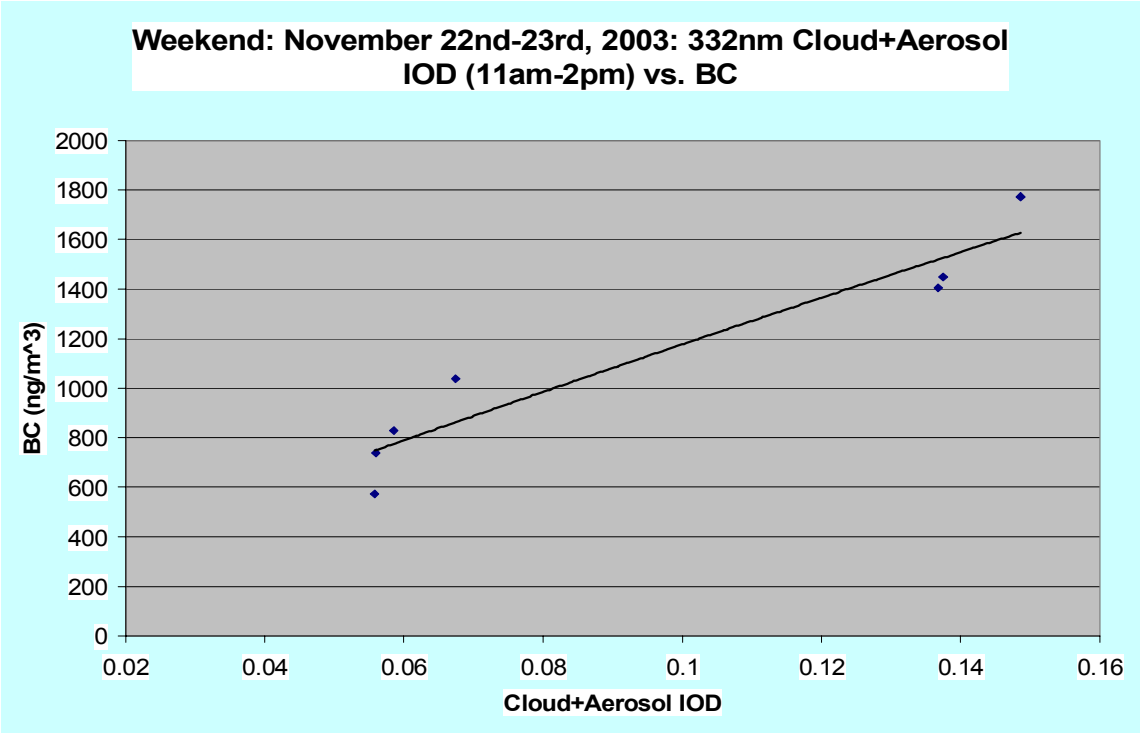

Figure 155. November 2003 Weekend 332nm Cloud+Aerosol IOD vs. BC (ng/m^3)

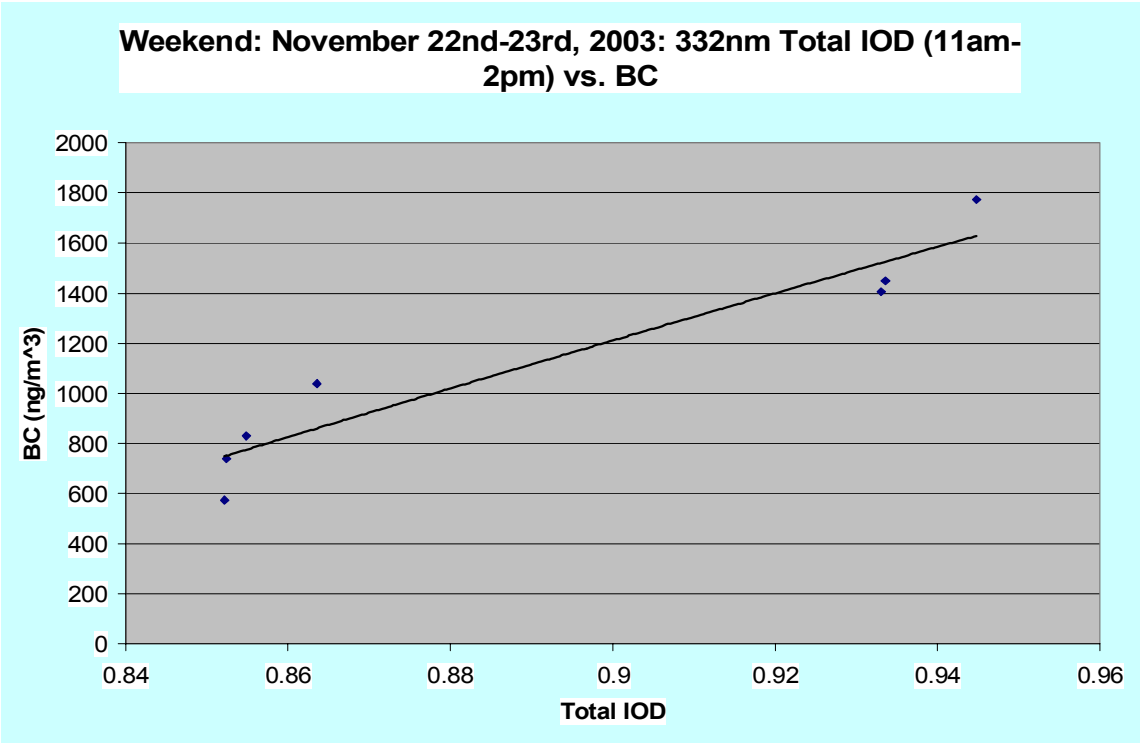

Figure 156. November 2003 Weekend 332nm Total IOD vs. BC (ng/m^3)

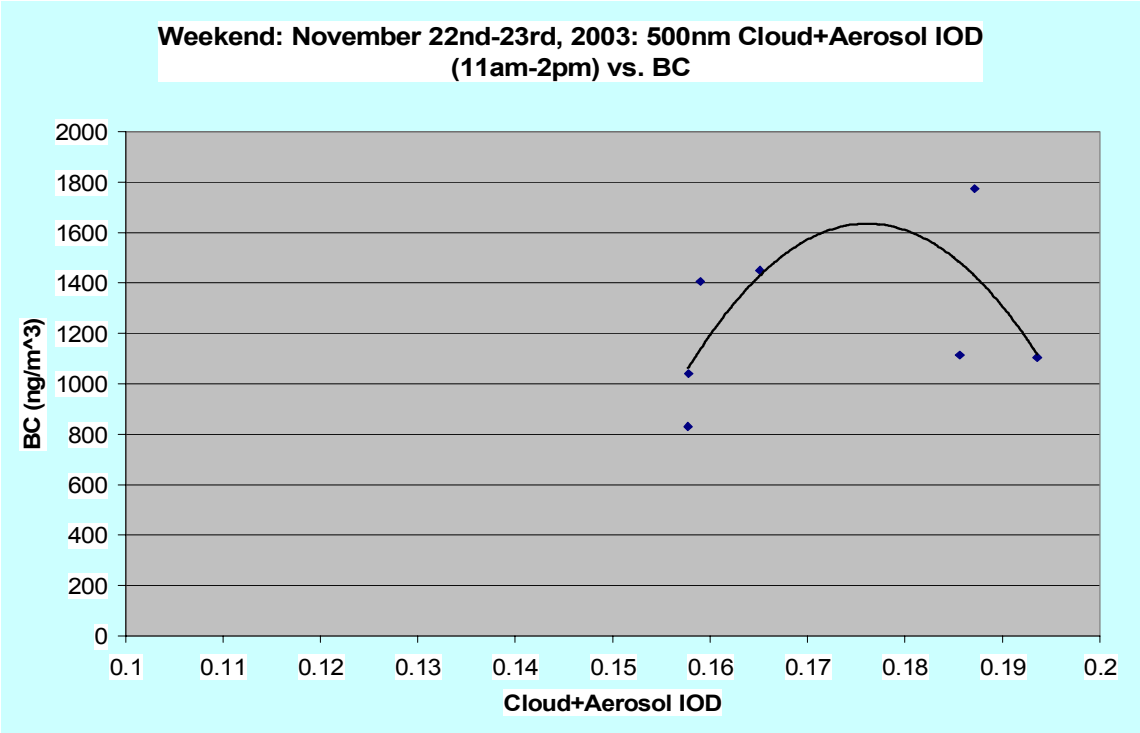

Figure 157. November 2003 Weekend 500nm Cloud+Aerosol IOD vs. BC (ng/m^3)

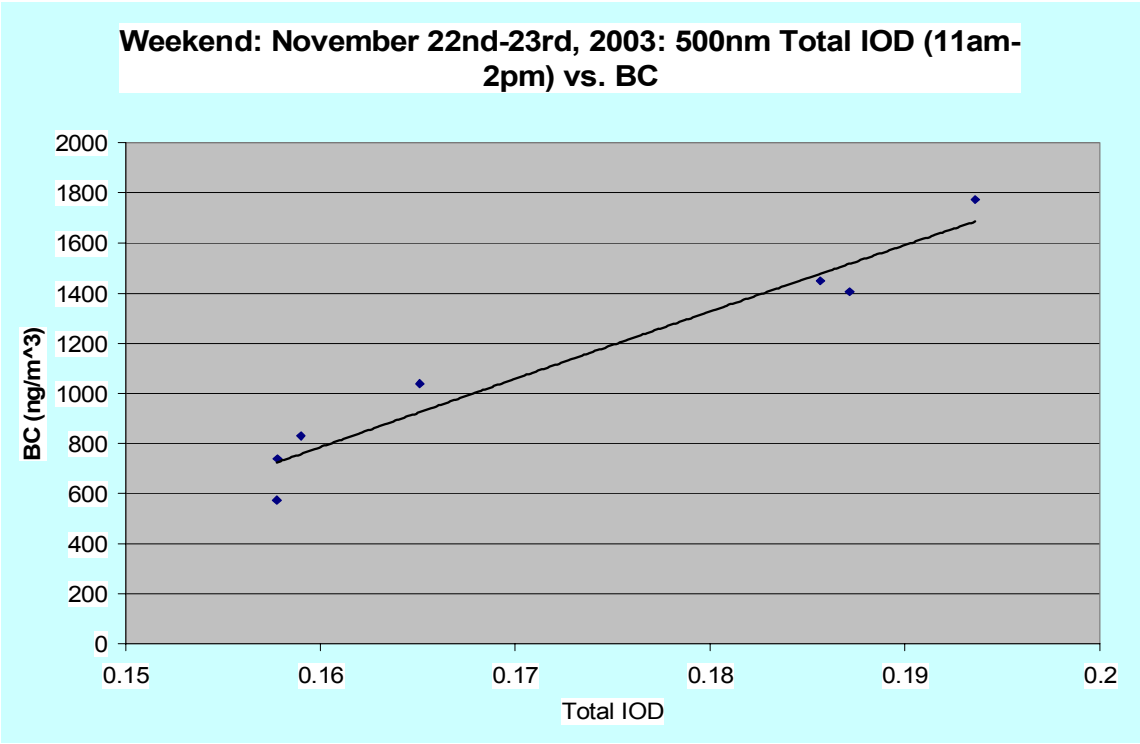

Figure 158. November 2003 Weekend 500nm Total IOD vs. BC (ng/m^3)

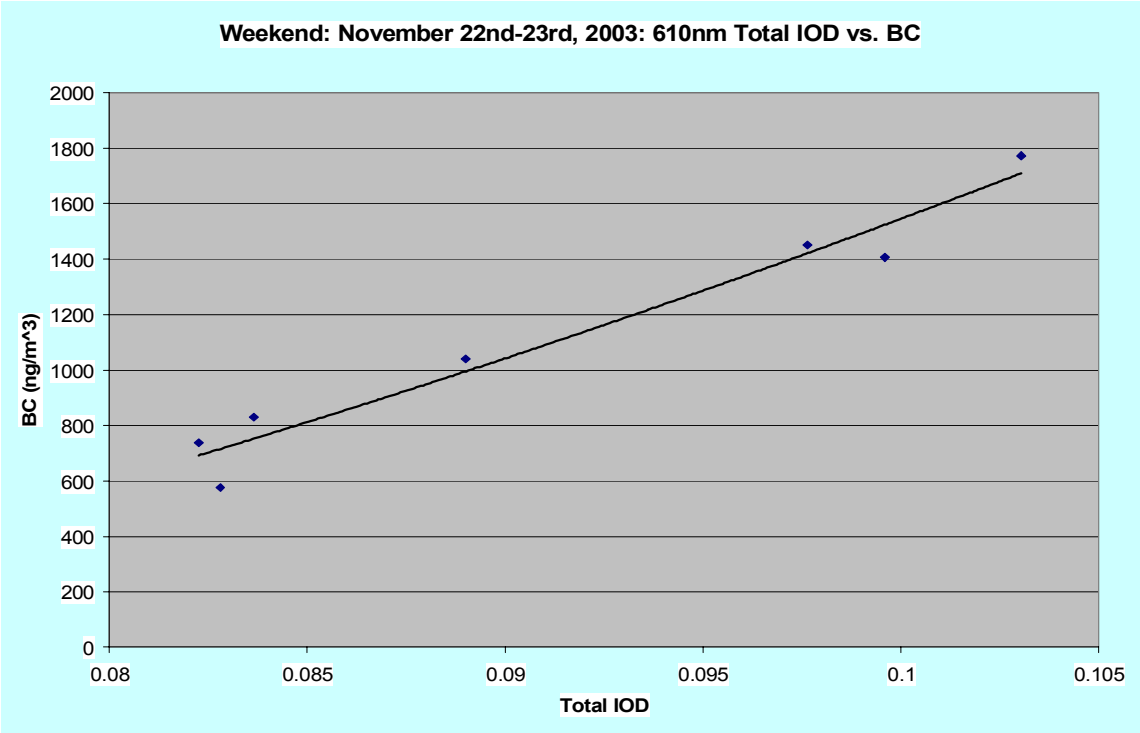

Figure 159. November 2003 Weekend 610nm Total IOD vs. BC (ng/m^3)

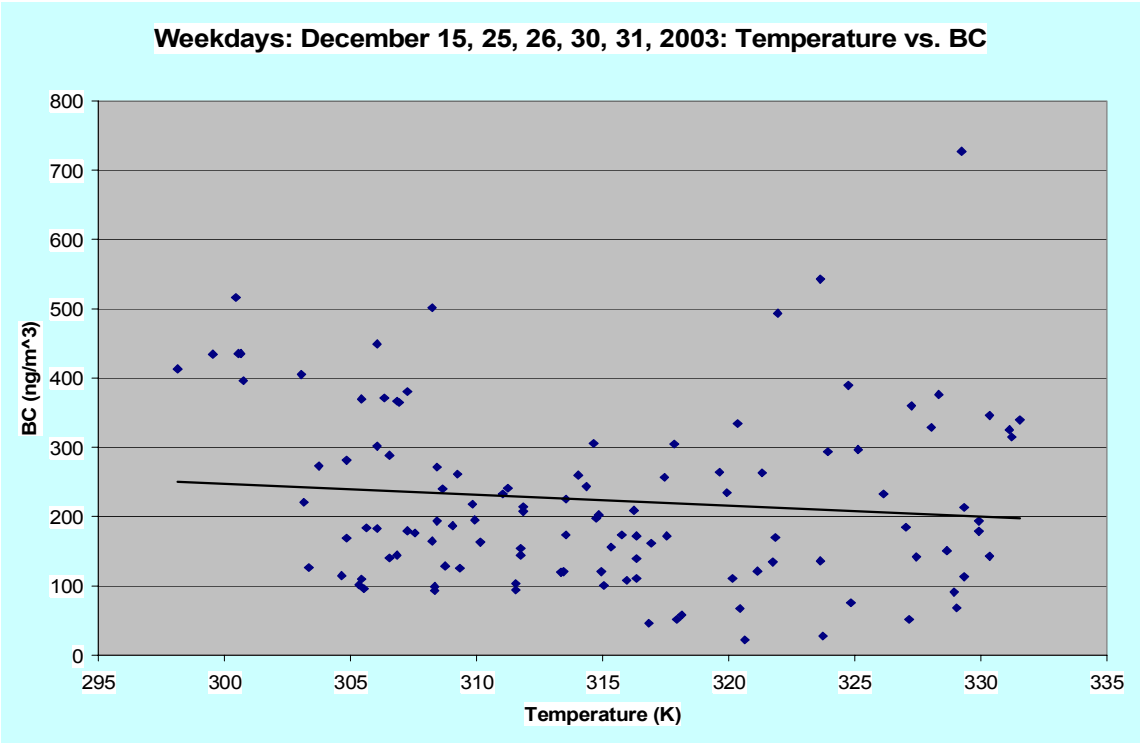

Figure 160. December 2003 Weekdays Temperature (K) vs. BC Concentrations (ng/m^3)

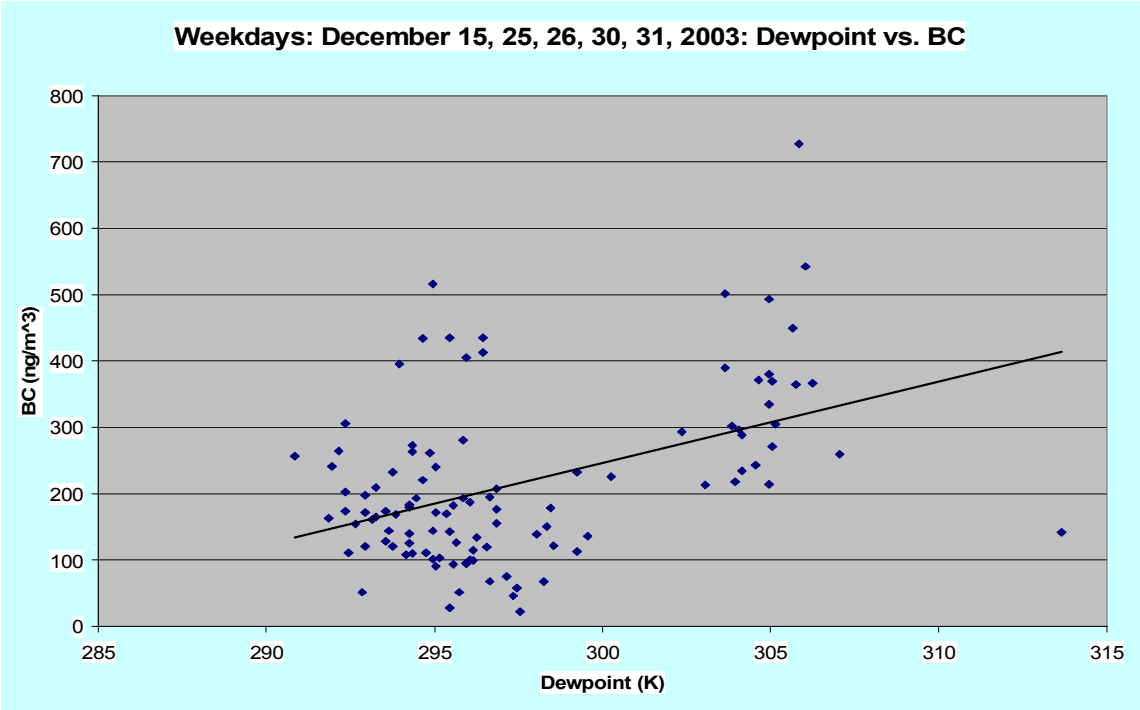

Figure 161. December 2003 Weekdays Dewpooint (K) vs. BC Concentrations (ng/m^3)

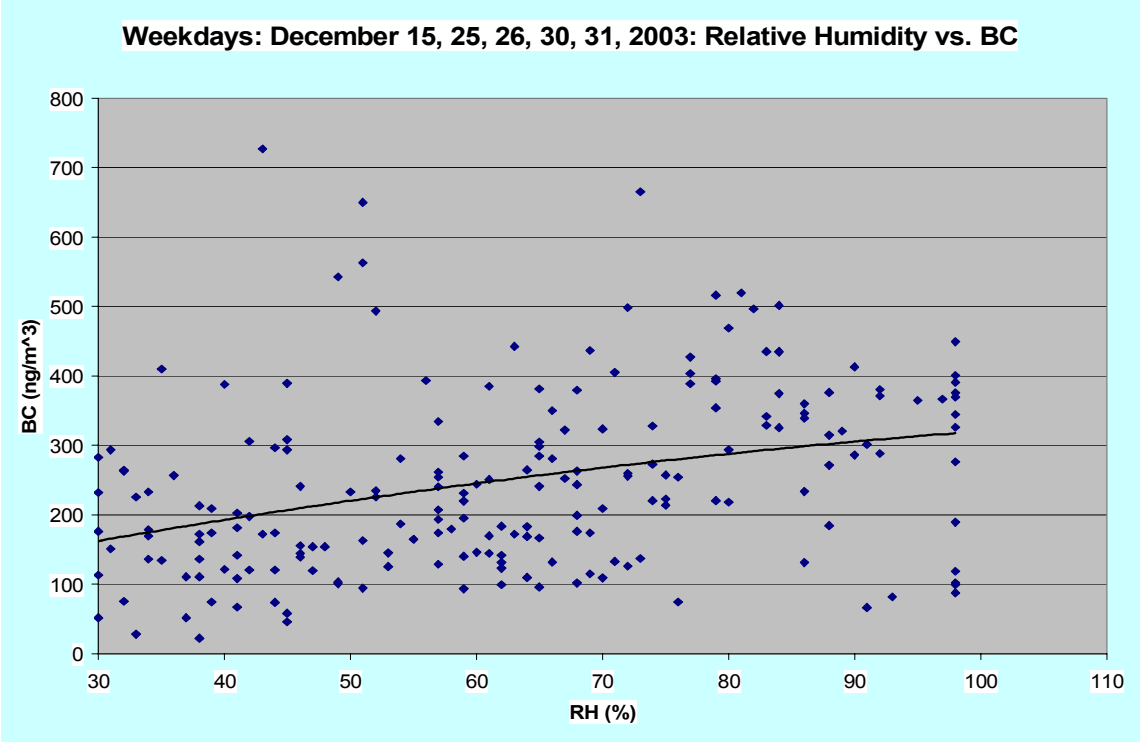

Figure 162. December 2003 Weekdays Relative Humidity (%) vs. BC Concentrations (ng/m^3)

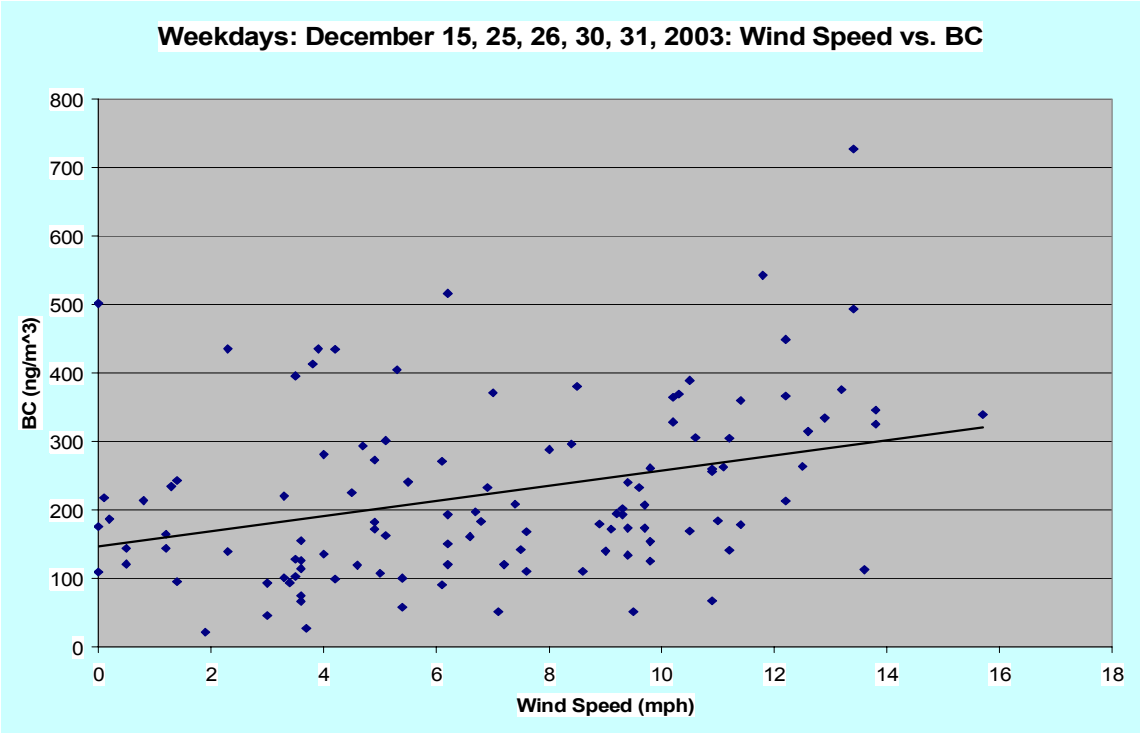

Figure 163. December 2003 Weekdays Wind Speed (mph) vs. BC Concentrations (ng/m^3)

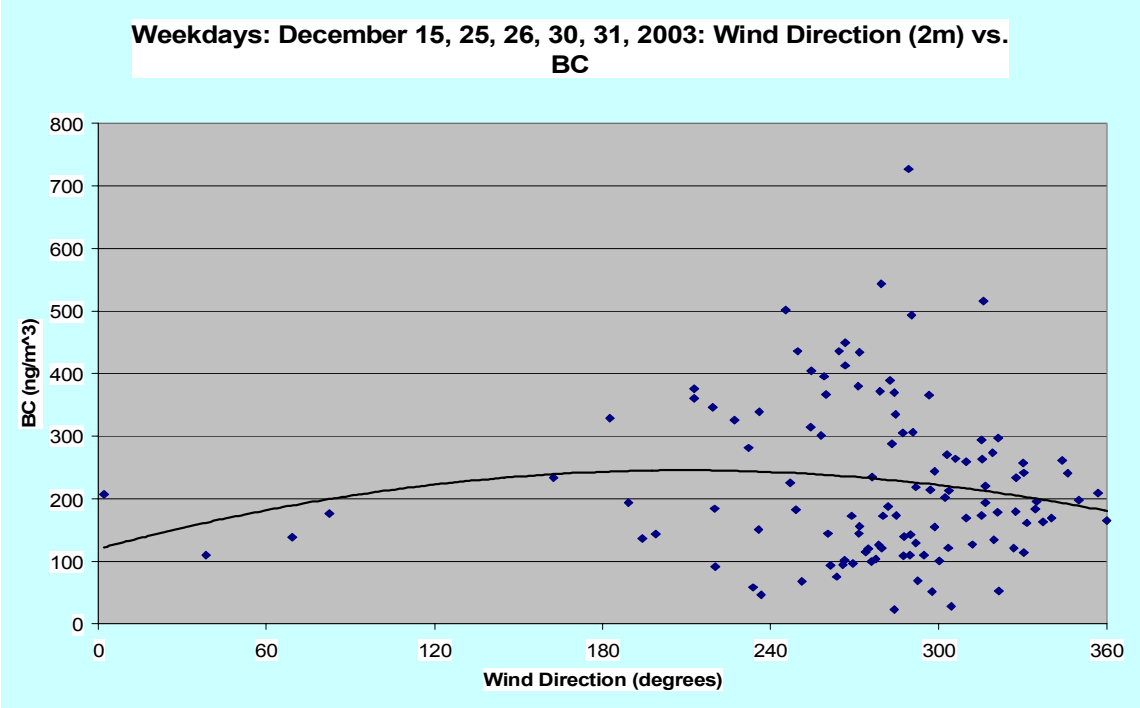

Figure 164. December 2003 Weekdays Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

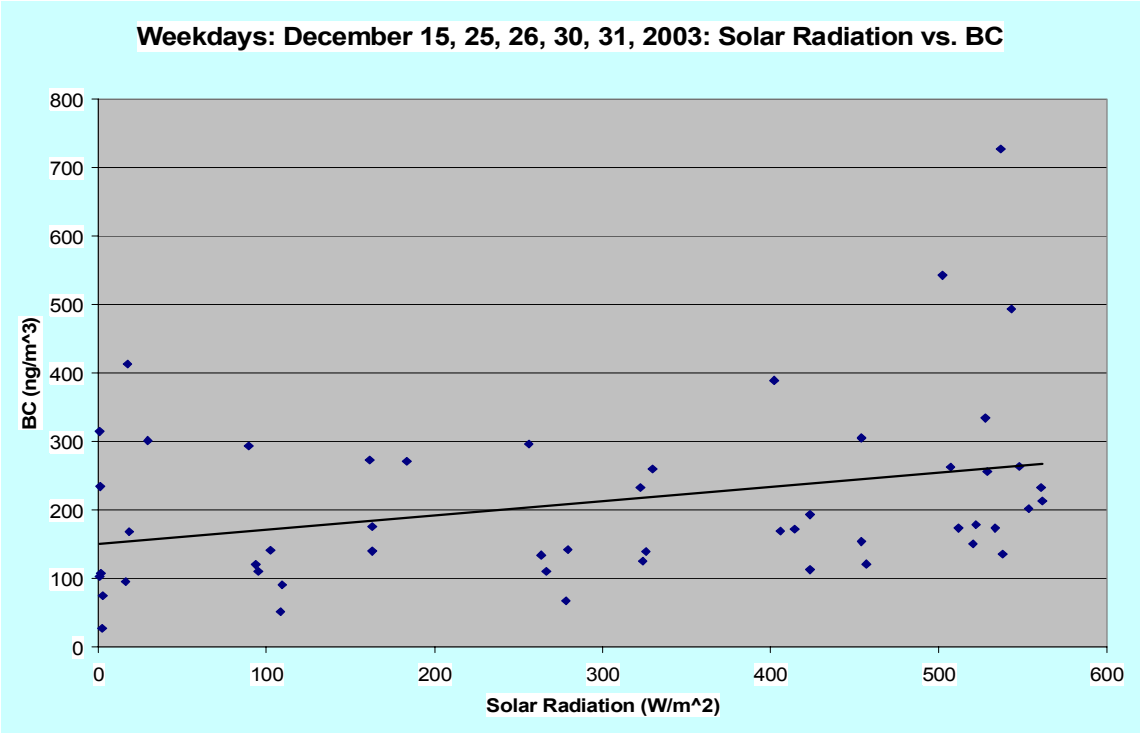

Figure 165. December 2003 Weekdays Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

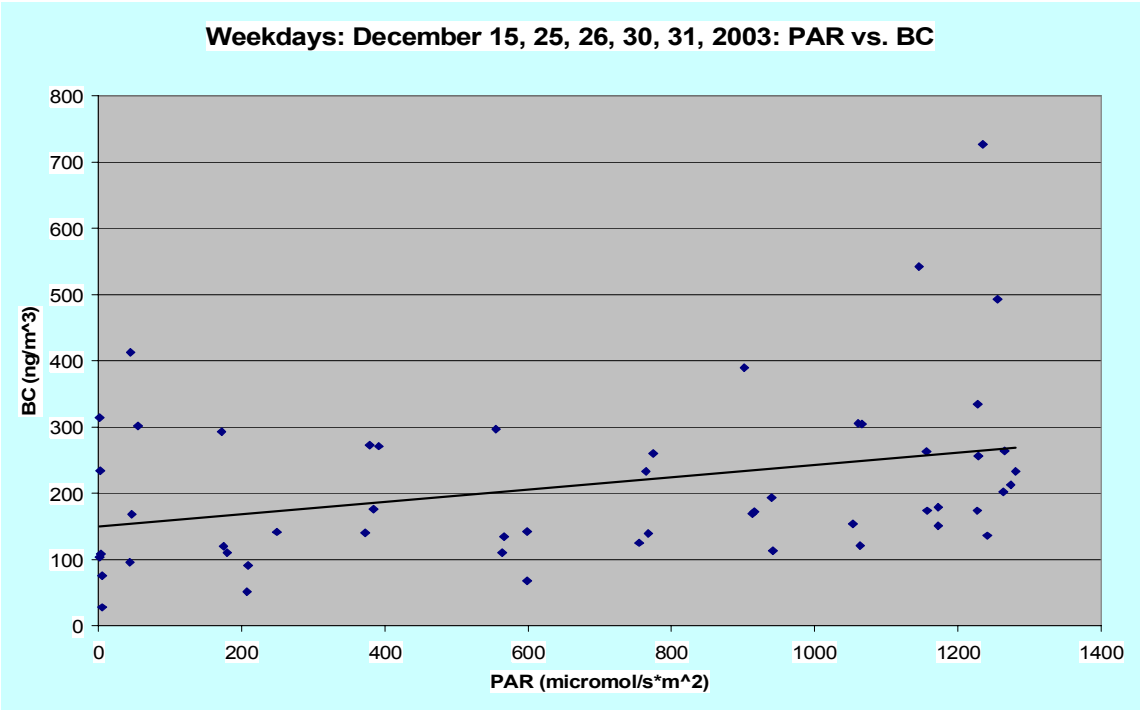

Figure 166. December 2003 Weekdays PAR (micromol/s*m^2) vs. BC Concentrations (ng/m^3)

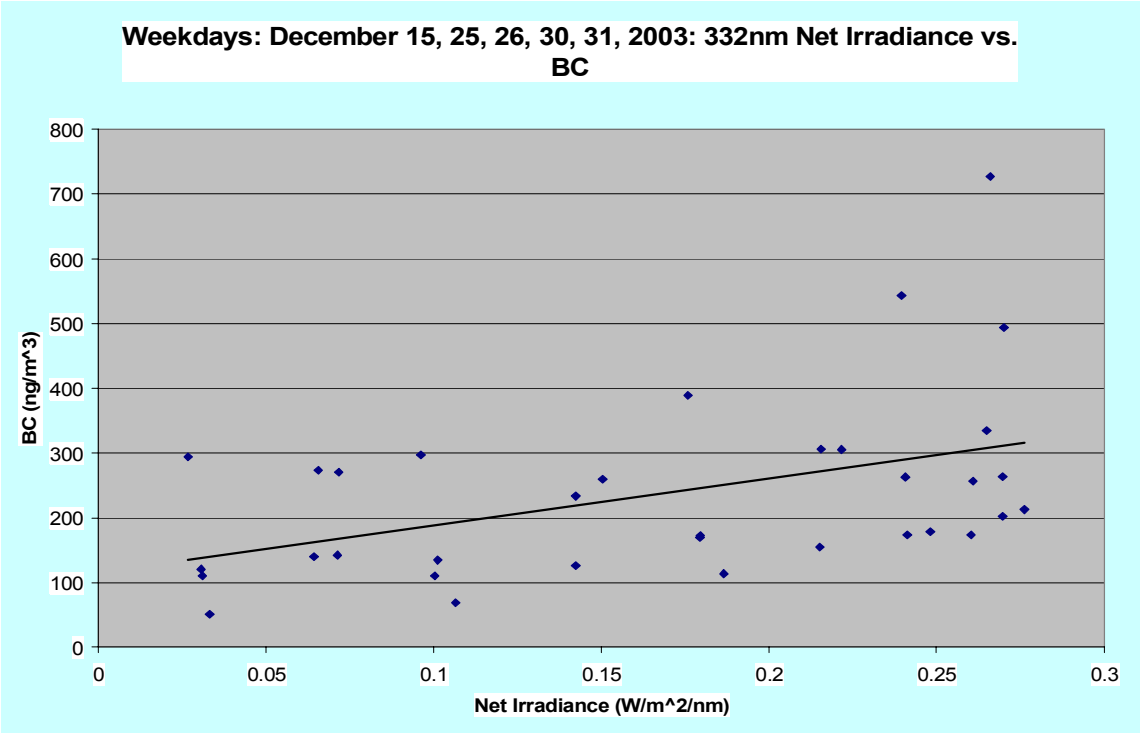

Figure 167. December 2003 Weekdays 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

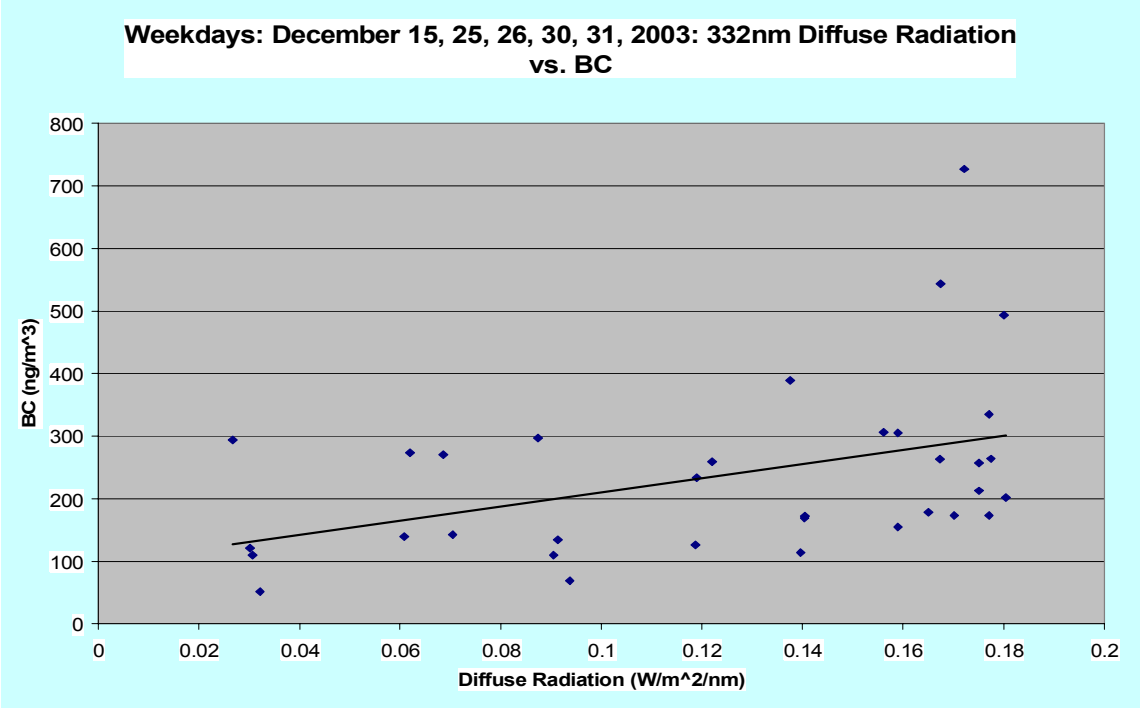

Figure 168. December 2003 Weekdays 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

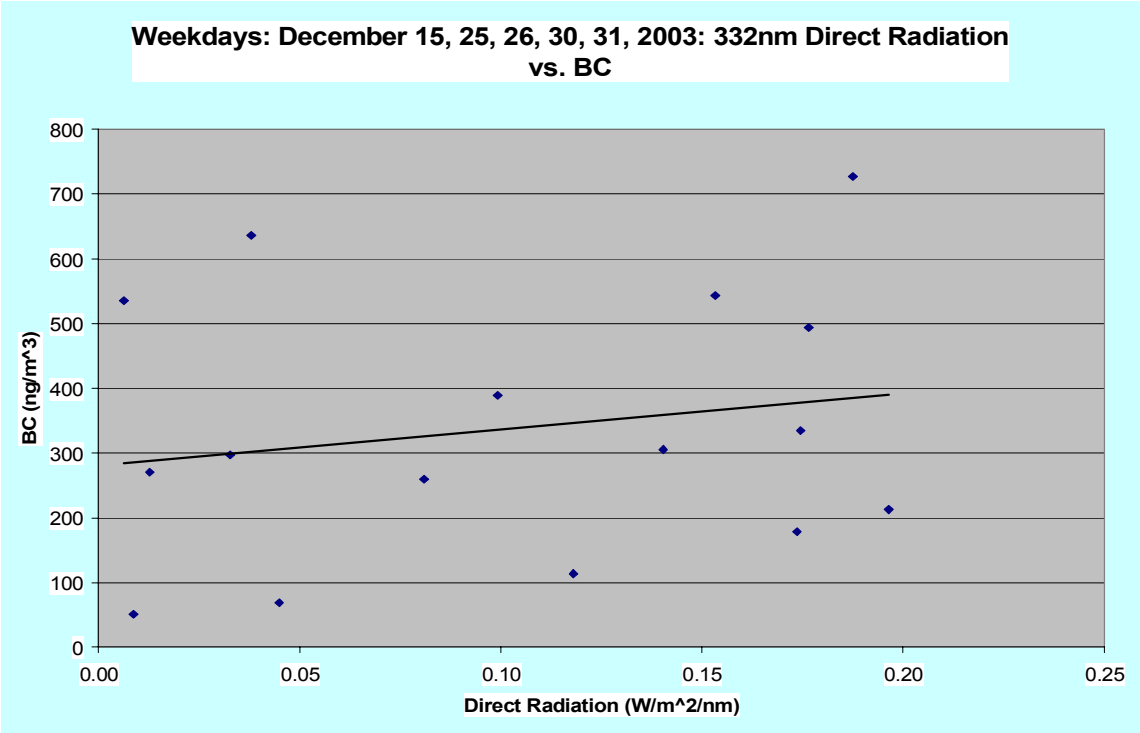

Figure 169. December 2003 Weekdays 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

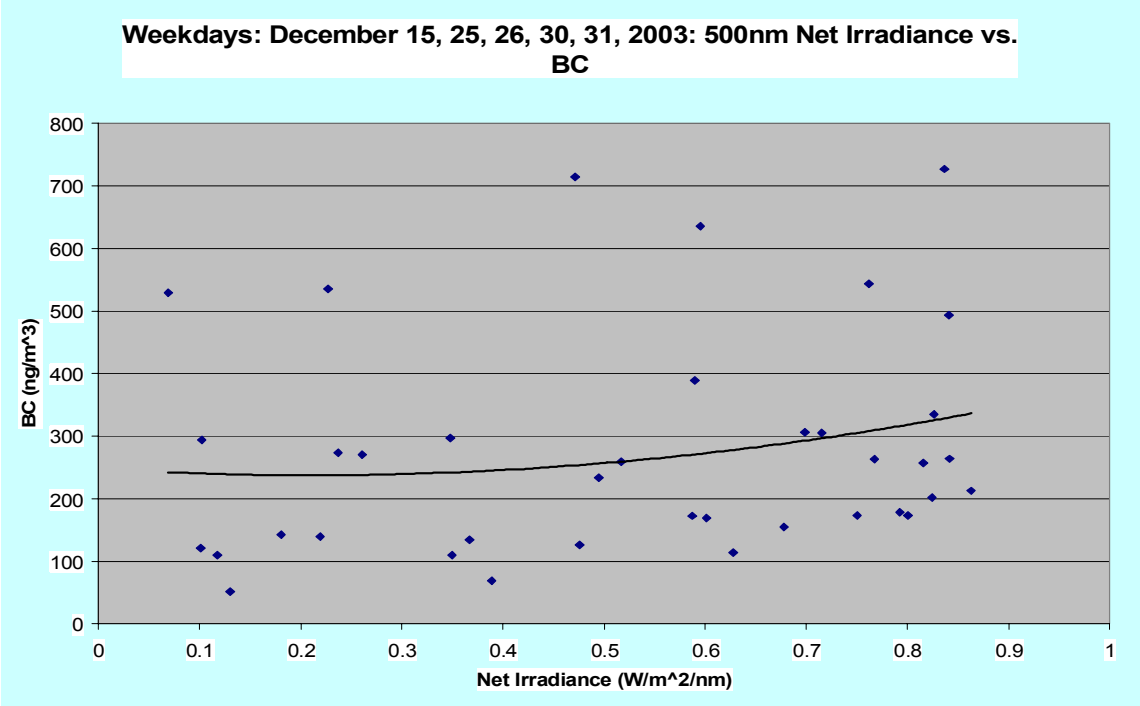

Figure 170. December 2003 Weekdays 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

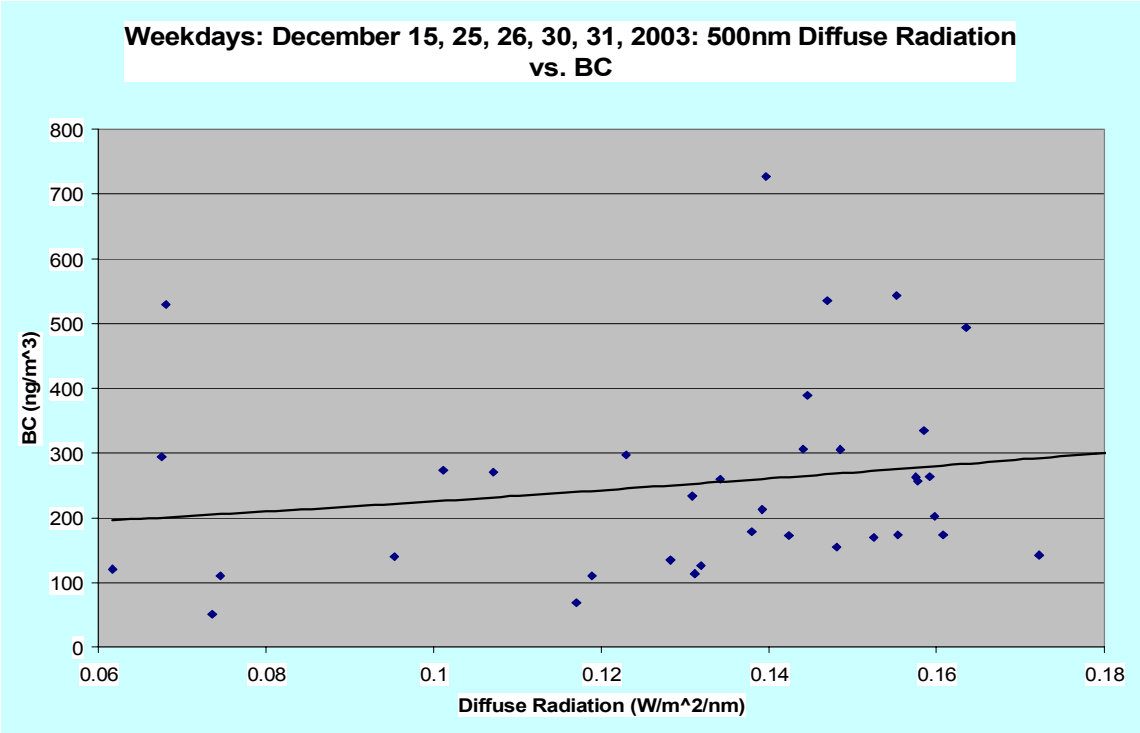

Figure 171. December 2003 Weekdays 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

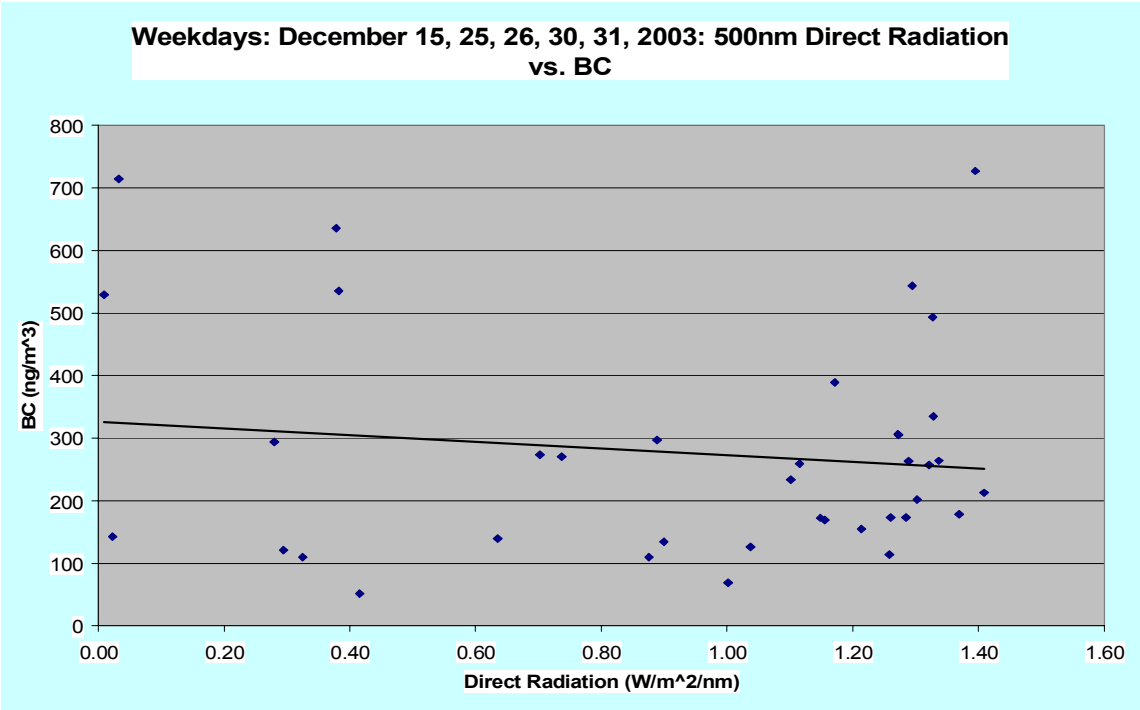

Figure 172. December 2003 Weekdays 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

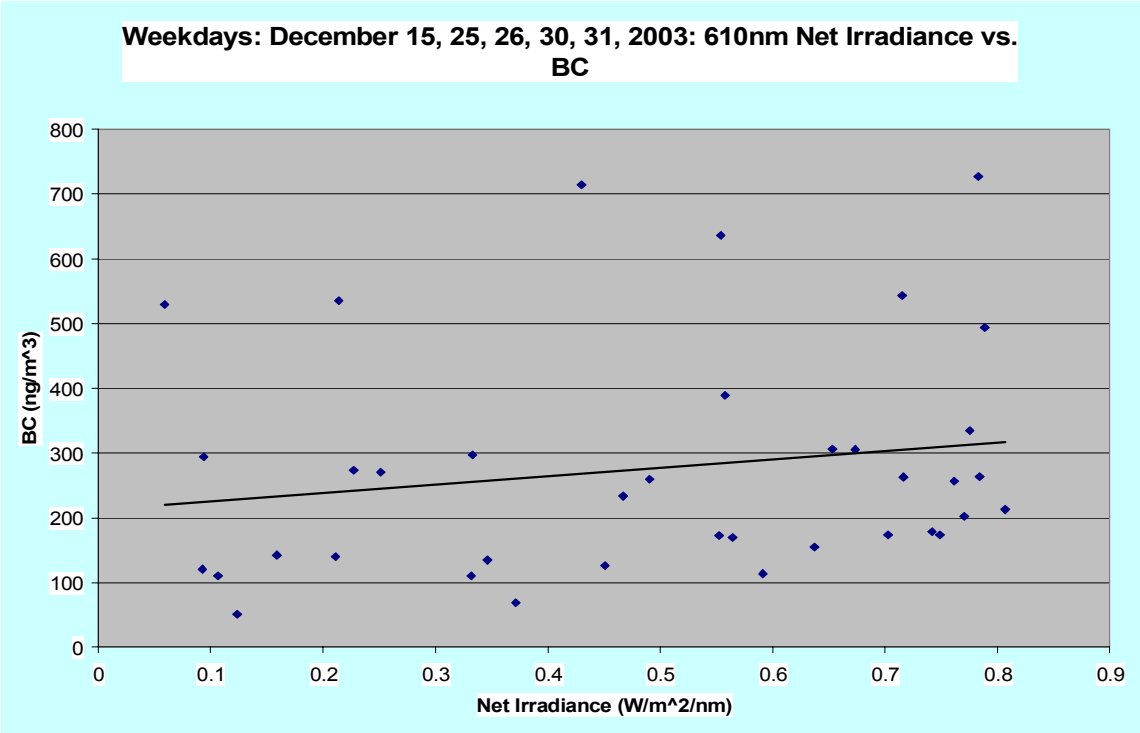

Figure 173. December 2003 Weekdays 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

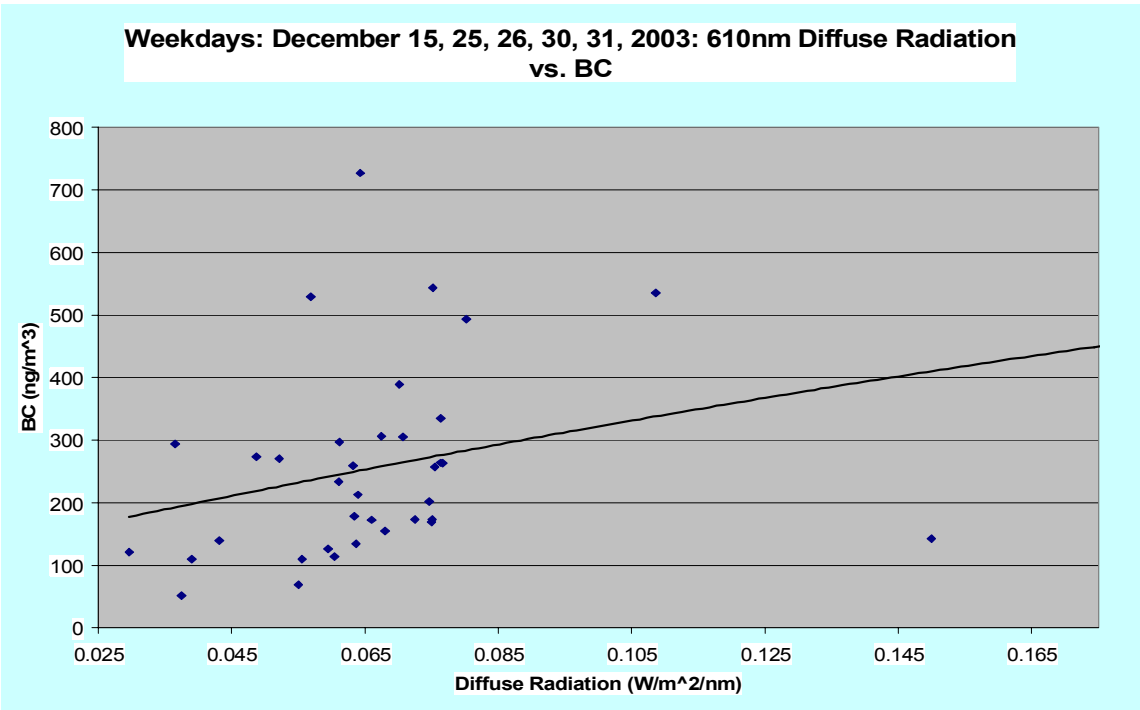

Figure 174. December 2003 Weekdays 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

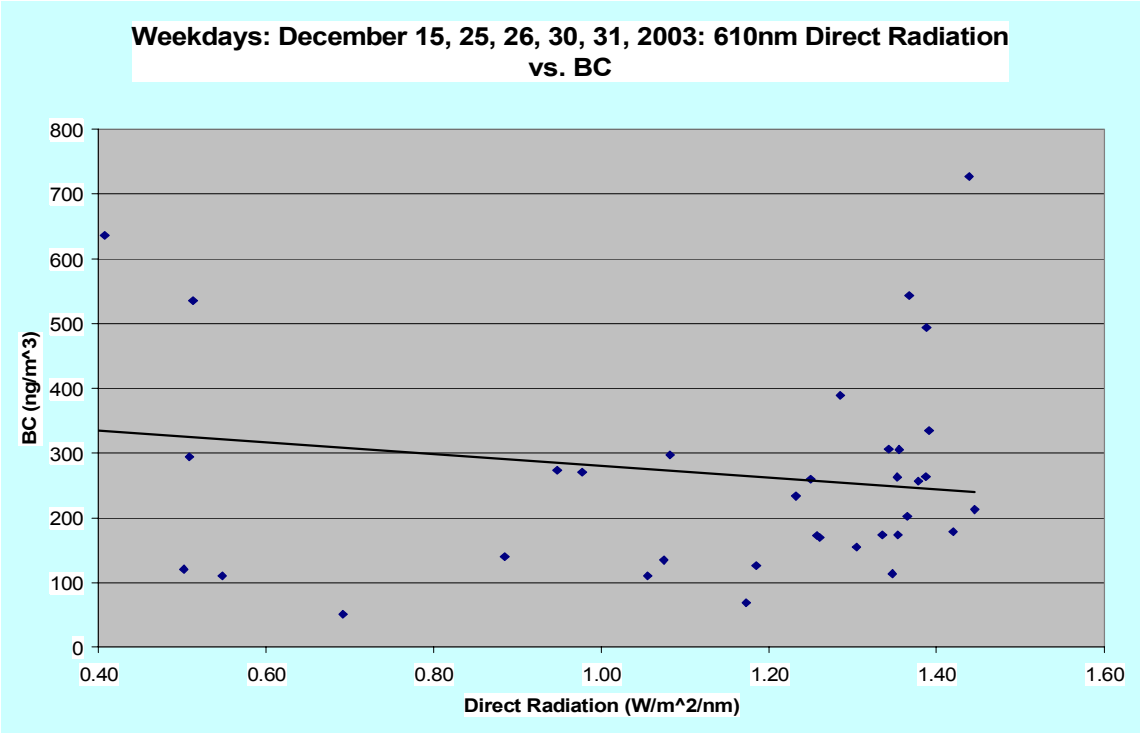

Figure 175. December 2003 Weekdays 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

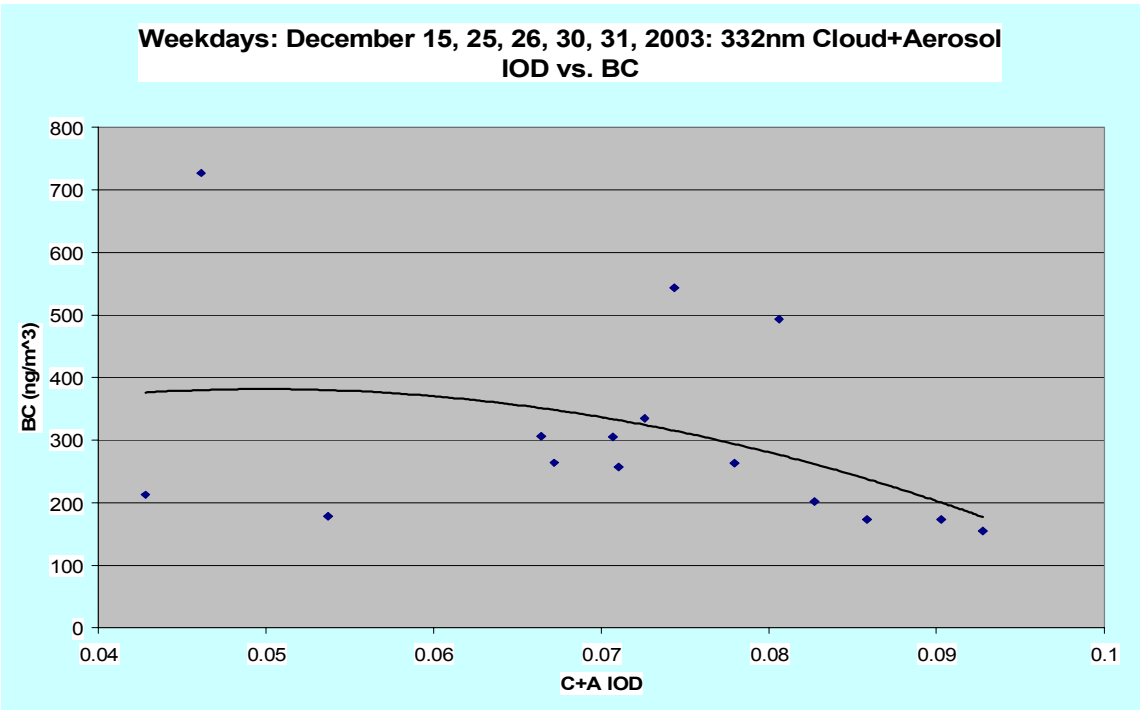

Figure 176. December 2003 Weekdays 332nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

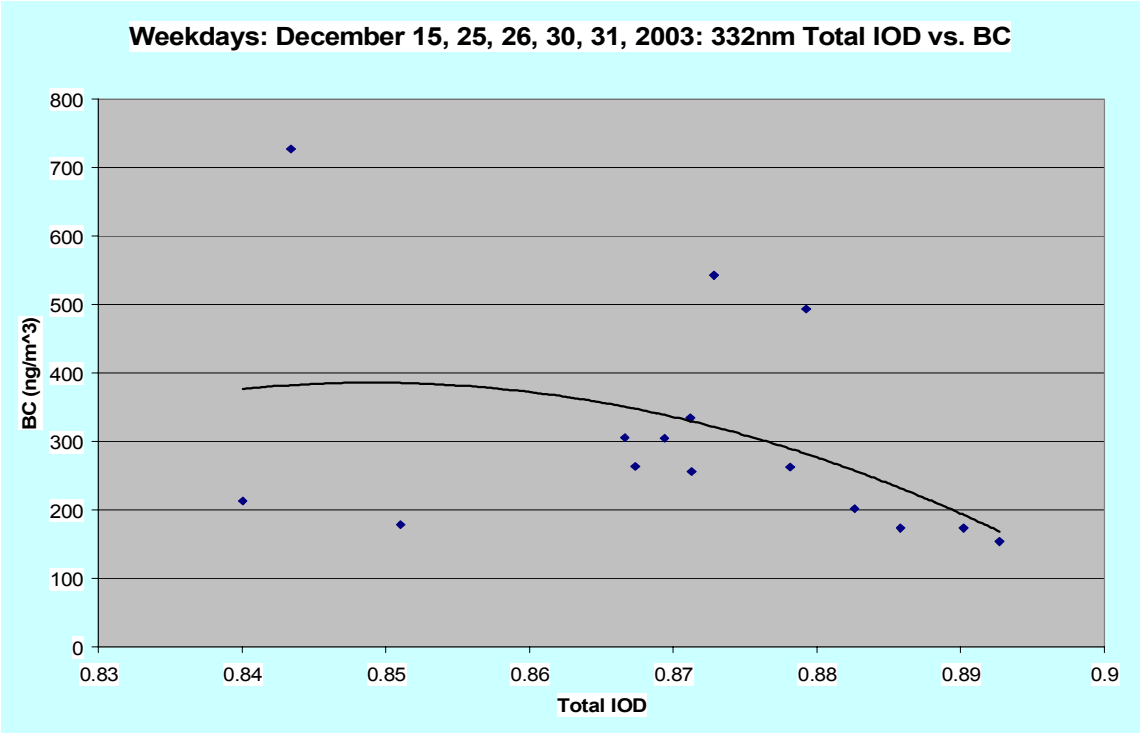

Figure 177. December 2003 Weekdays 332nm Total IOD vs. BC Concentrations (ng/m^3)

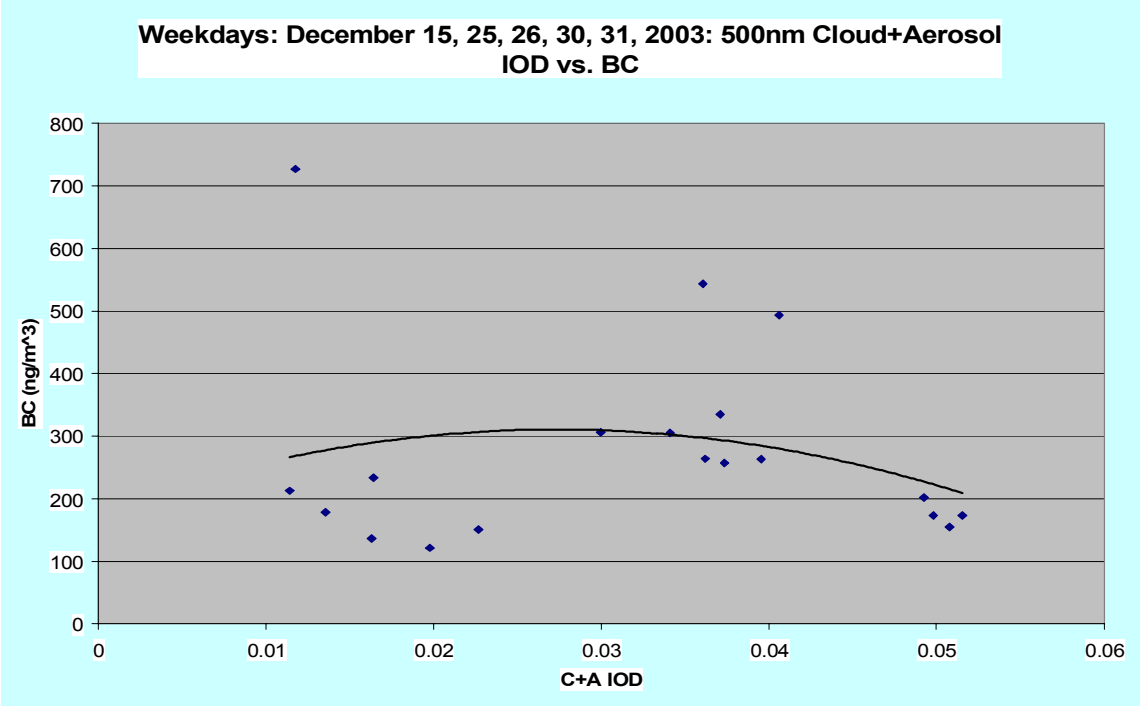

Figure 178. December 2003 Weekdays 500nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

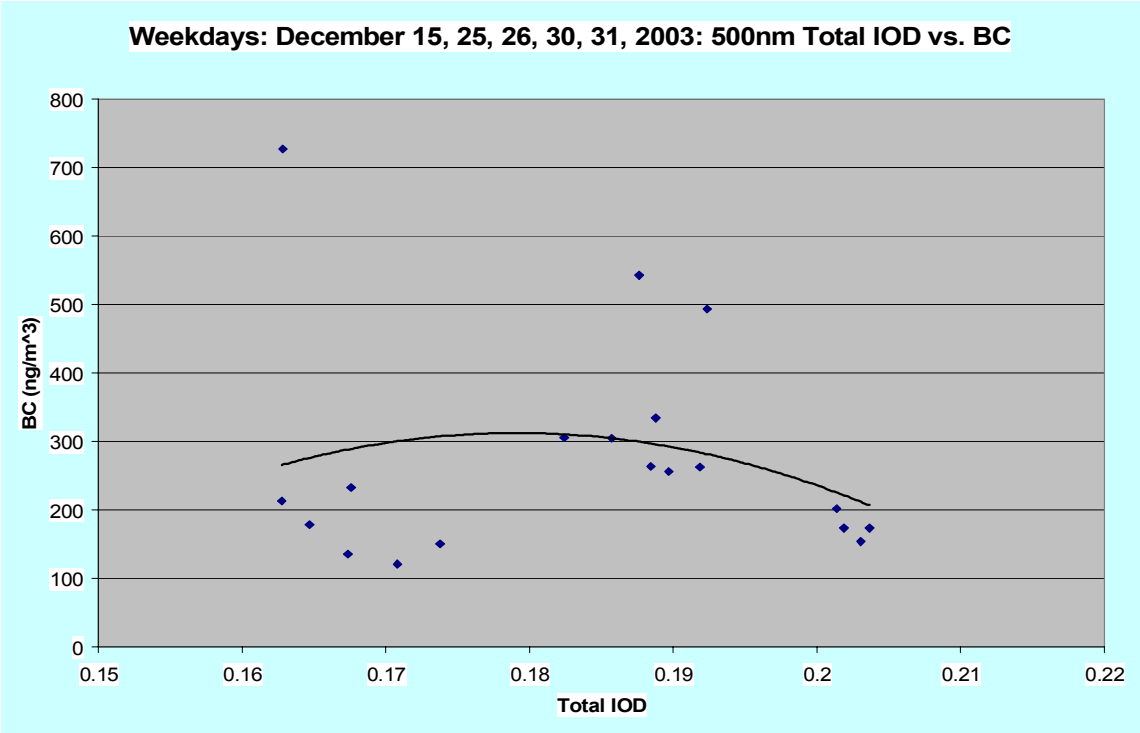

Figure 179. December 2003 Weekdays 500nm Total IOD vs. BC Concentrations (ng/m^3)

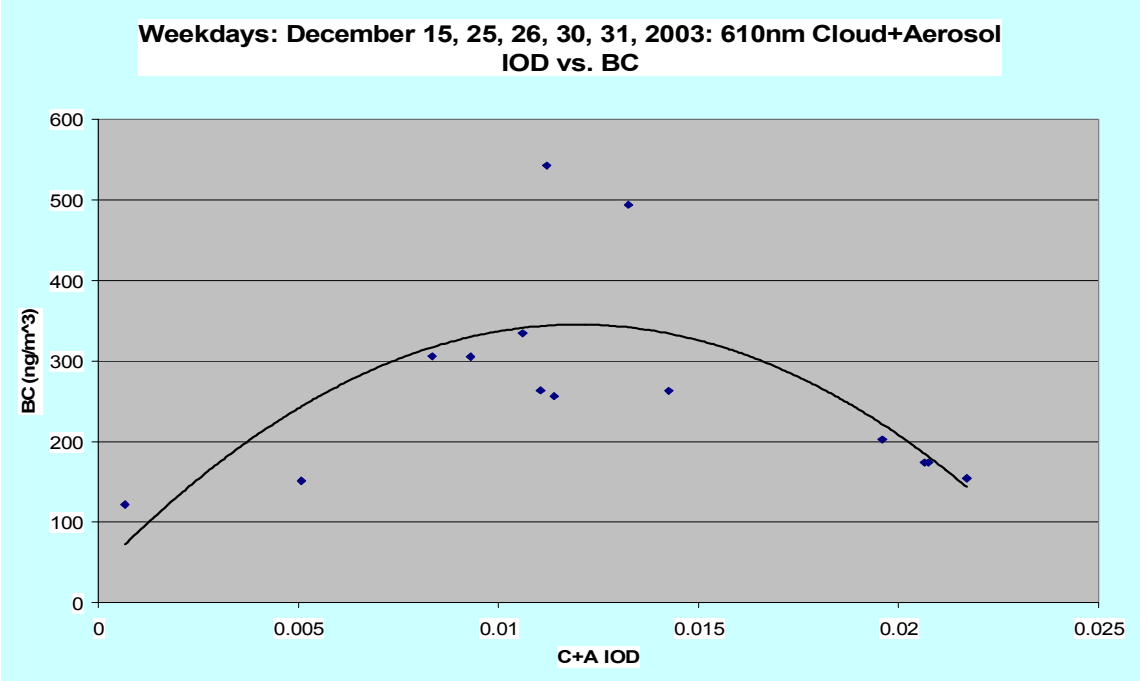

Figure 180. December 2003 Weekdays 610nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

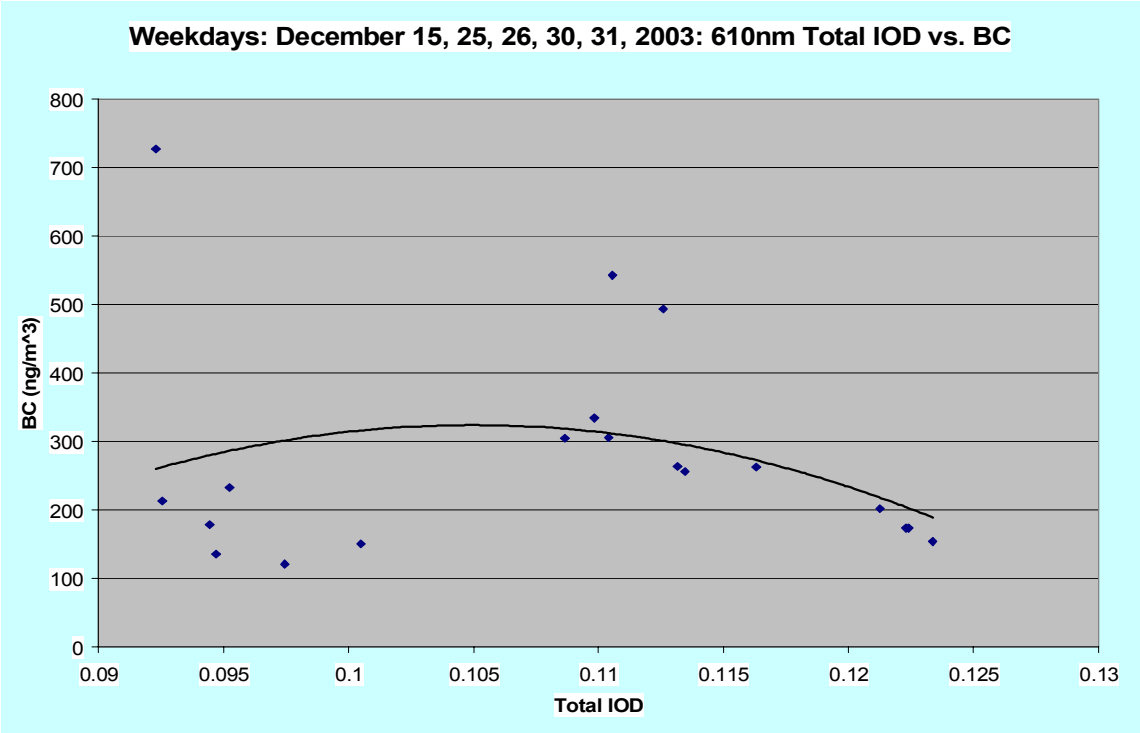

Figure 181. December 2003 Weekdays 610nm Total IOD vs. BC Concentrations (ng/m^3)

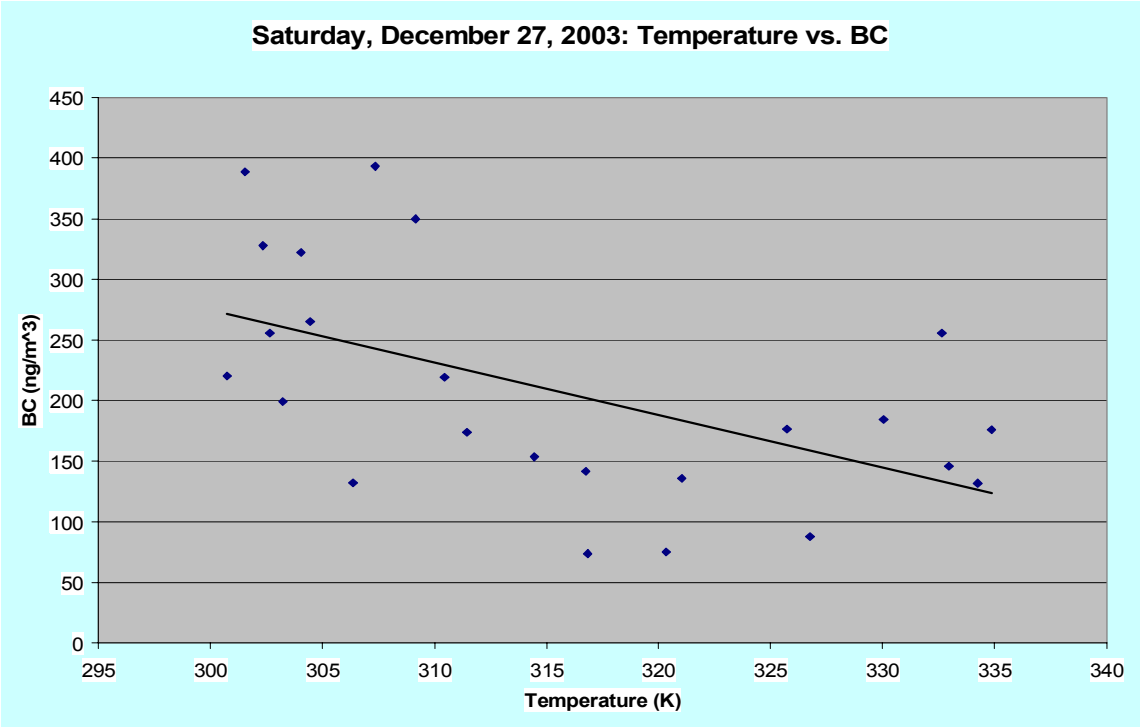

Figure 182. December 2003 Weekend Temperature (K) vs. BC Concentrations (ng/m^3)

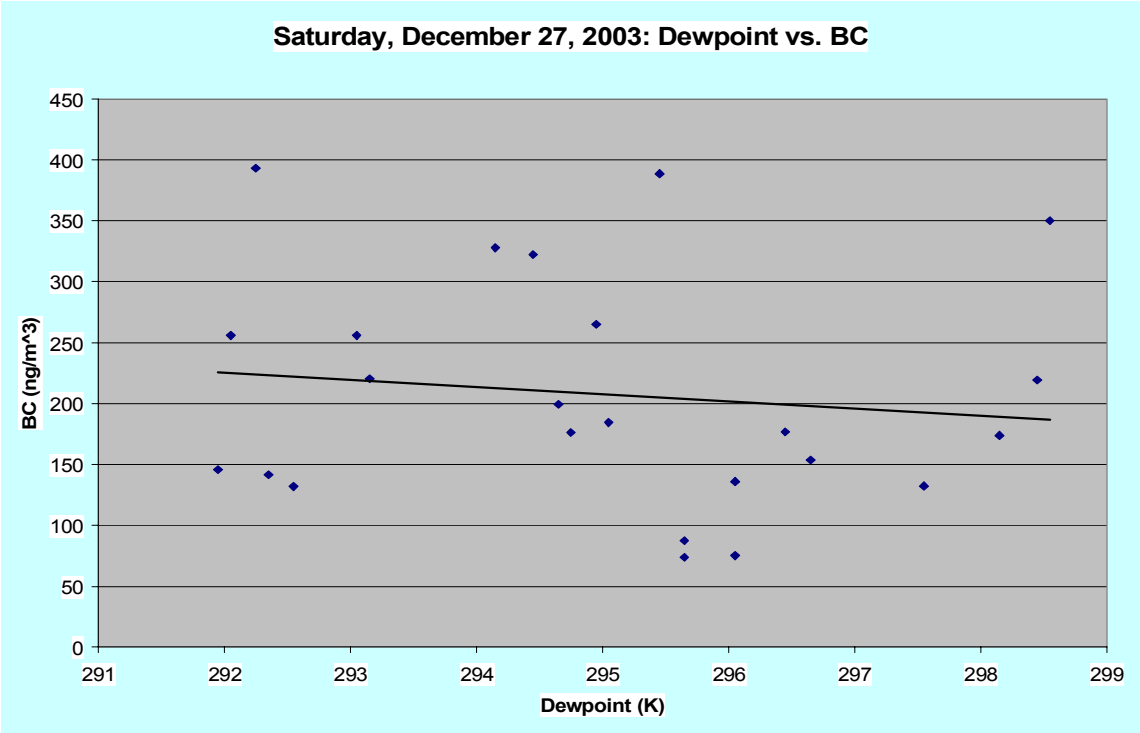

Figure 183. December 2003 Weekend Dewpoint (K) vs. BC Concentrations (ng/m^3)

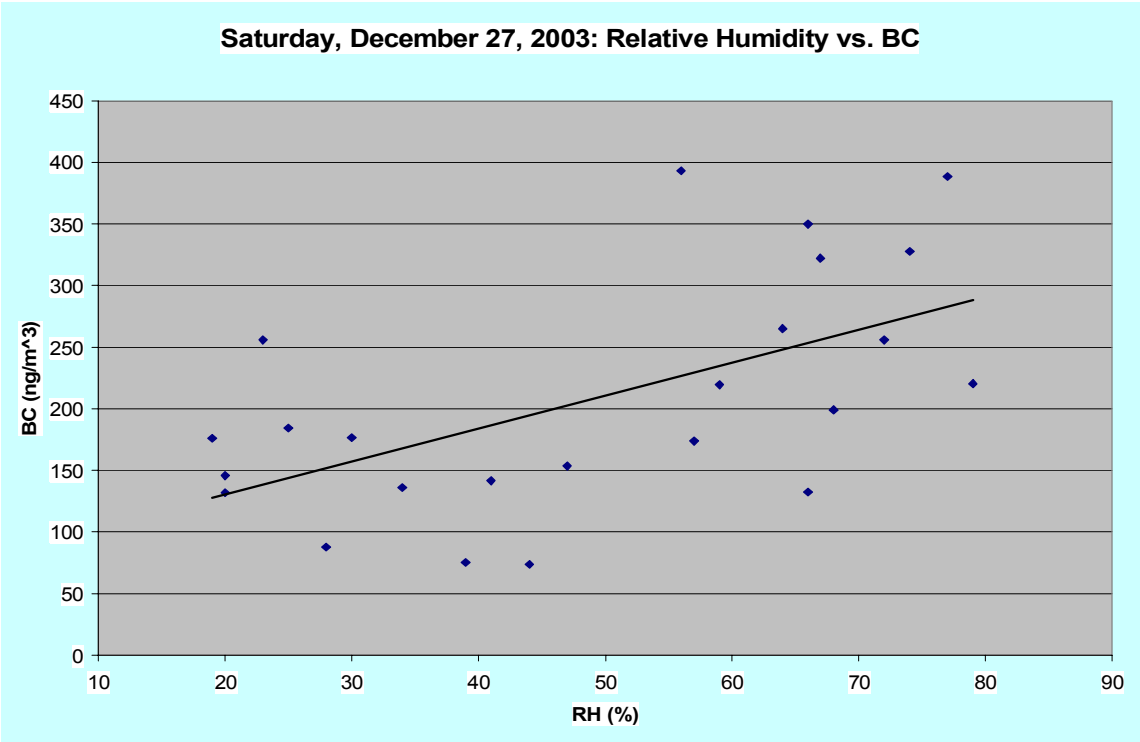

Figure 184. December 2003 Weekend Relative Humidity (%) vs. BC Concentrations (ng/m^3)

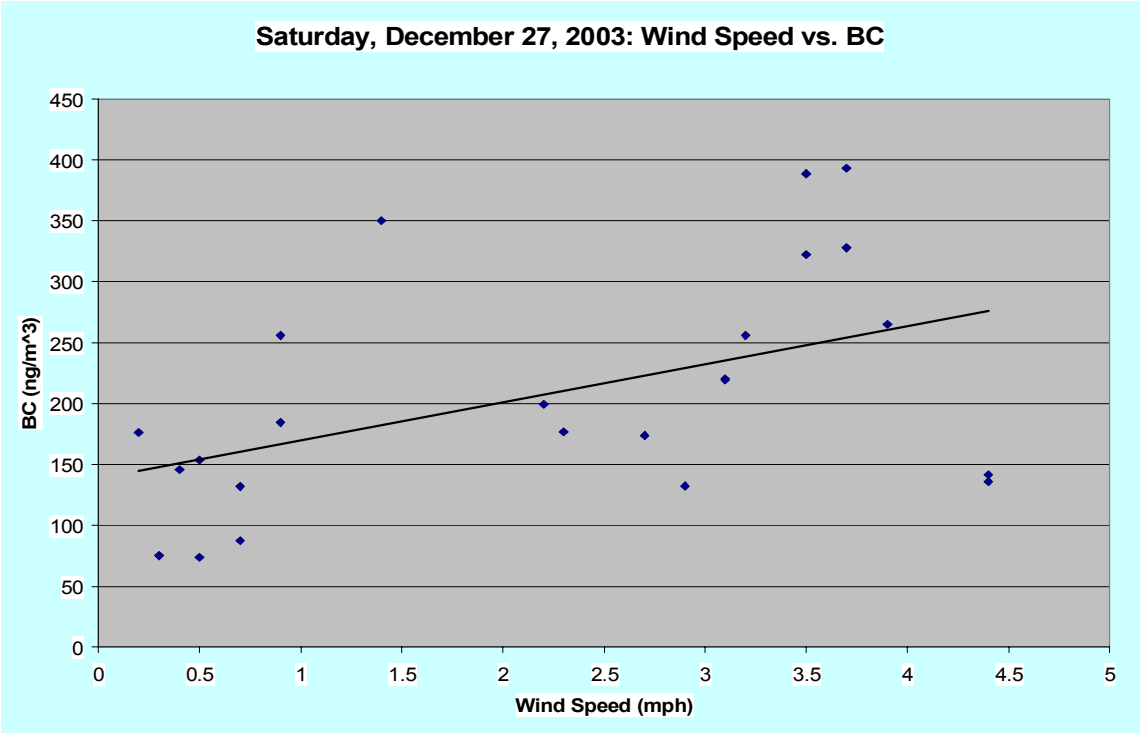

Figure 185. December 2003 Weekend Wind Speed (mph) vs. BC Concentrations (ng/m^3)

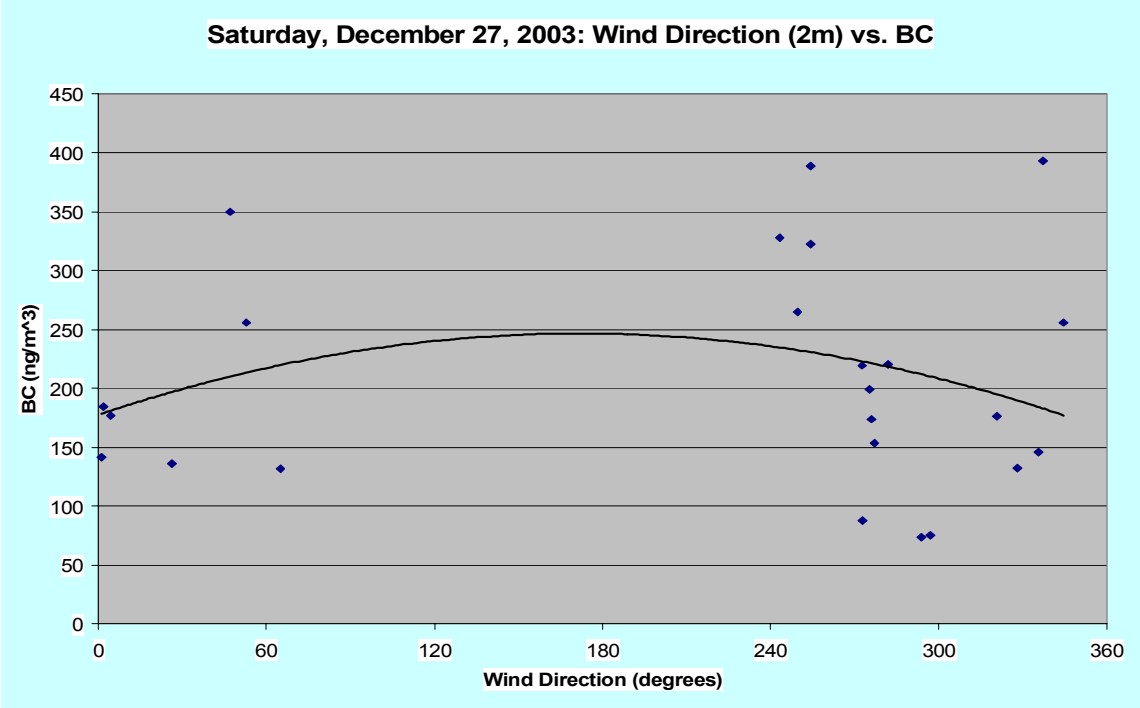

Figure 186. December 2003 Weekend Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

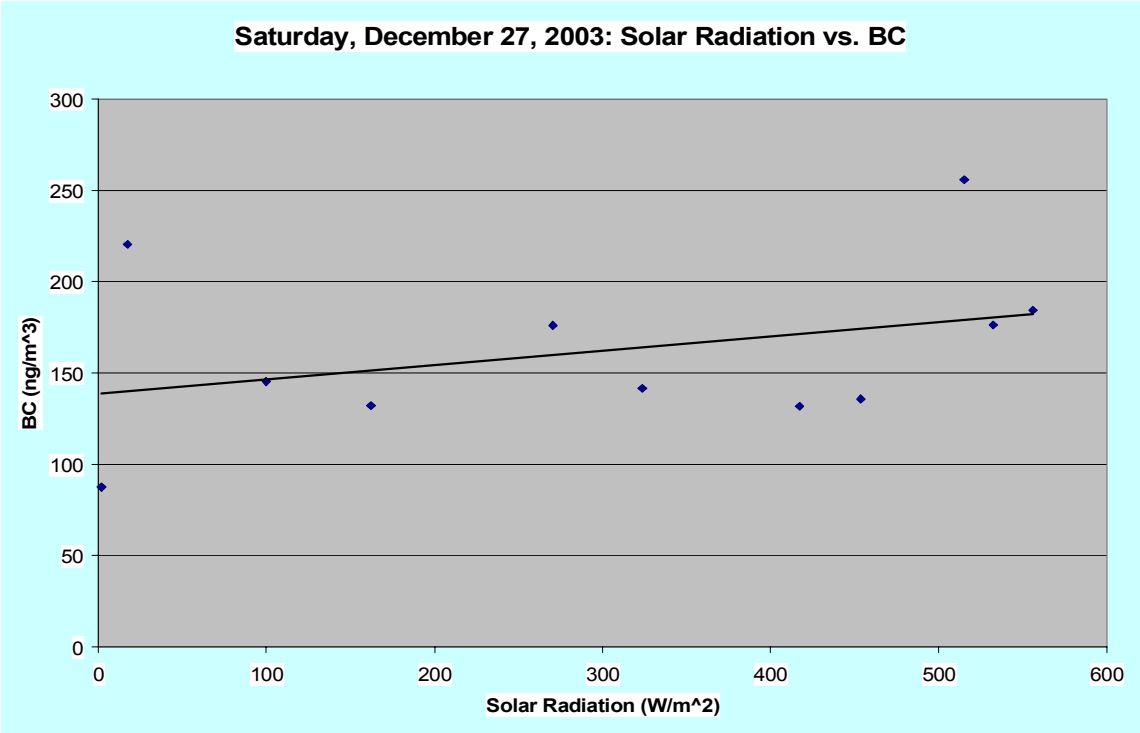

Figure 187. December 2003 Weekend Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

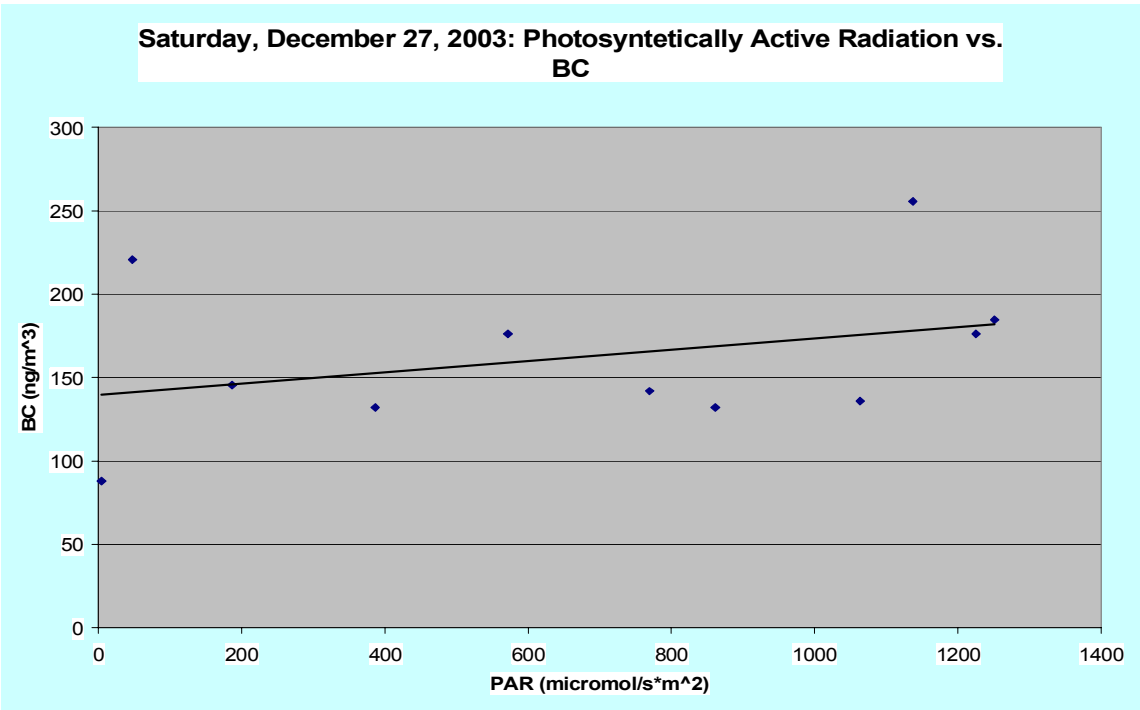

Figure 188. December 2003 Weekend PAR (microlmol/s*m^2) vs. BC Concentrations (ng/m^3)

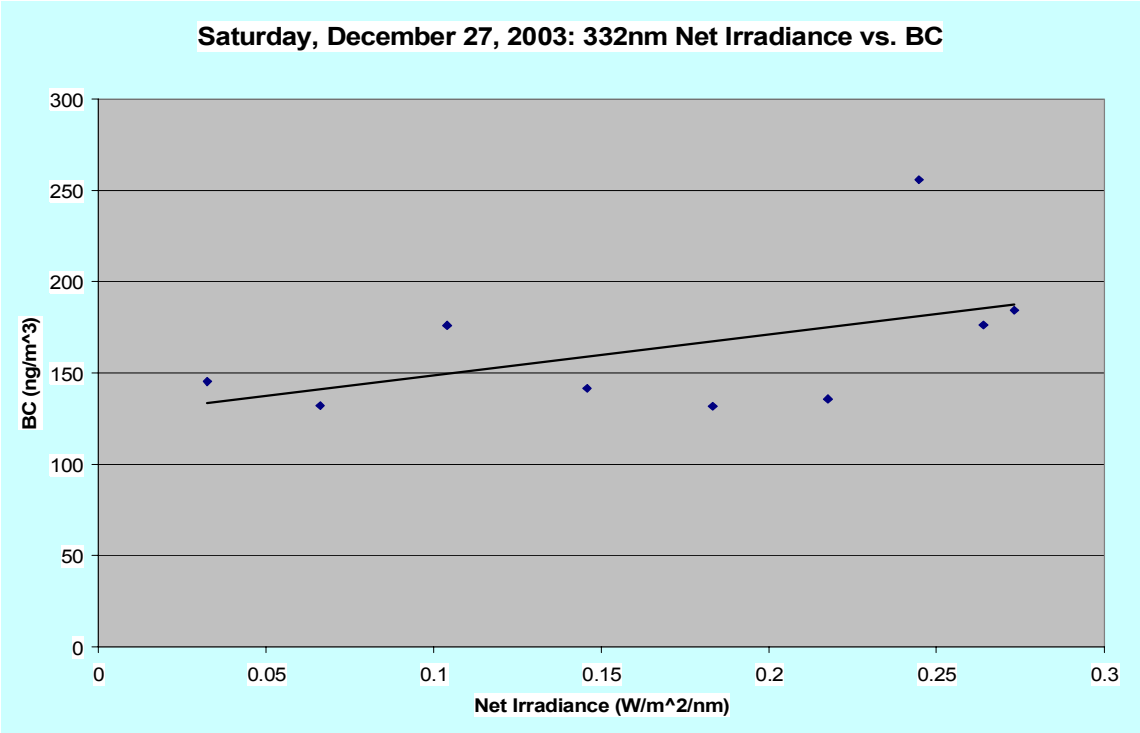

Figure 189. December 2003 Weekend 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

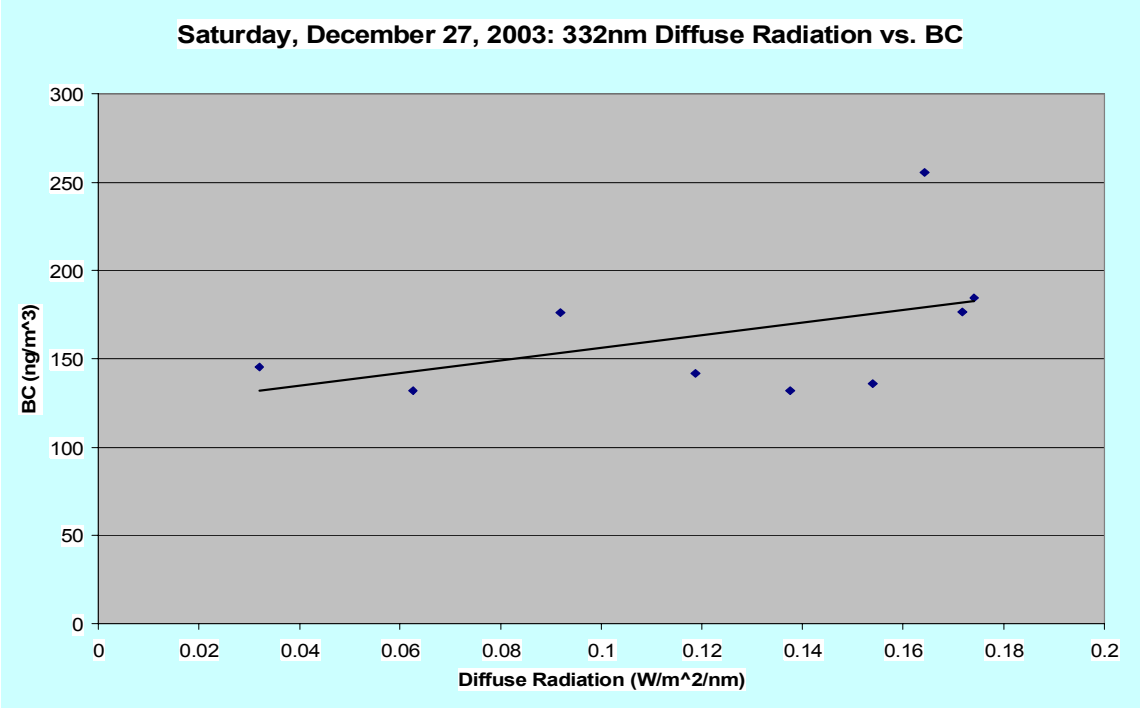

Figure 190. December 2003 Weekend 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

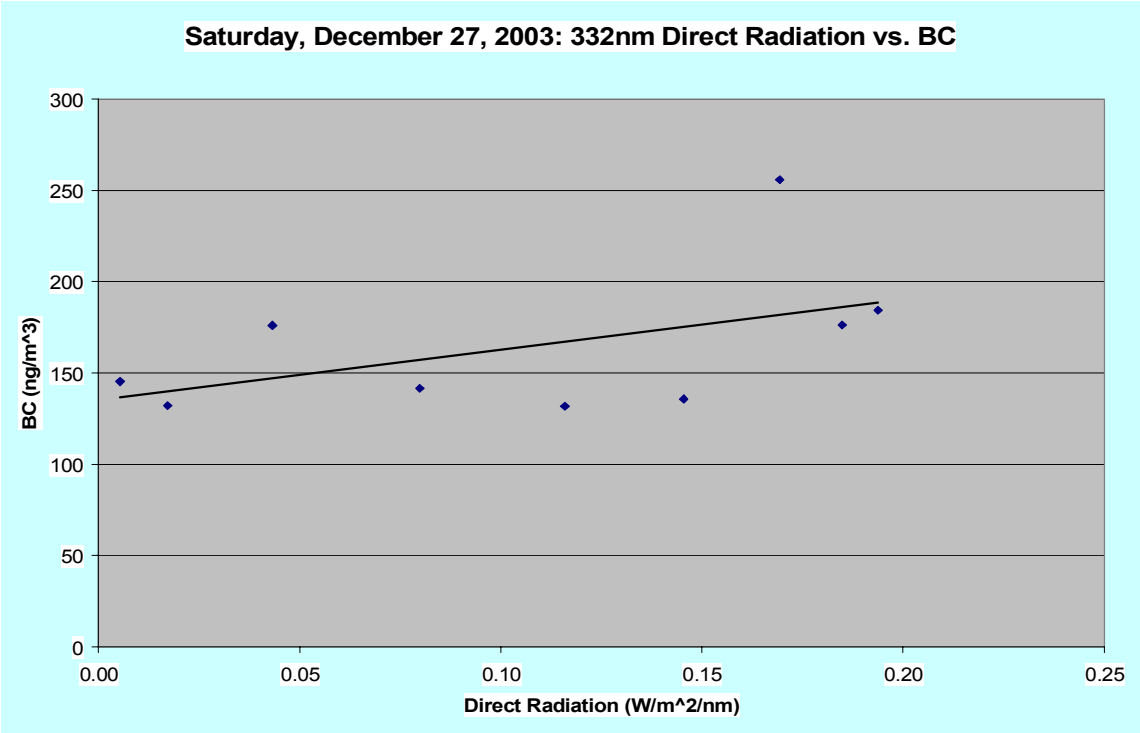

Figure 191. December 2003 Weekend 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

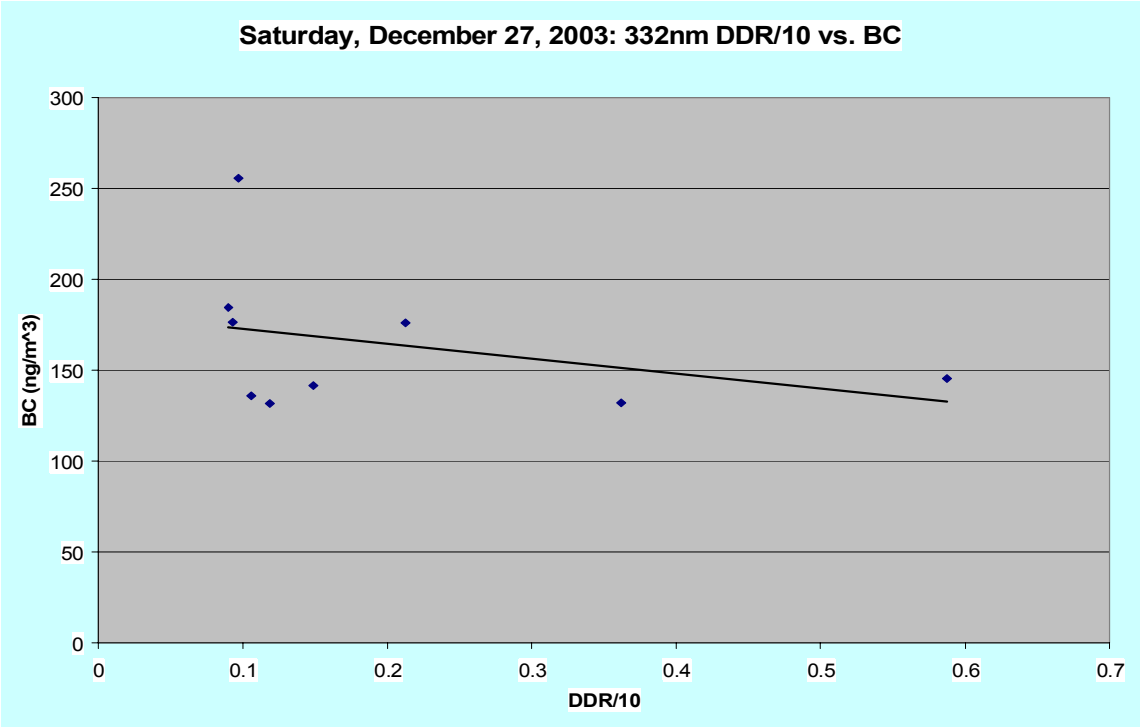

Figure 192. December 2003 Weekend 332nm DDR/10 vs. BC Concentrations (ng/m^3)

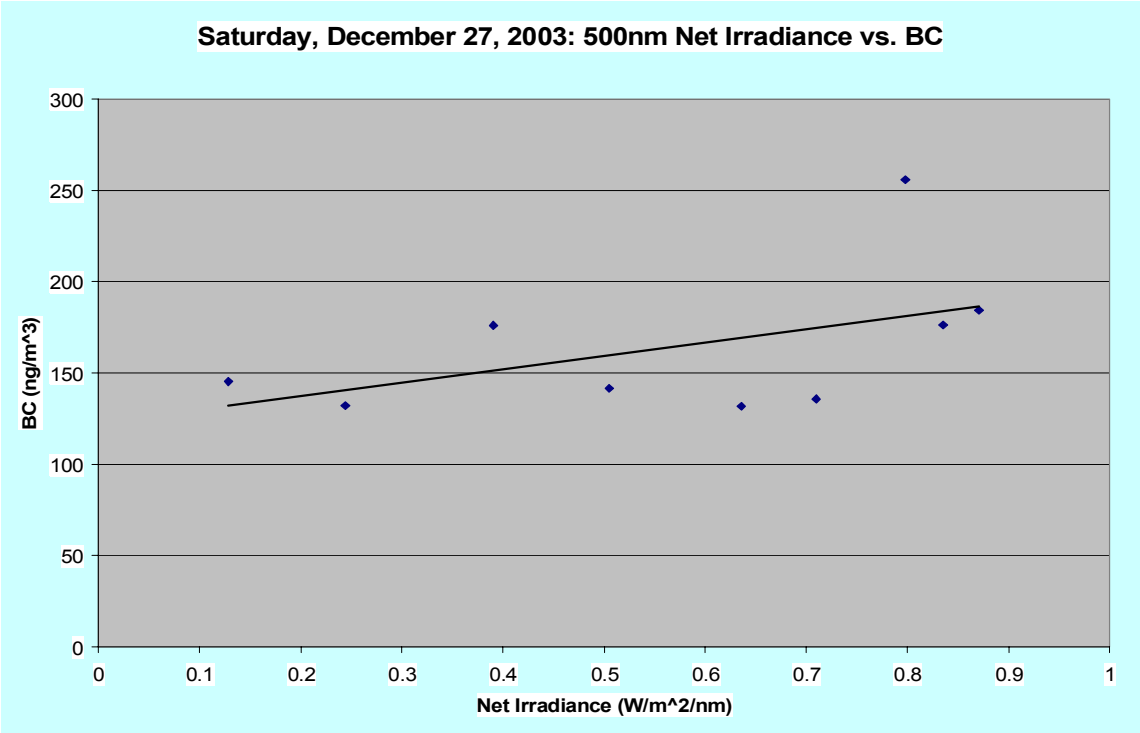

Figure 193. December 2003 Weekend 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

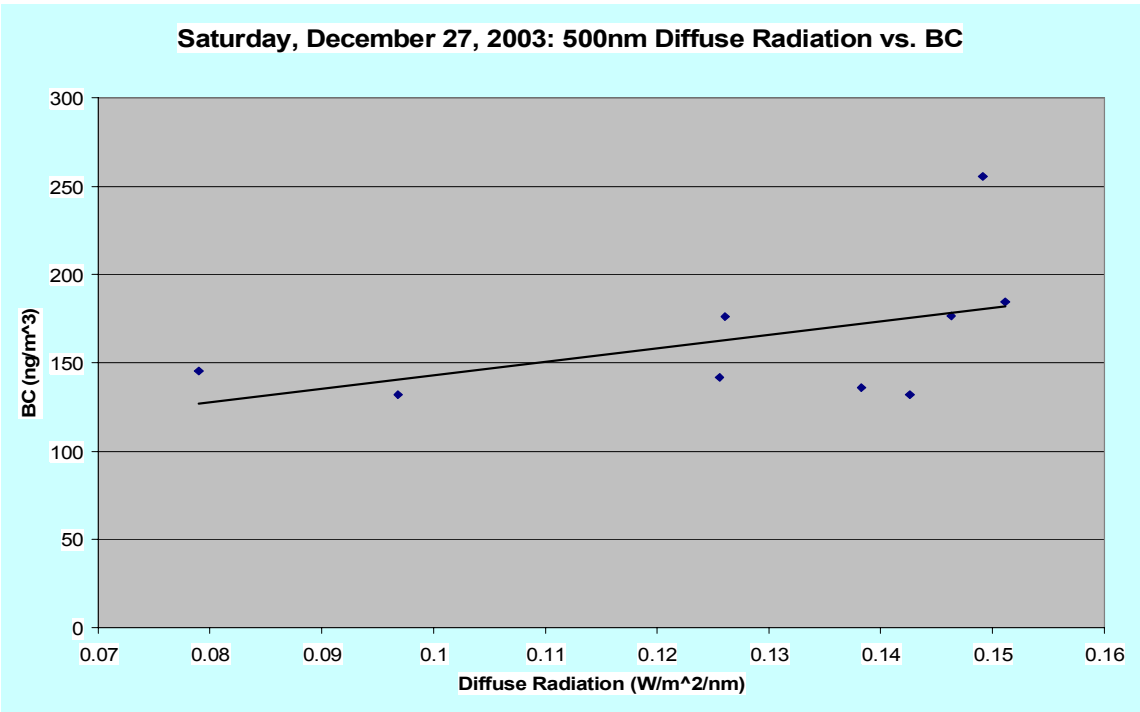

Figure 194. December 2003 Weekend 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

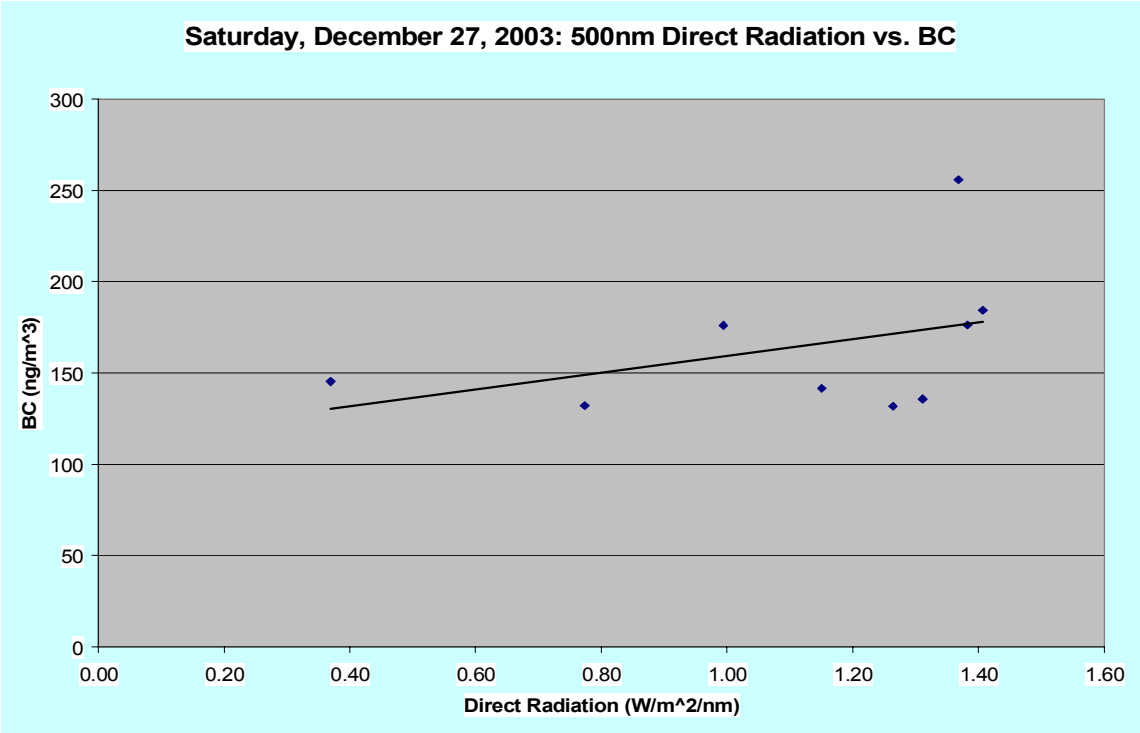

Figure 195. December 2003 Weekend 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

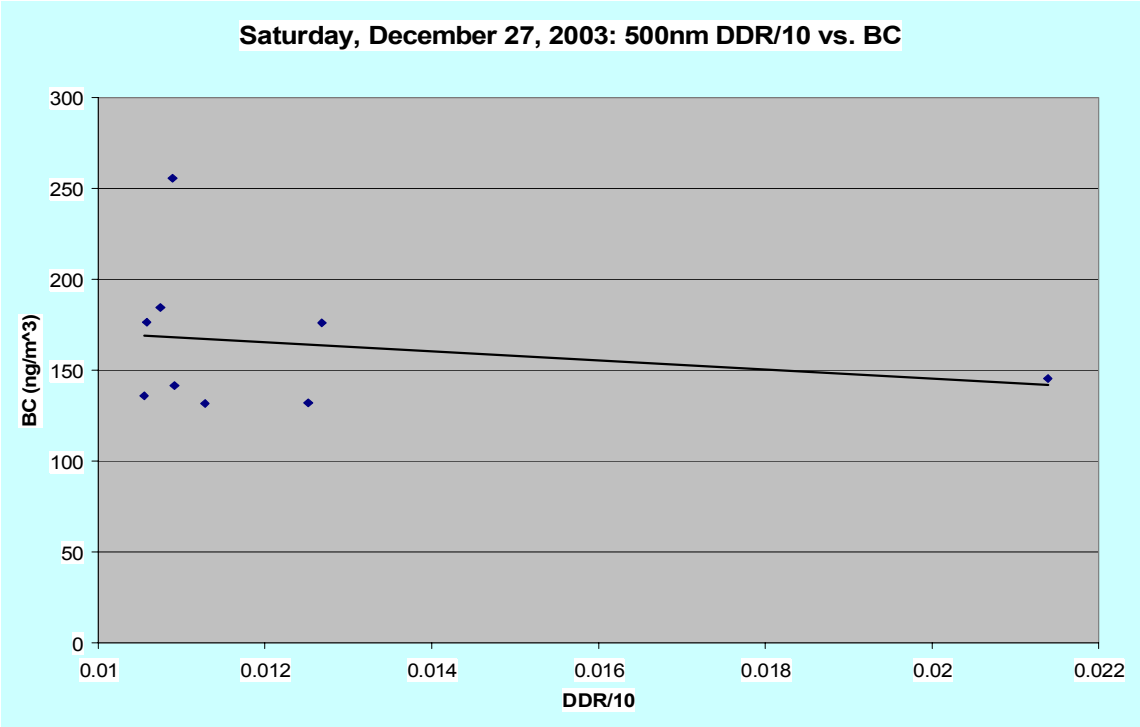

Figure 196. December 2003 Weekend 500nm DDR/10 vs. BC Concentrations (ng/m^3)

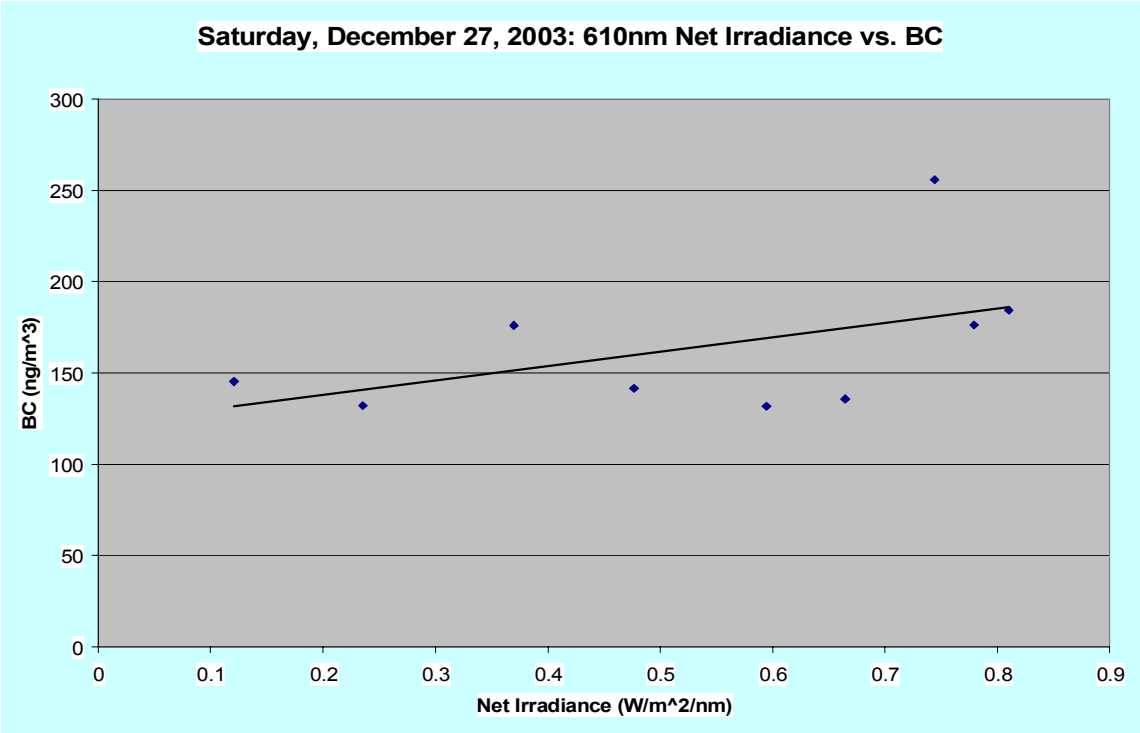

Figure 197. December 2003 Weekend 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

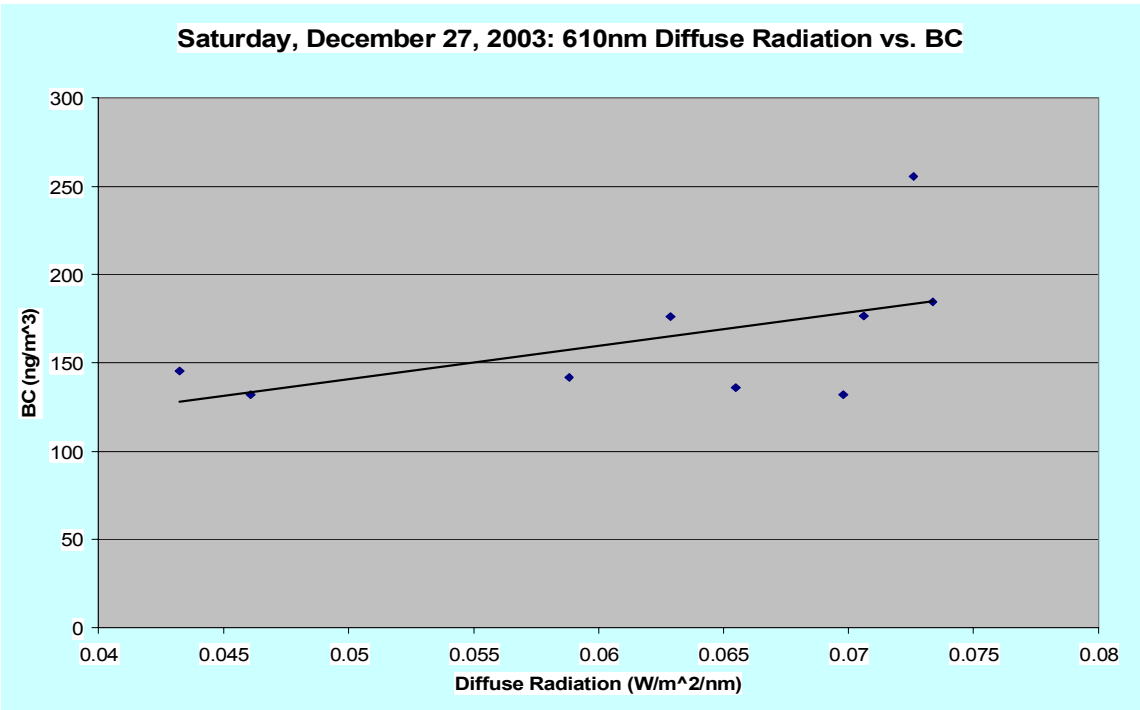

Figure 198. December 2003 Weekend 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

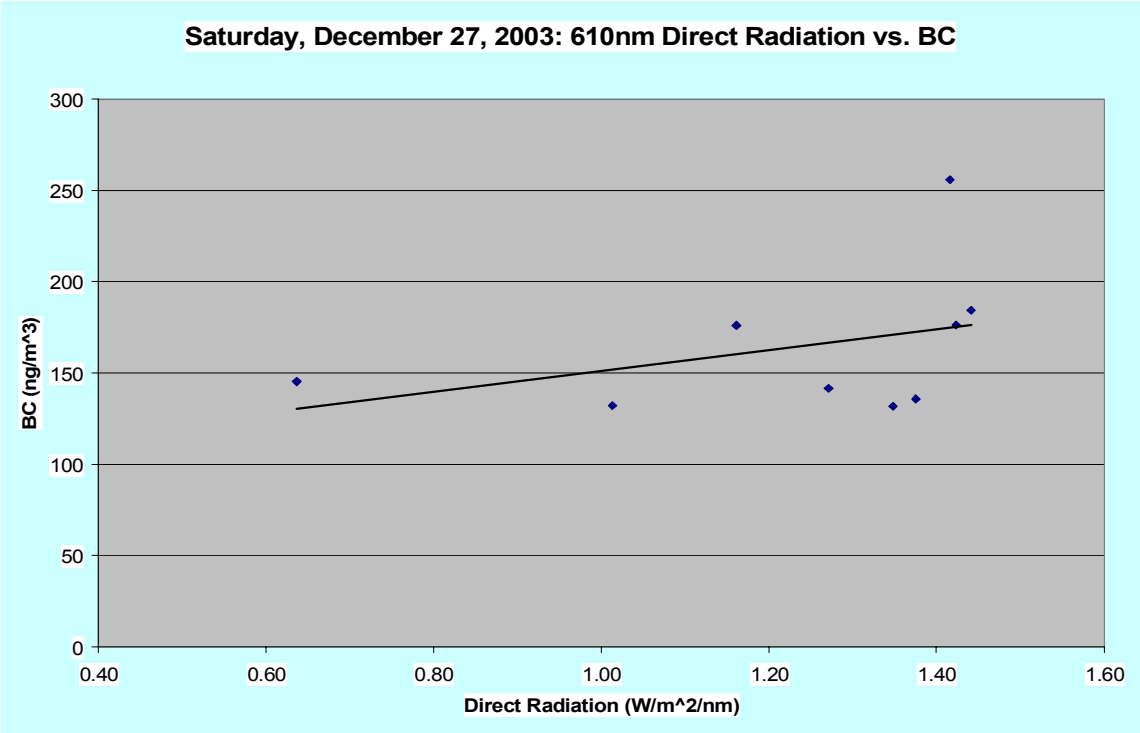

Figure 199. December 2003 Weekend 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

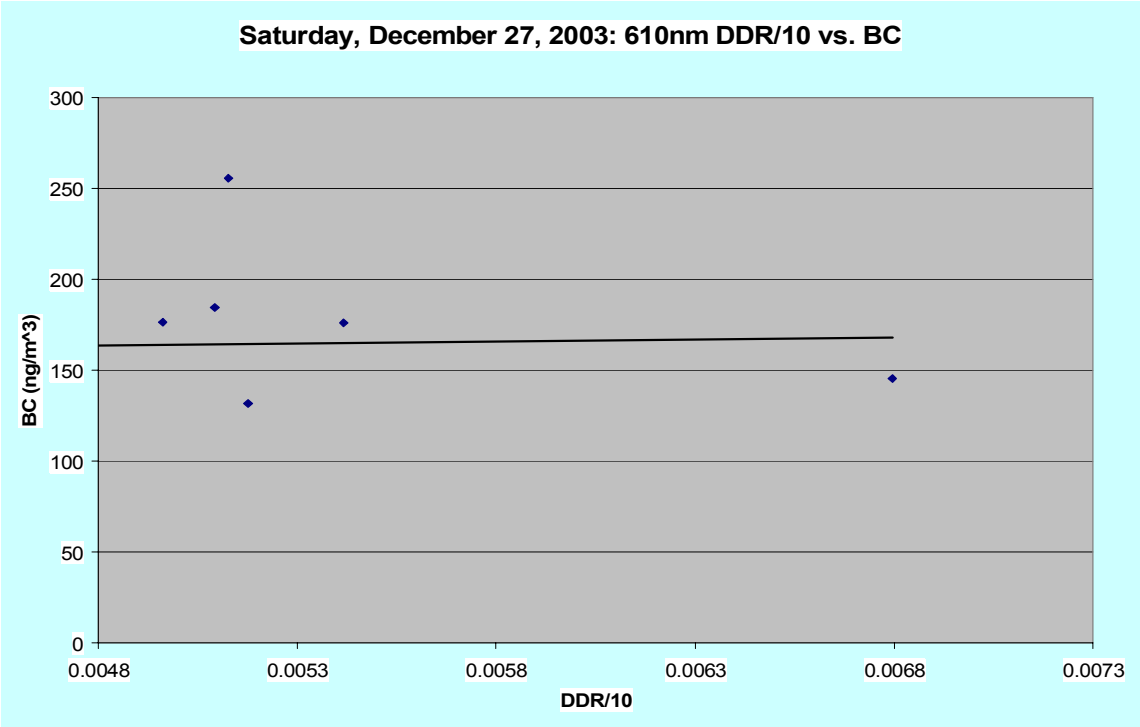

Figure 200. December 2003 Weekend 610nm DDR/10 vs. BC Concentrations (ng/m^3)

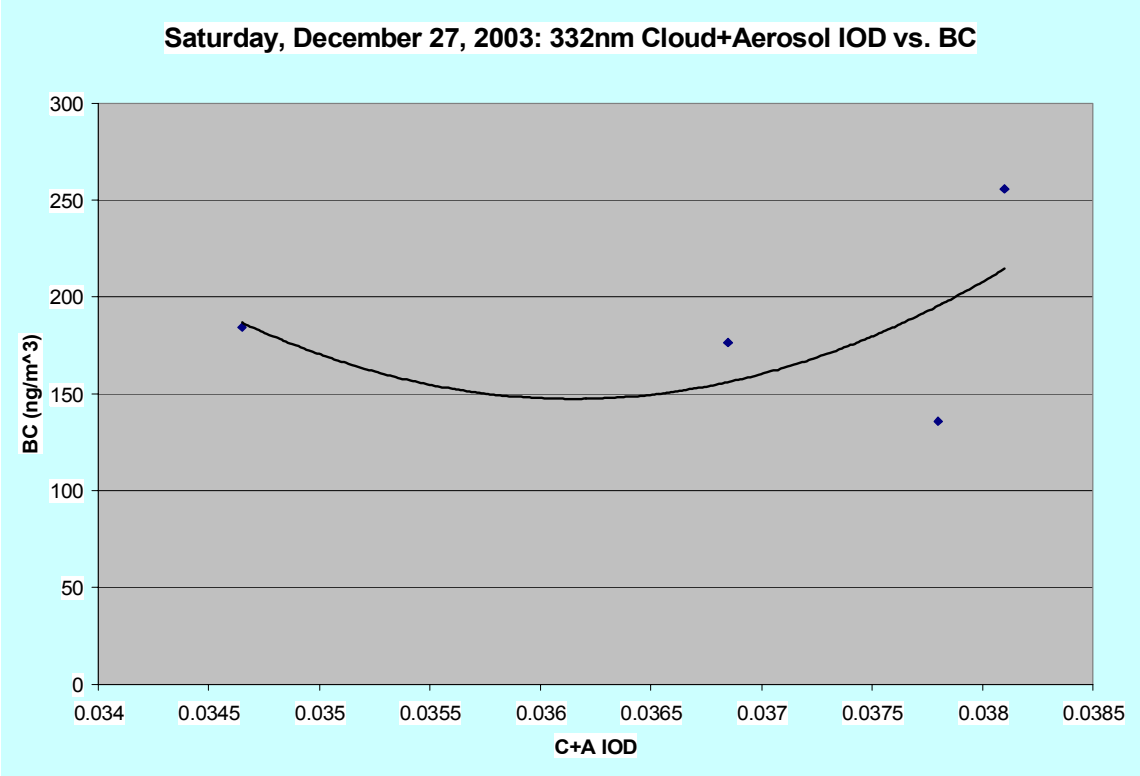

Figure 201. December 2003 Weekend 332nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

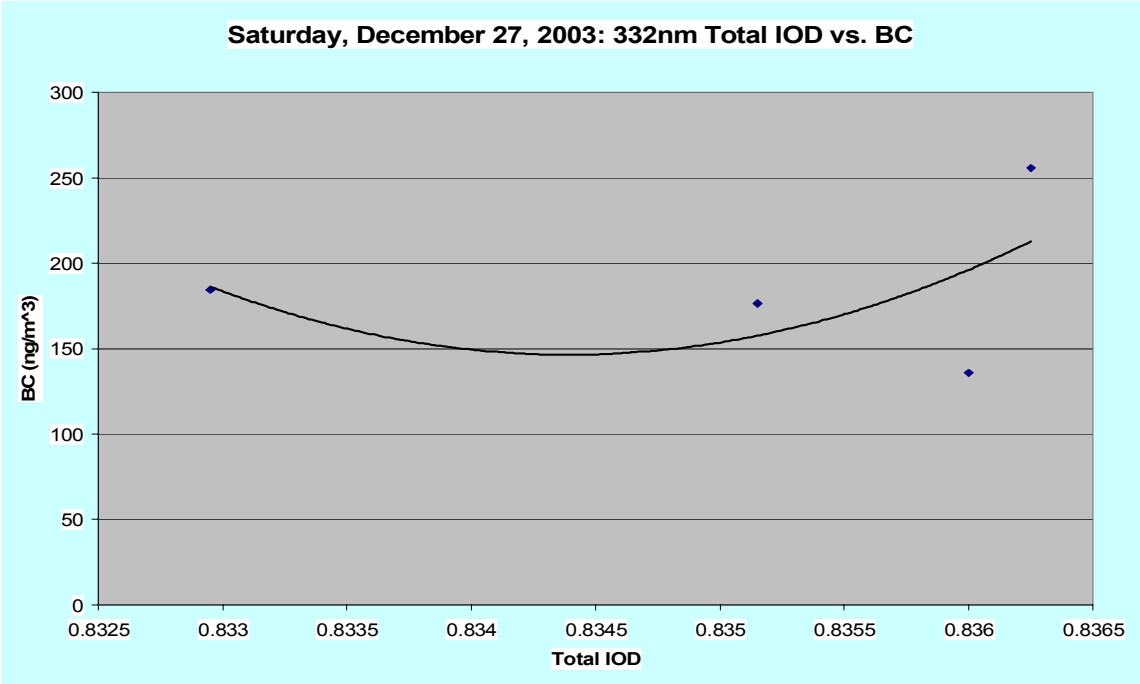

Figure 202. December 2003 Weekend 332nm Total IOD vs. BC Concentrations (ng/m^3)

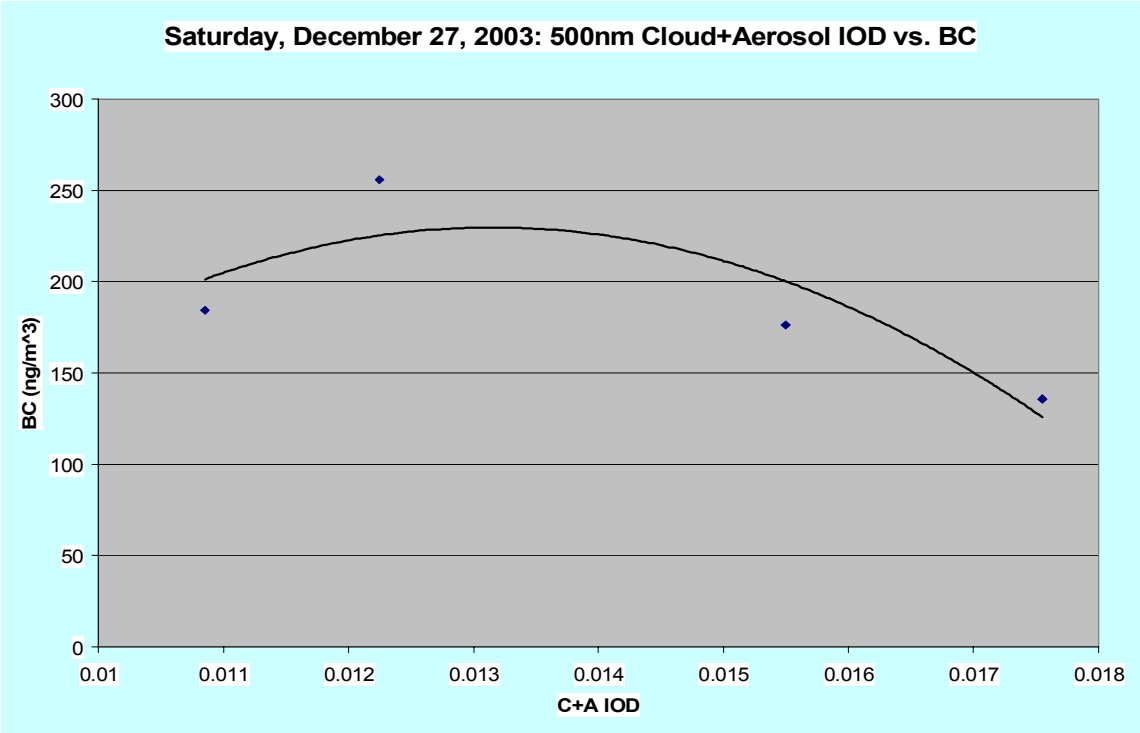

Figure 203. December 2003 Weekend 500nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

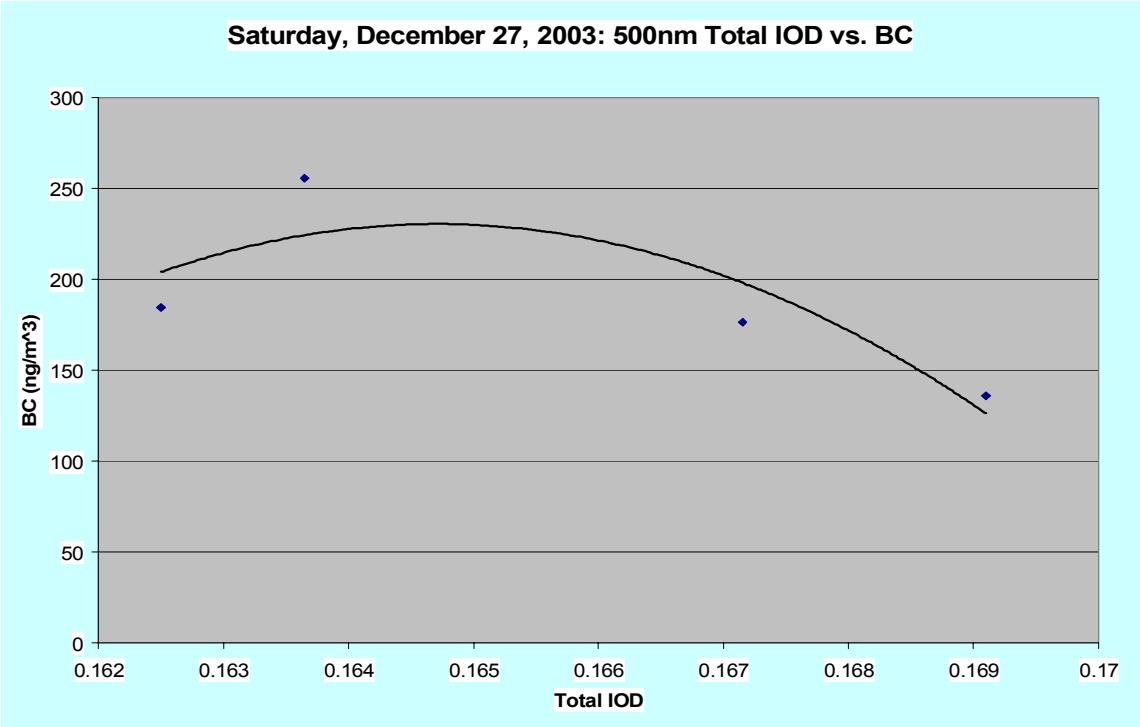

Figure 204. December 2003 Weekend 500nm Total IOD vs. BC Concentrations (ng/m^3)

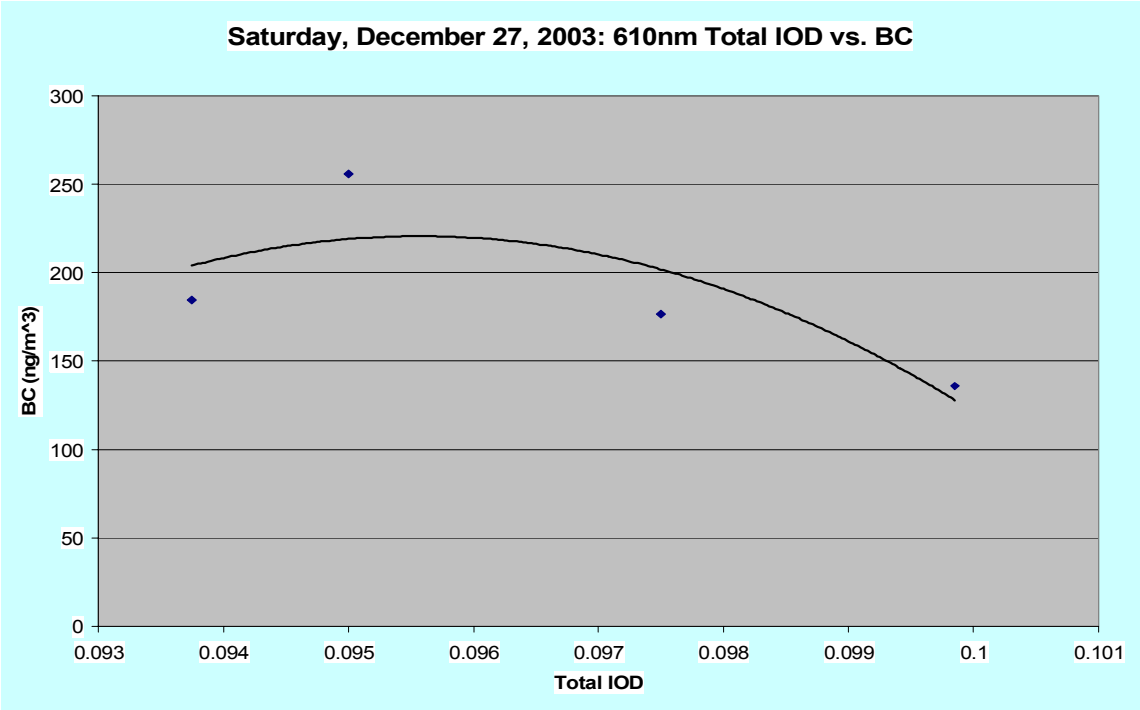

Figure 205. December 2003 Weekend 610nm Total IOD vs. BC Concentrations (ng/m^3)

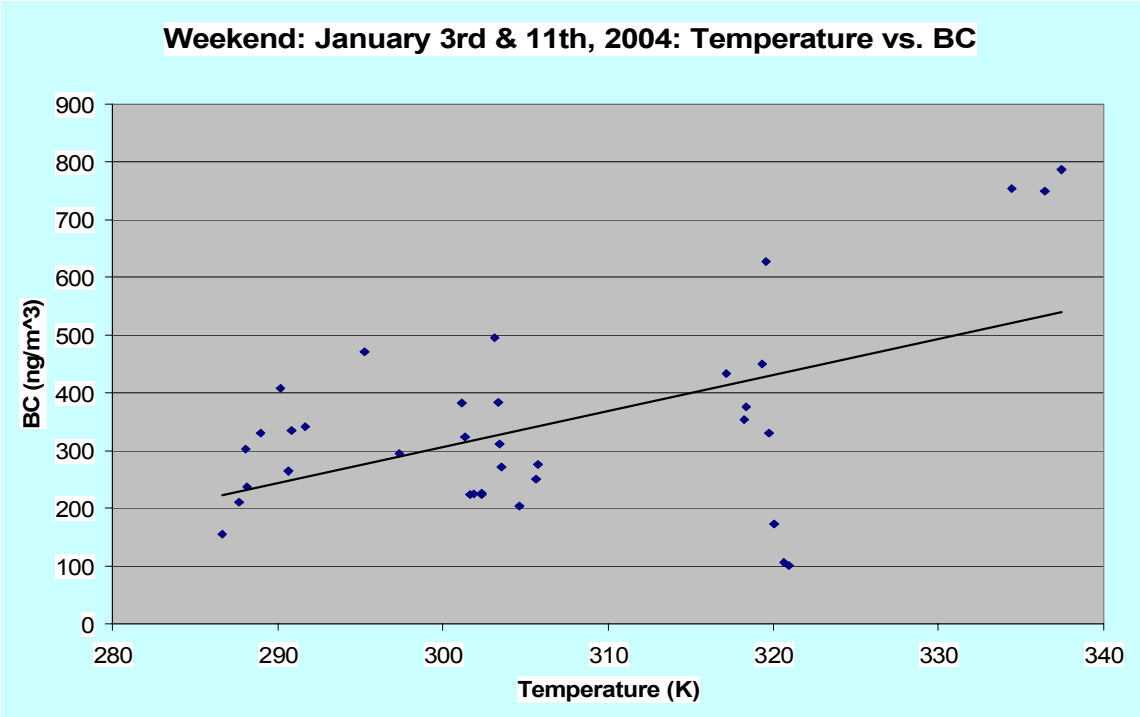

Figure 206. January 2004 Weekend Temperature (K) vs. BC Concentrations (ng/m^3)

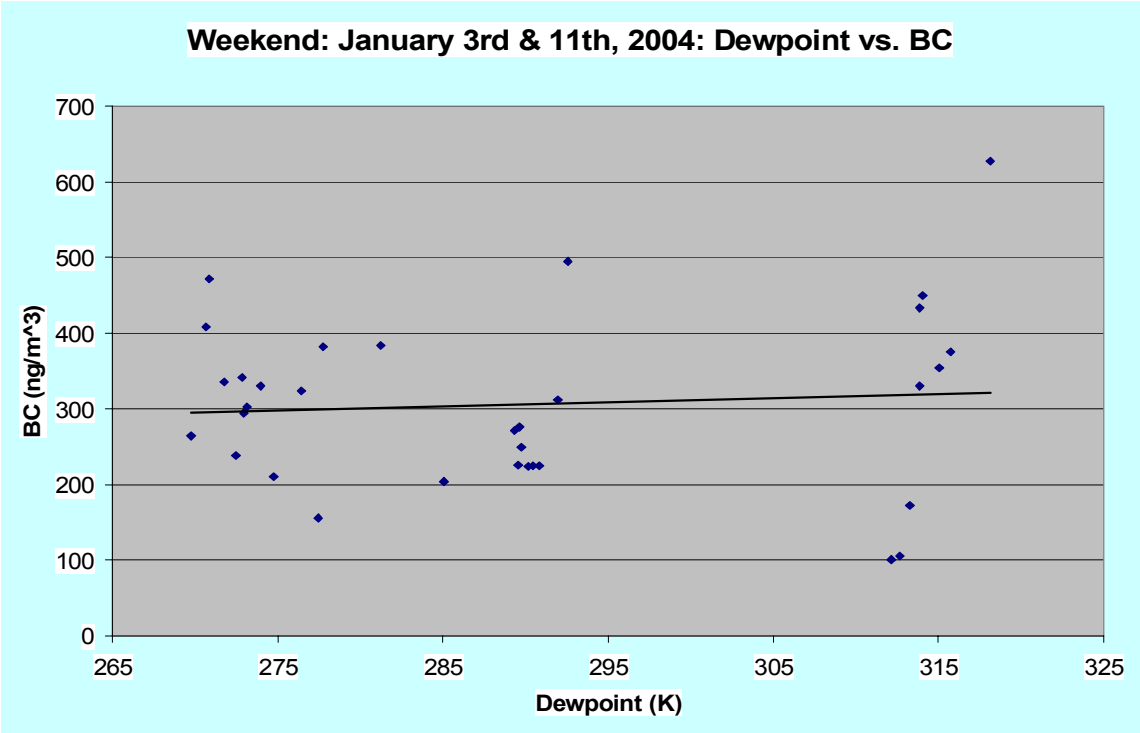

Figure 207. January 2004 Weekend Dewpoint (K) vs. BC Concentrations (ng/m^3)

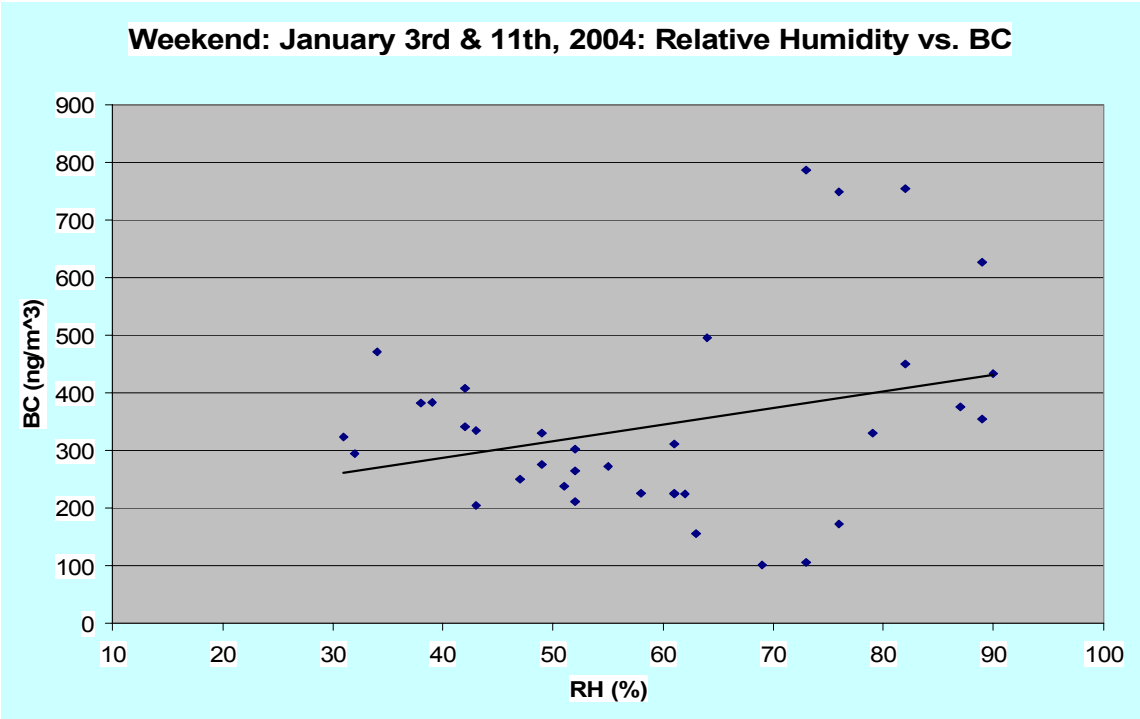

Figure 208. January 2004 Weekend Relative Humidity (%) vs. BC Concentrations (ng/m^3)

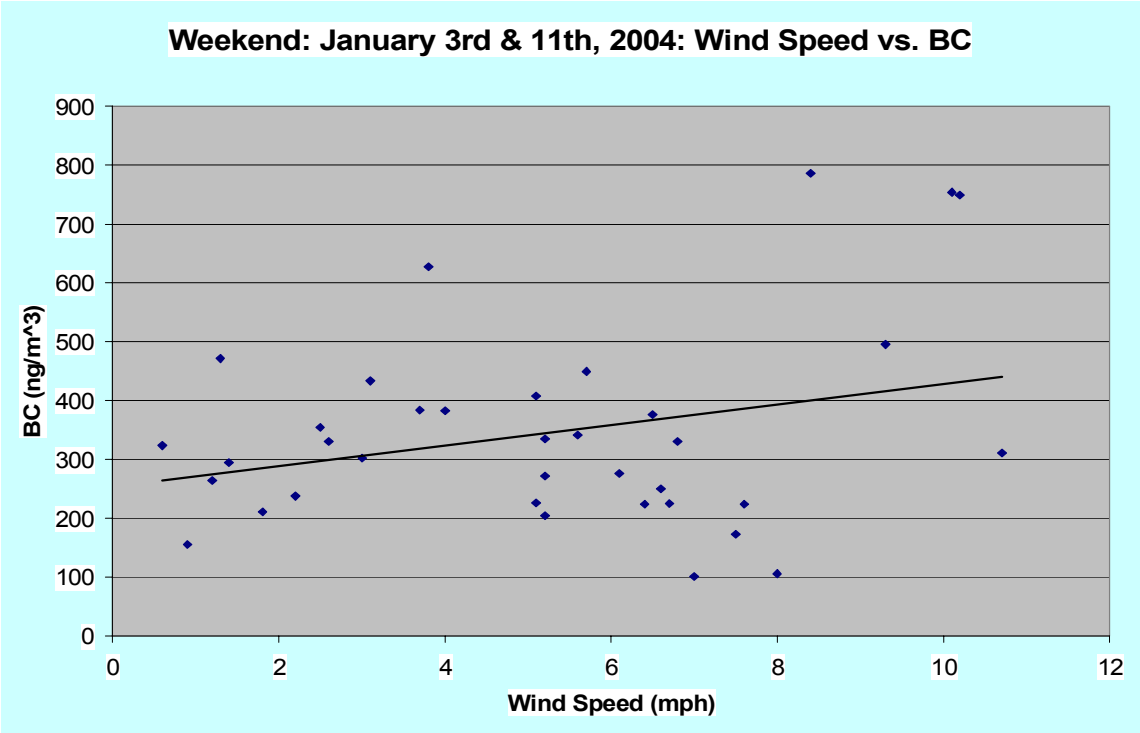

Figure 209. January 2004 Weekend Wind Speed (mph) vs. BC Concentrations (ng/m^3)

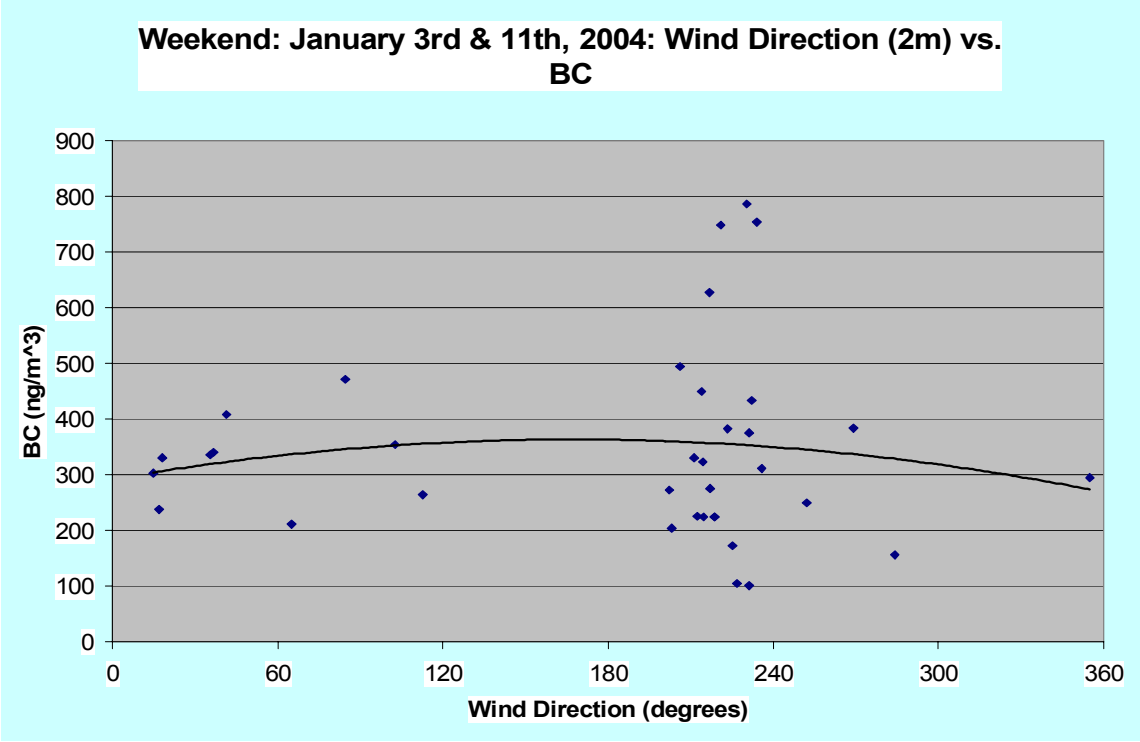

Figure 210. January 2004 Weekend Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

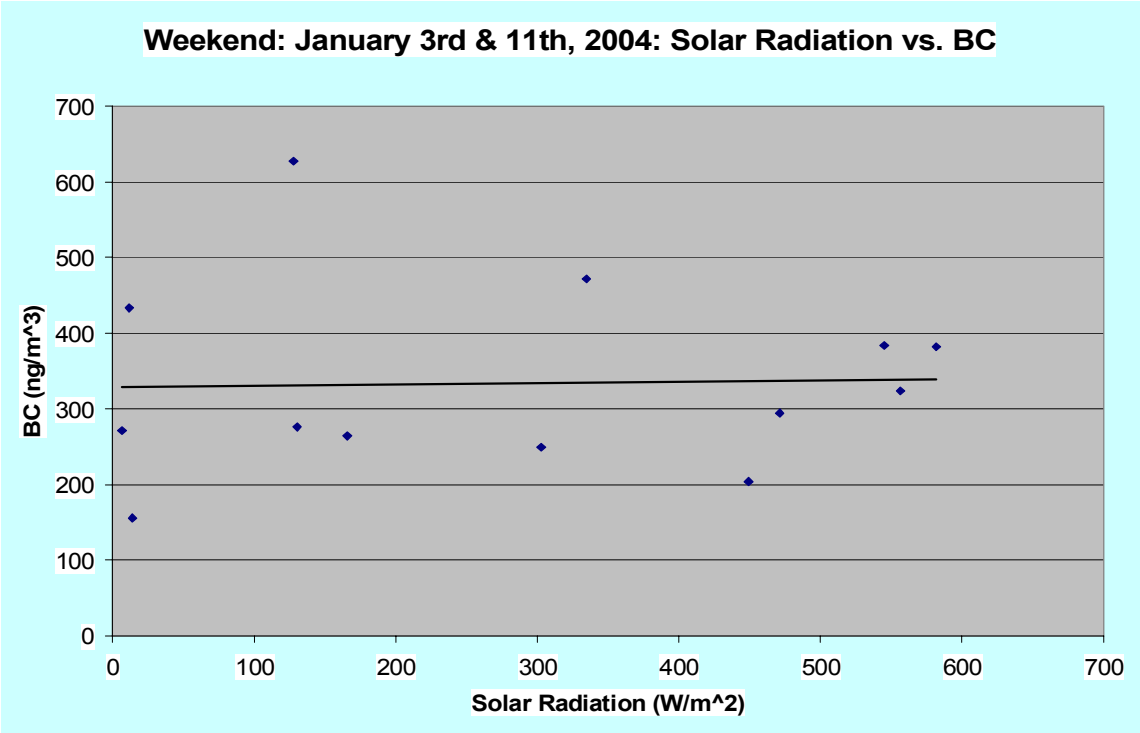

Figure 211. January 2004 Weekend Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

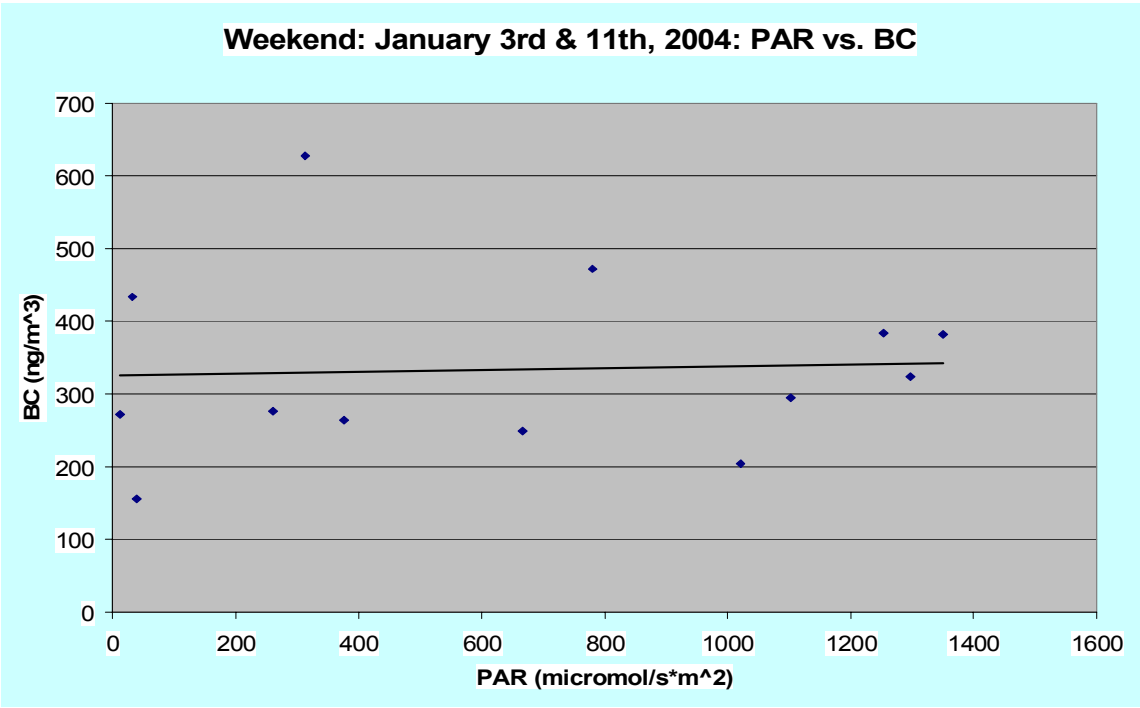

Figure 212. January 2004 Weekend PAR (micromol/s*m^2) vs. BC Concentrations (ng/m^3)

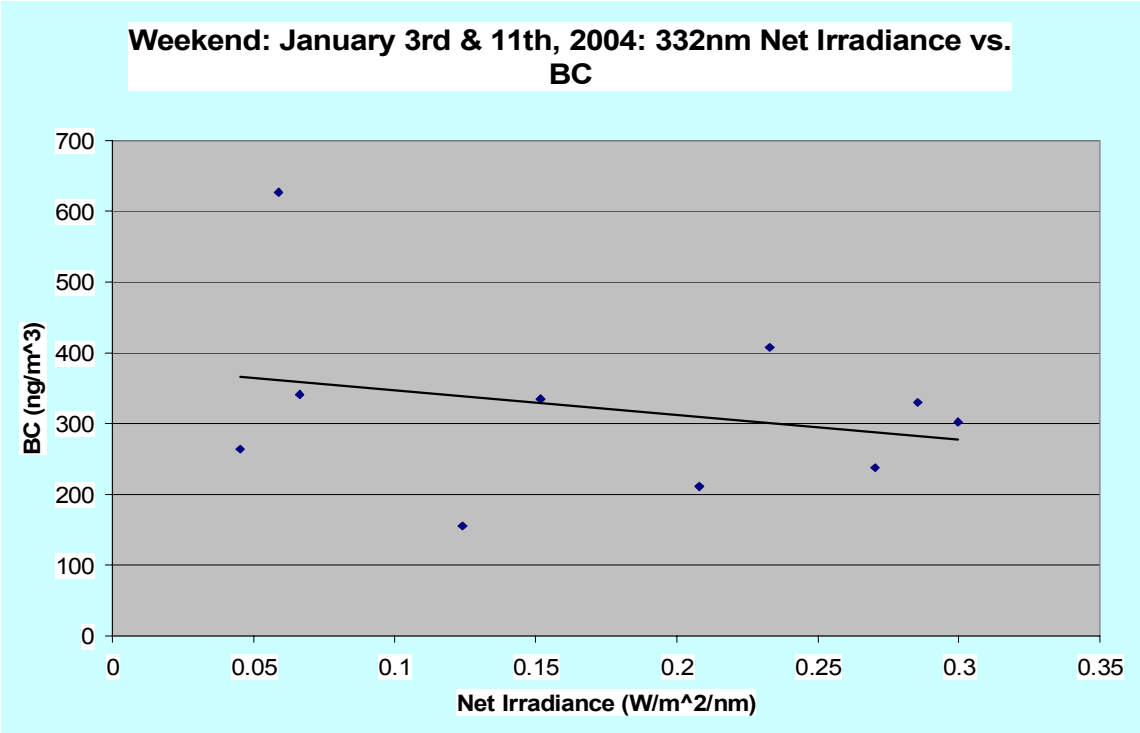

Figure 213. January 2004 Weekend 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

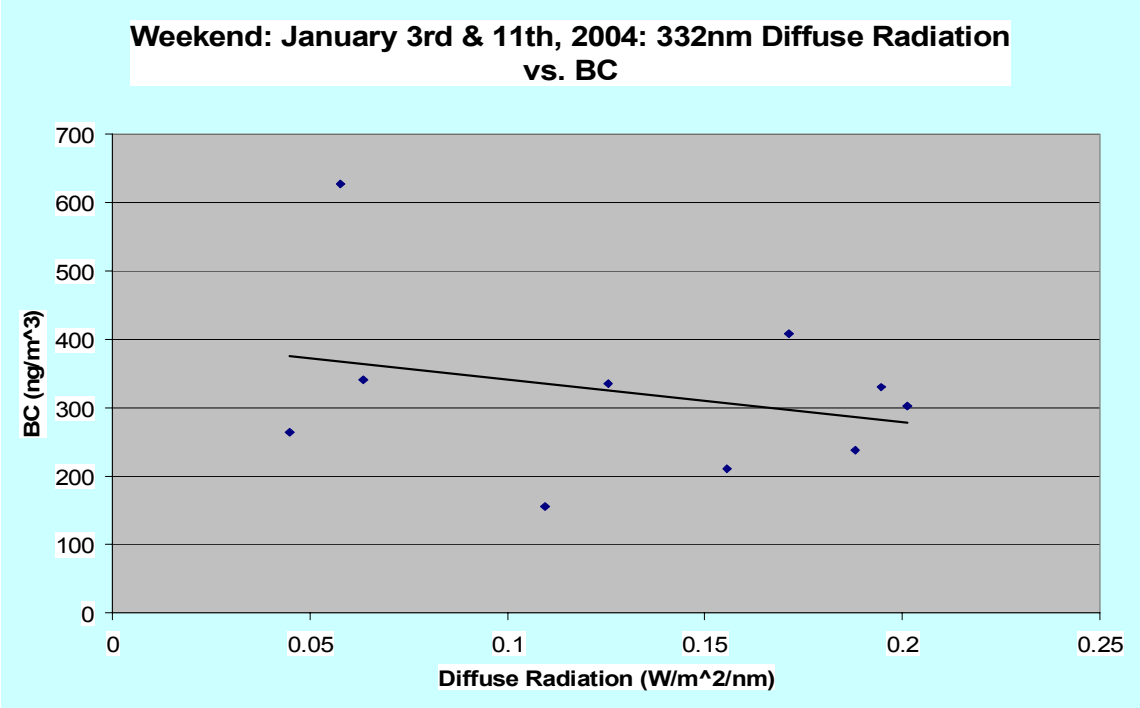

Figure 214. January 2004 Weekend 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

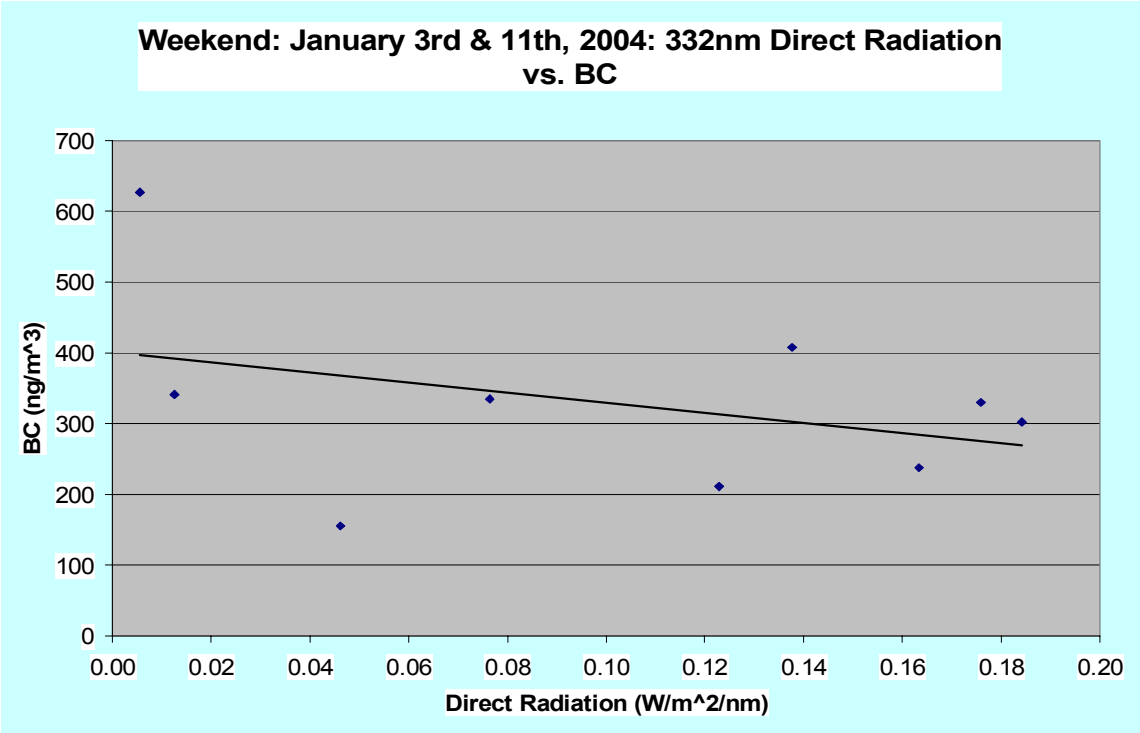

Figure 215. January 2004 Weekend 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

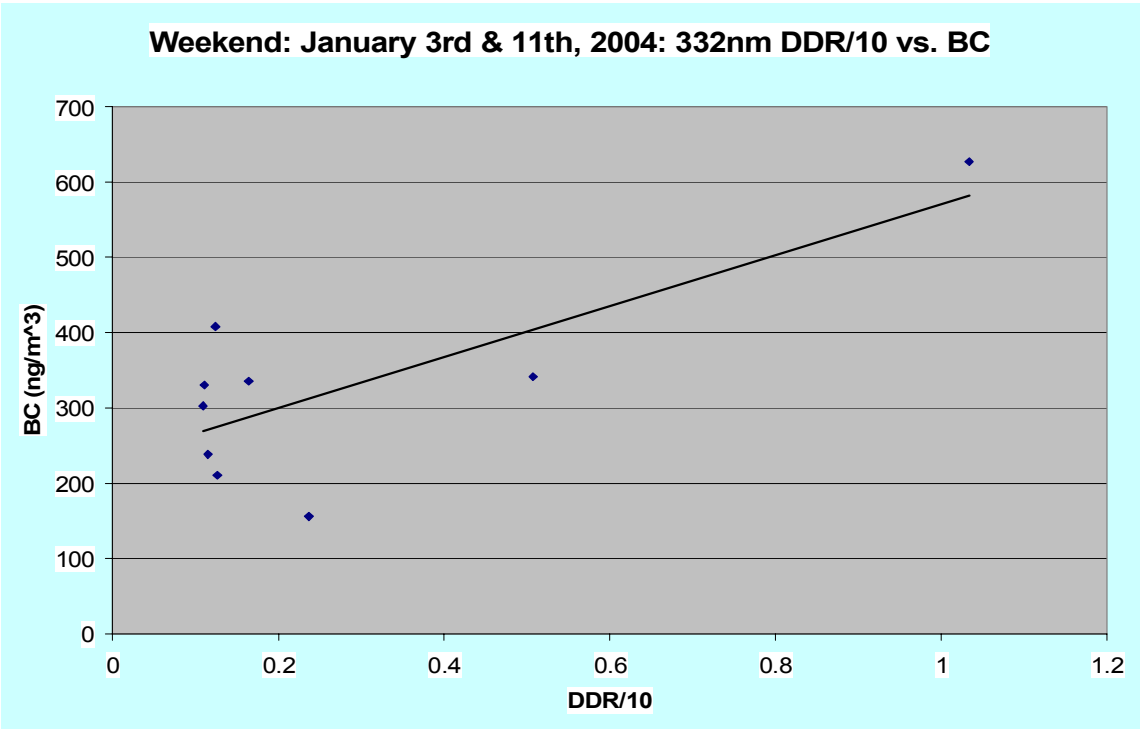

Figure 216. January 2004 Weekend 332nm DDRR/10 vs. BC Concentrations (ng/m^3)

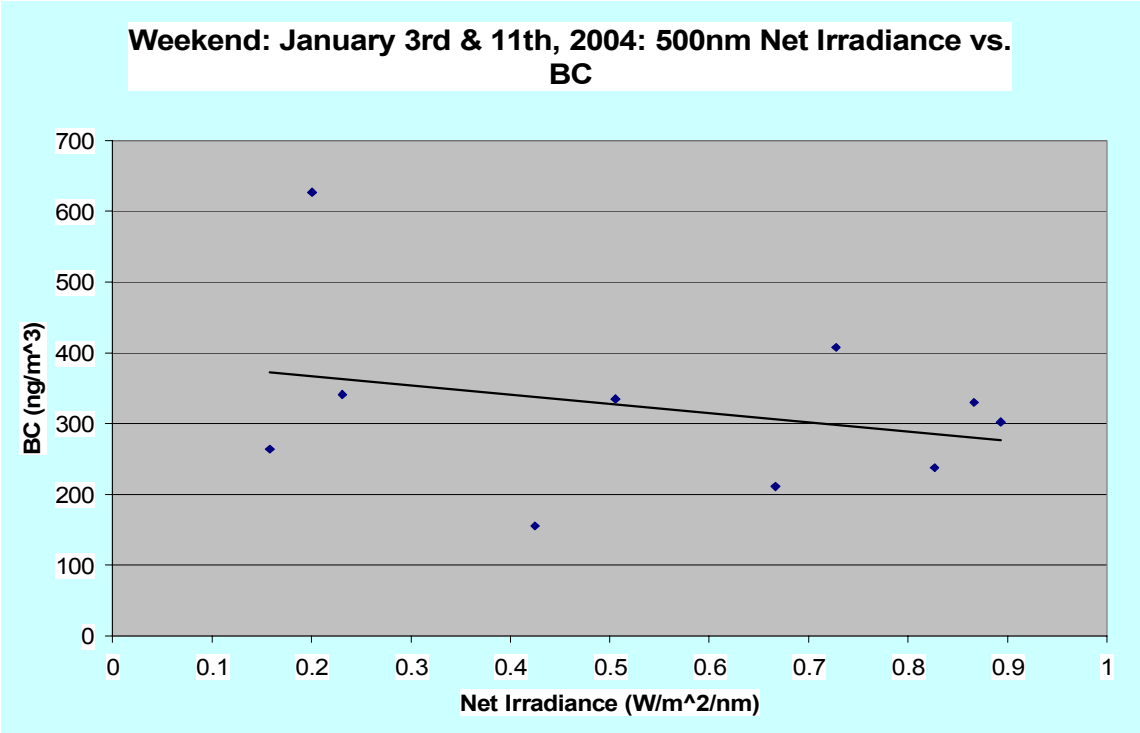

Figure 217. January 2004 Weekend 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

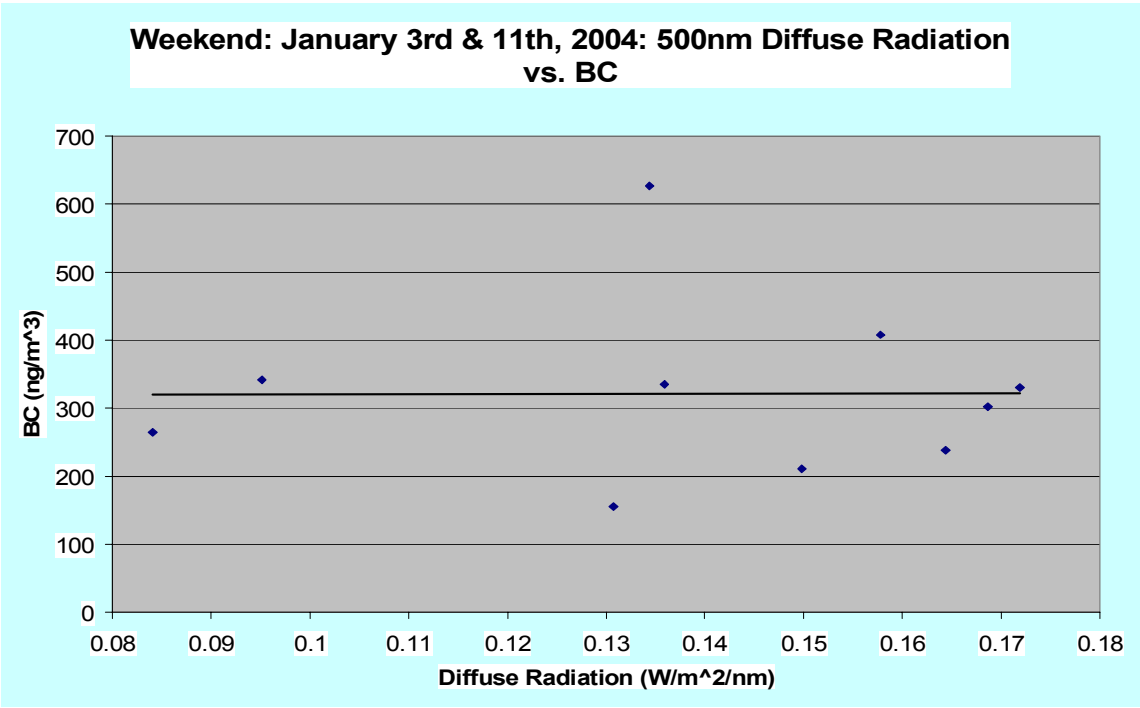

Figure 218. January 2004 Weekend 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

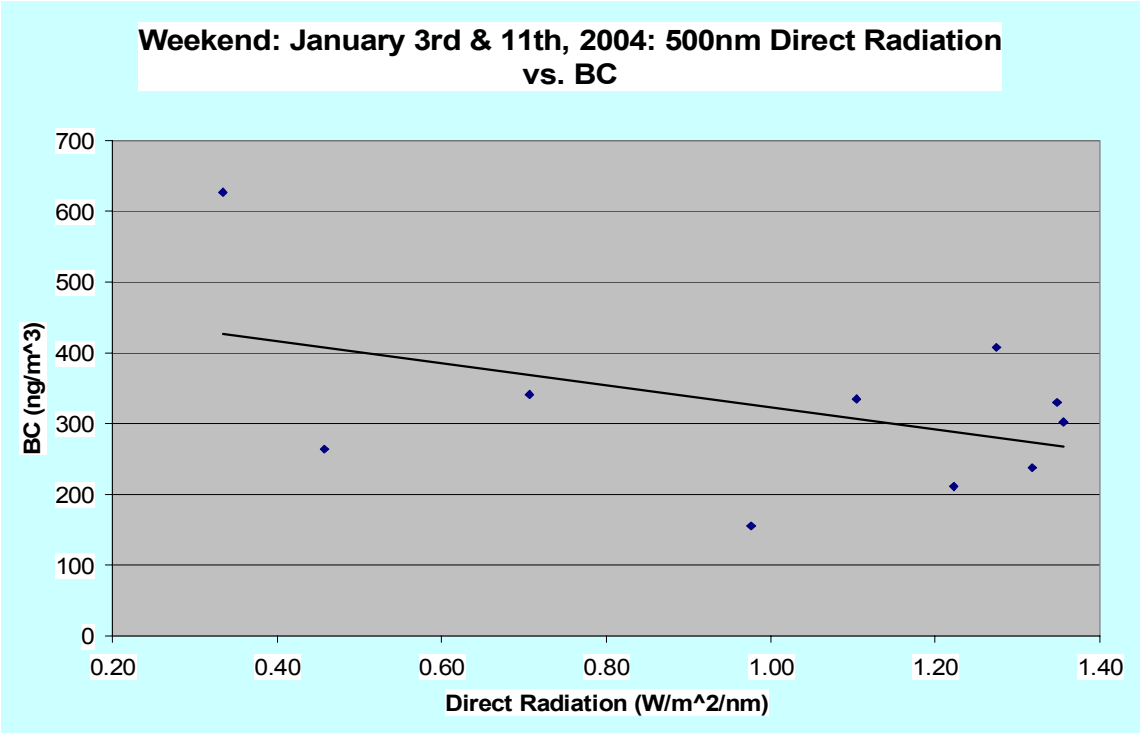

Figure 219. January 2004 Weekend 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

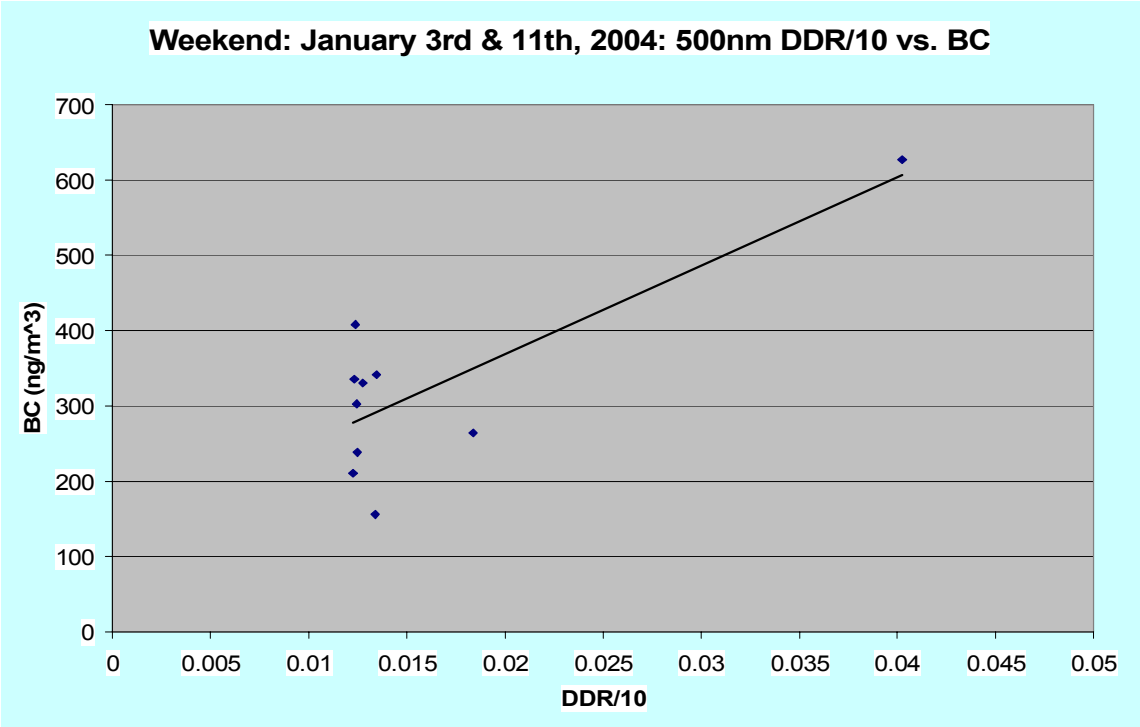

Figure 220. January 2004 Weekend 500nm DDR/10 vs. BC Concentrations (ng/m^3)

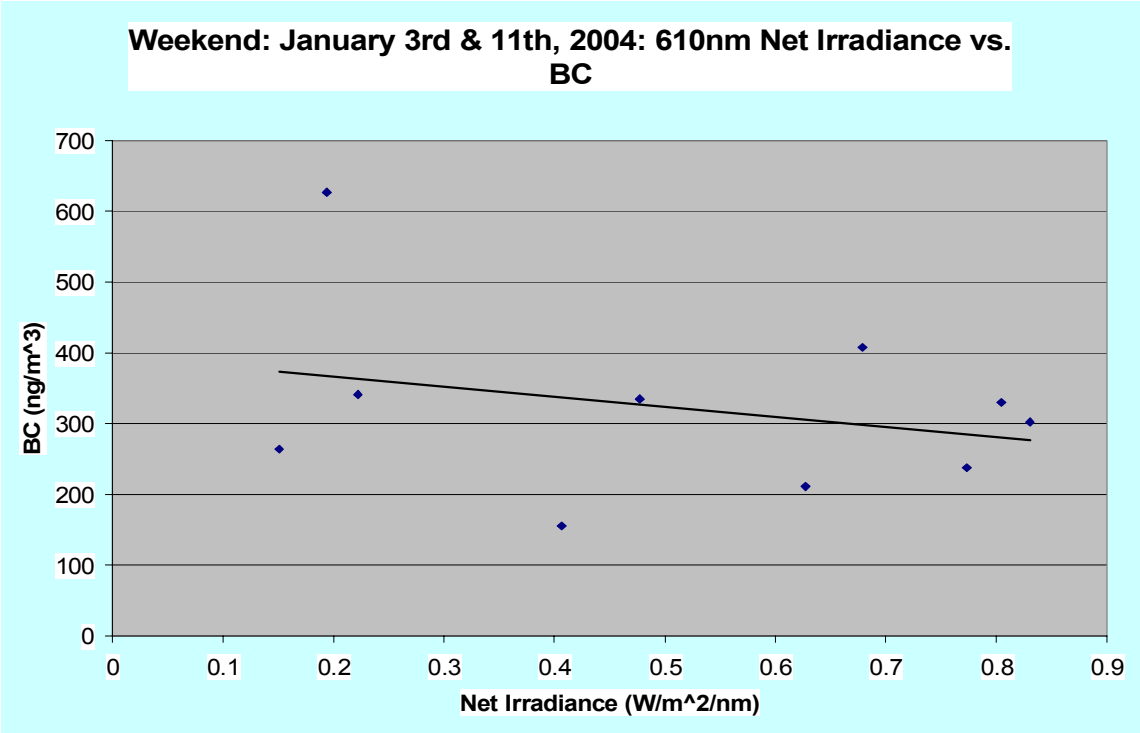

Figure 221. January 2004 Weekend 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

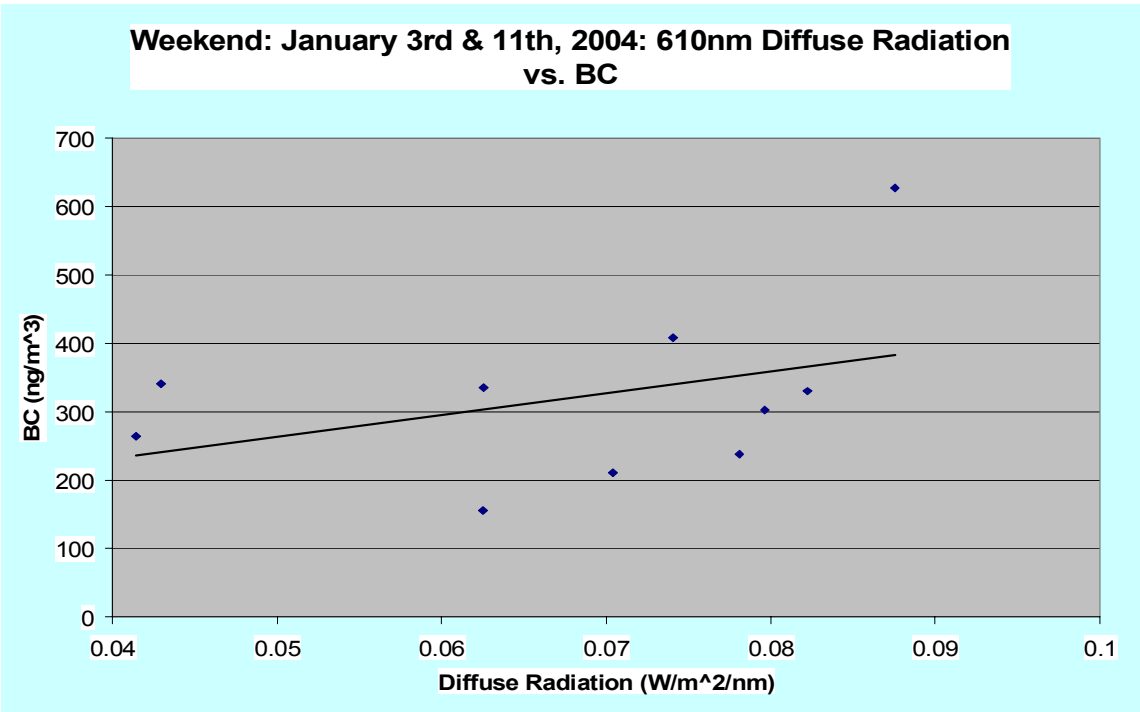

Figure 222. January 2004 Weekend 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

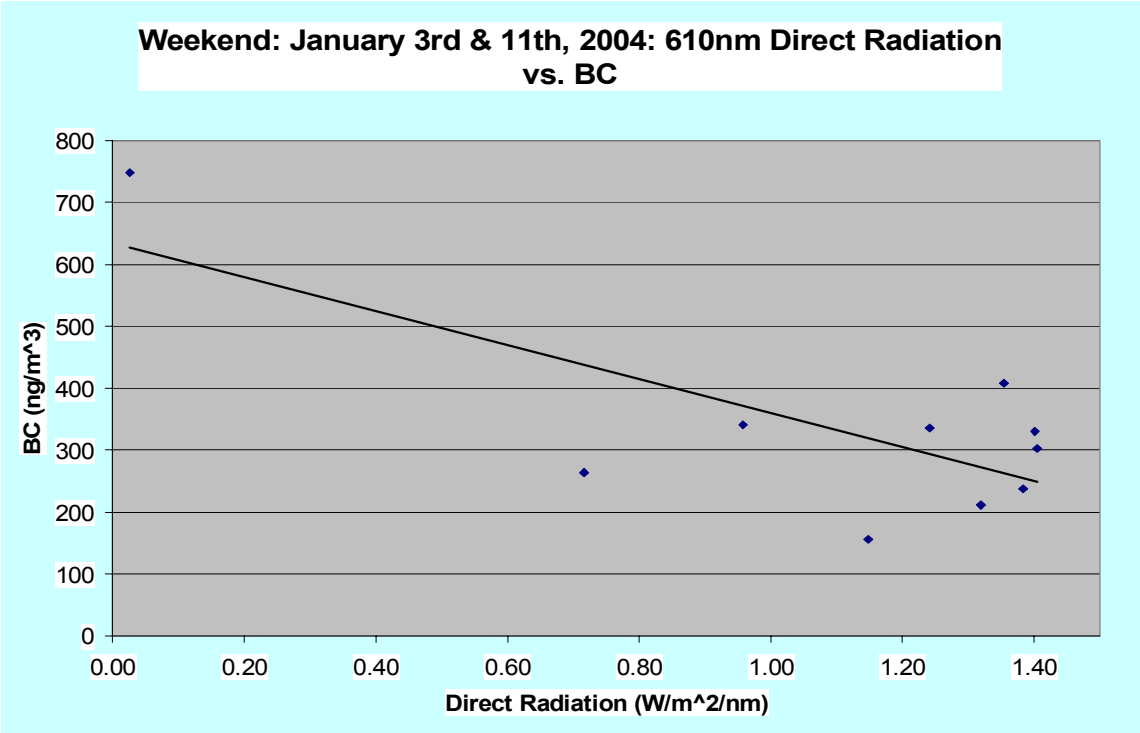

Figure 223. January 2004 Weekend 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

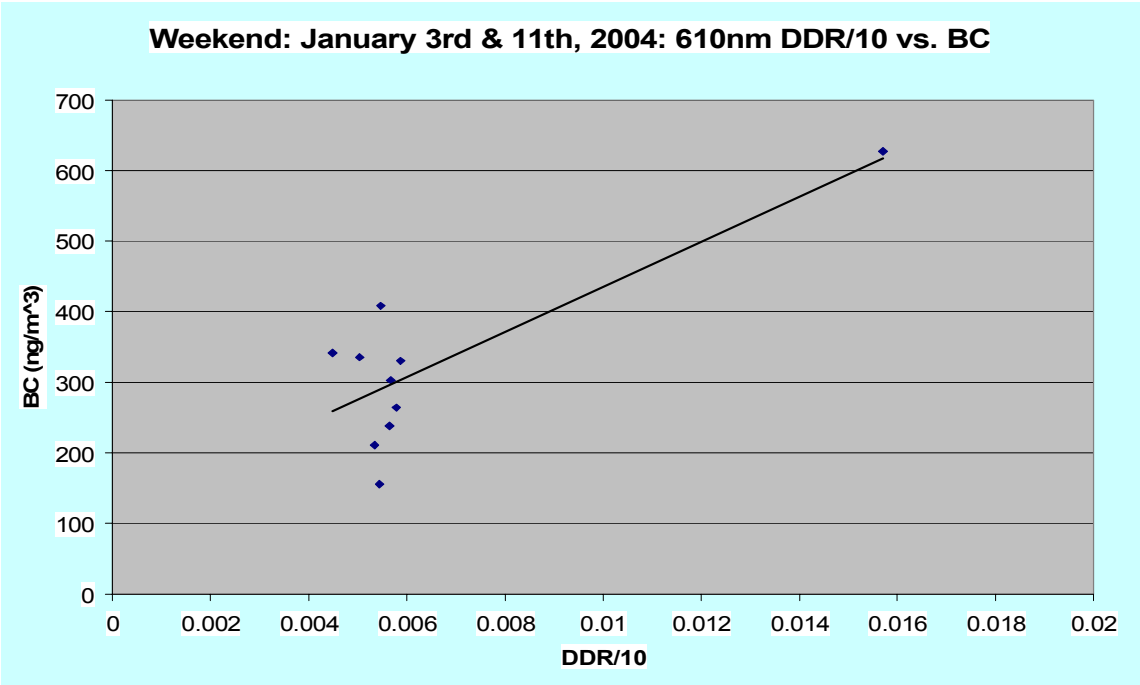

Figure 224. January 2004 Weekend 610nm DDR/10 vs. BC Concentrations (ng/m^3)

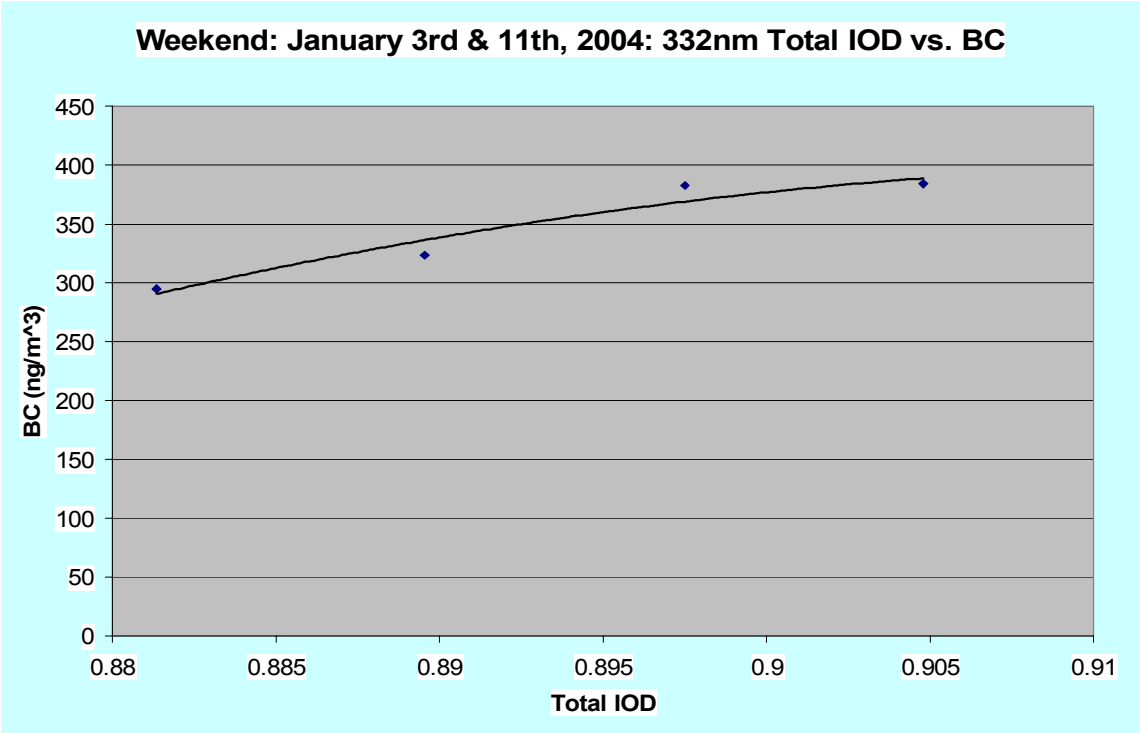

Figure 225. January 2004 Weekend 332nm Total IOD vs. BC Concentrations (ng/m^3)

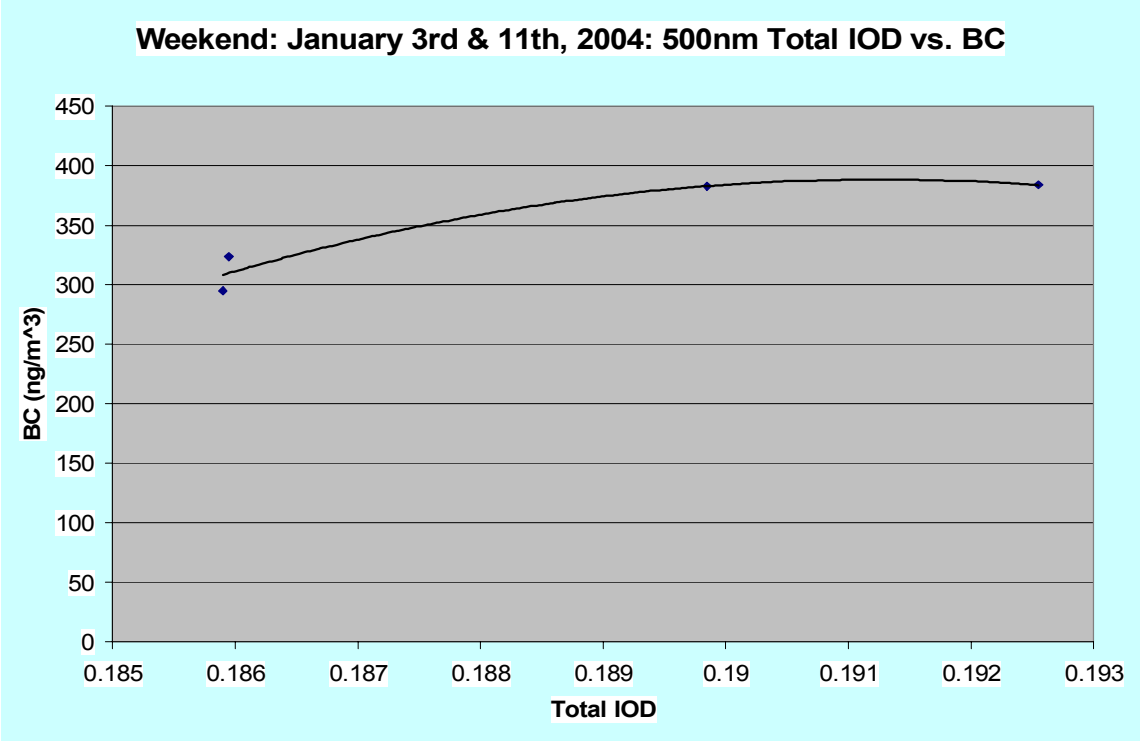

Figure 226. January 2004 Weekend 500nm Total IOD vs. BC Concentrations (ng/m^3)

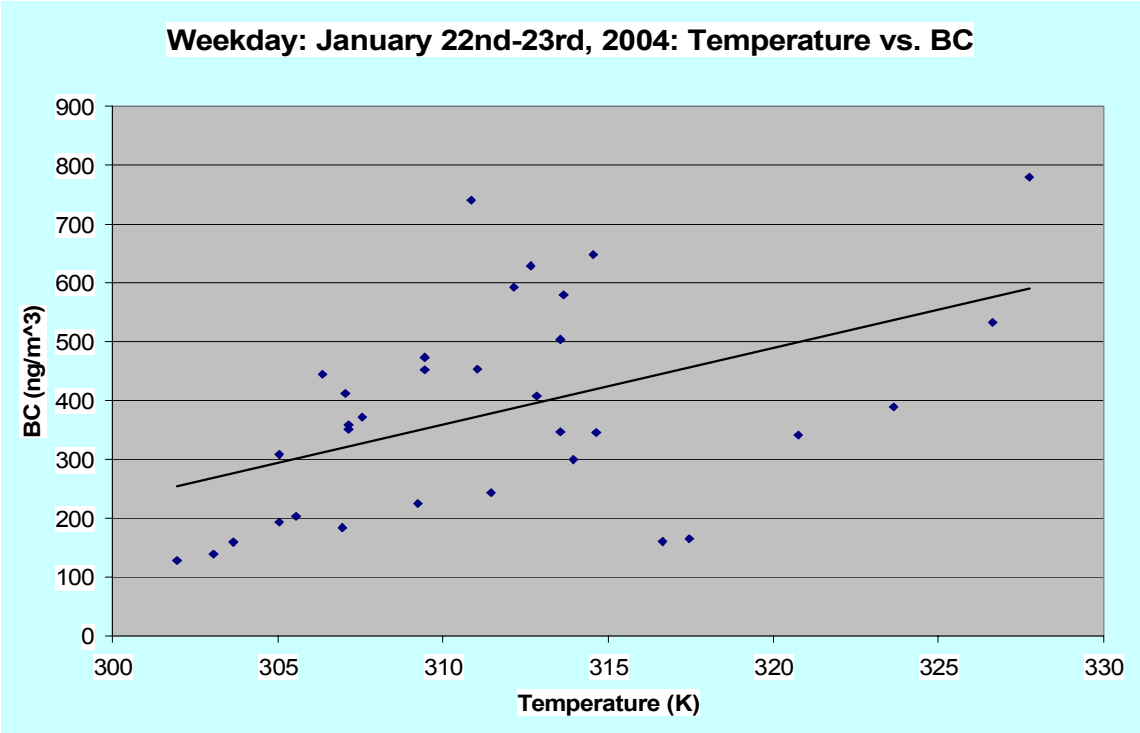

Figure 227. January 2004 Weekdays Temperature (K) vs. BC Concentrations (ng/m^3)

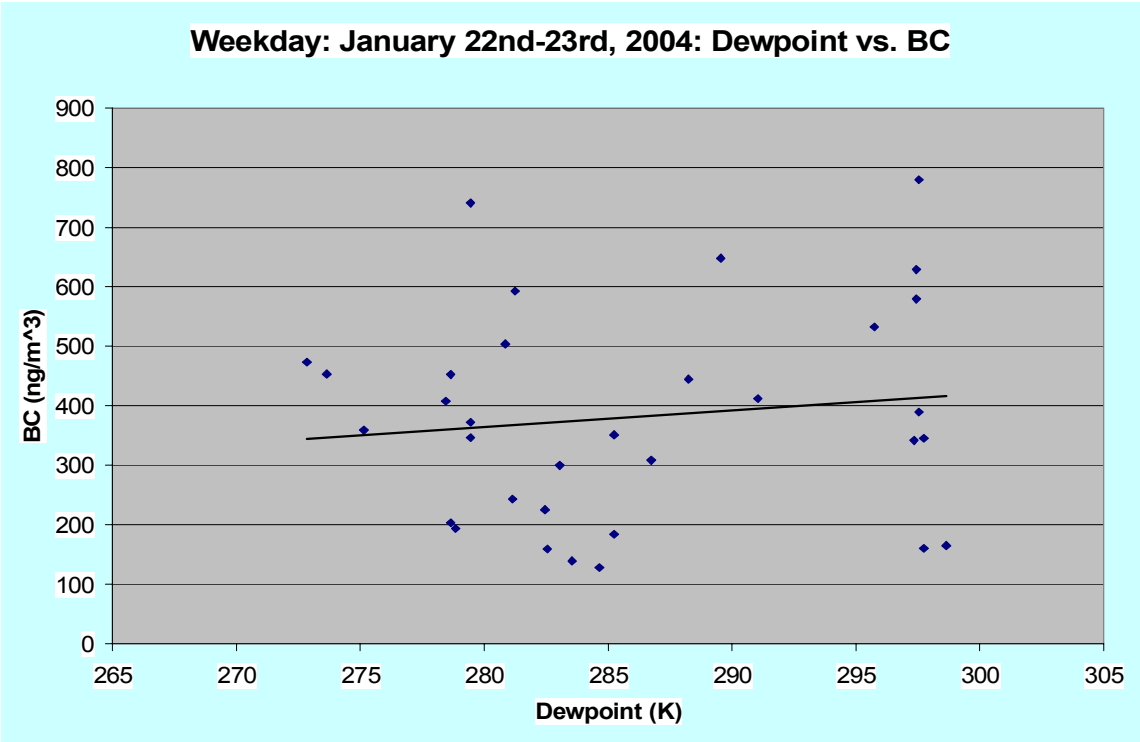

Figure 228. January 2004 Weekdays Dewpoint (K) vs. BC Concentrations (ng/m^3)

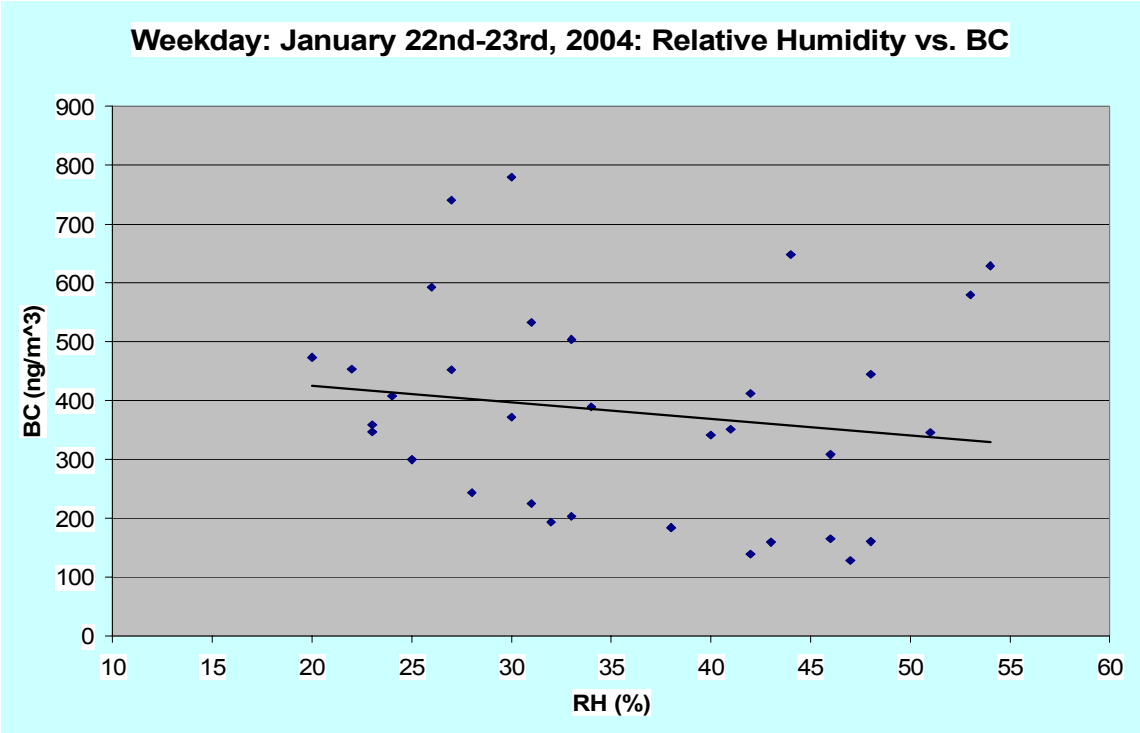

Figure 229. January 2004 Weekdays Relative Humidity (%) vs. BC Concentrations (ng/m^3)

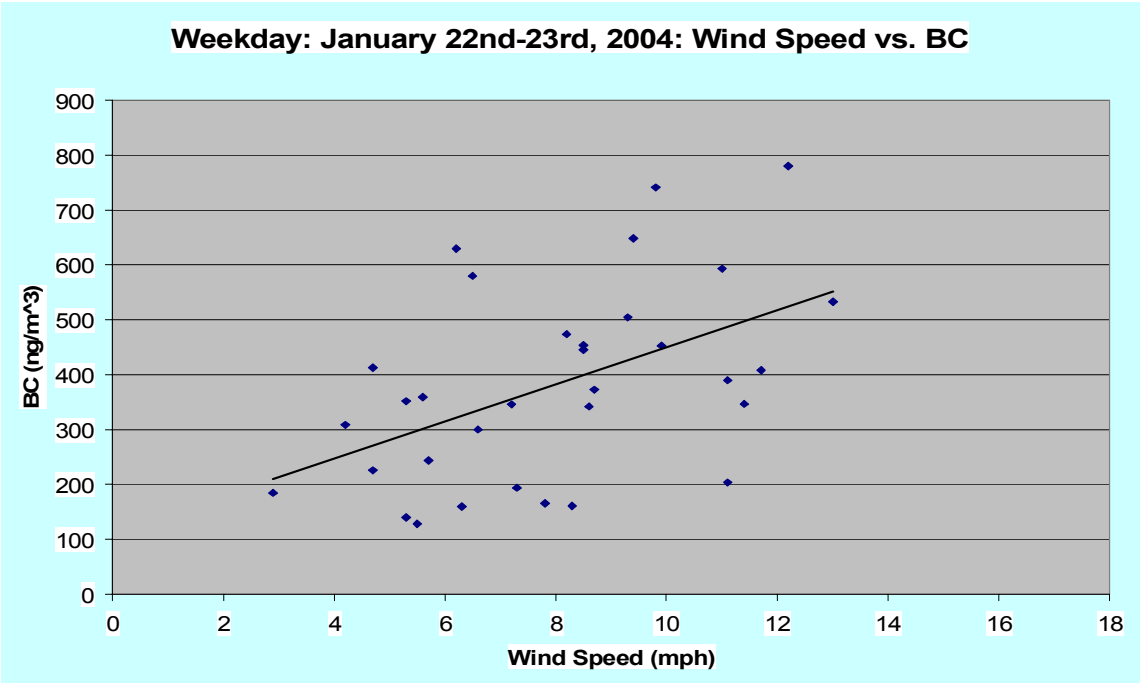

Figure 230. January 2004 Weekdays Wind Speed (mph) vs. BC Concentrations (ng/m^3)

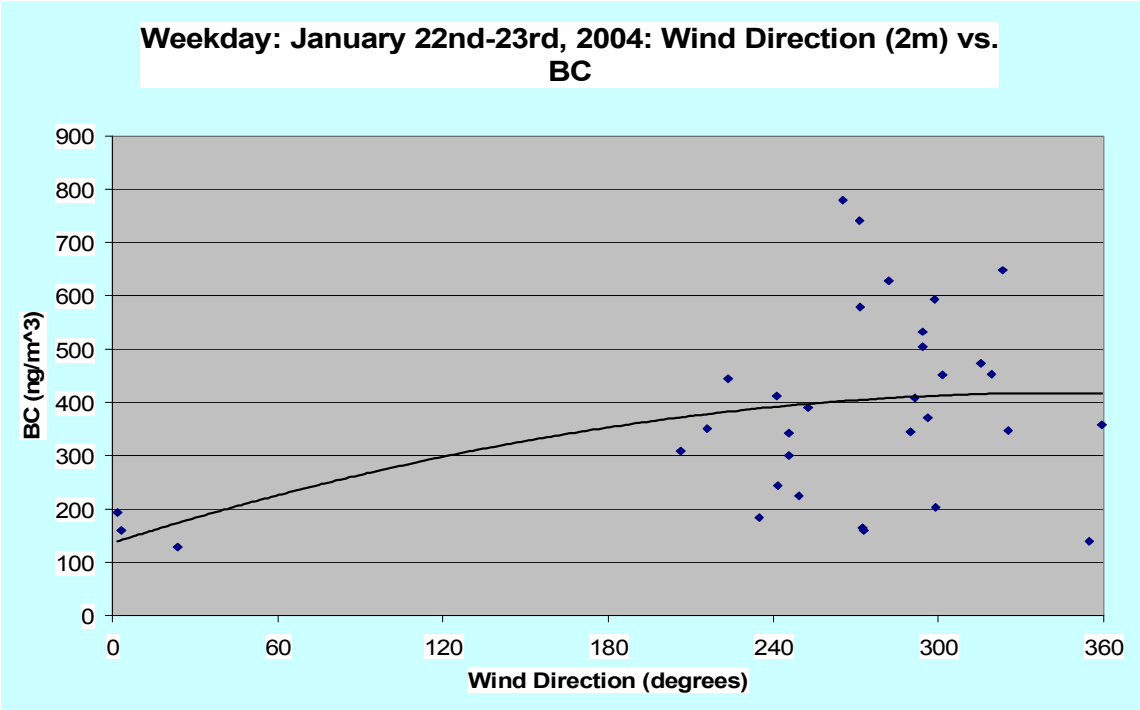

Figure 231. January 2004 Weekdays Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

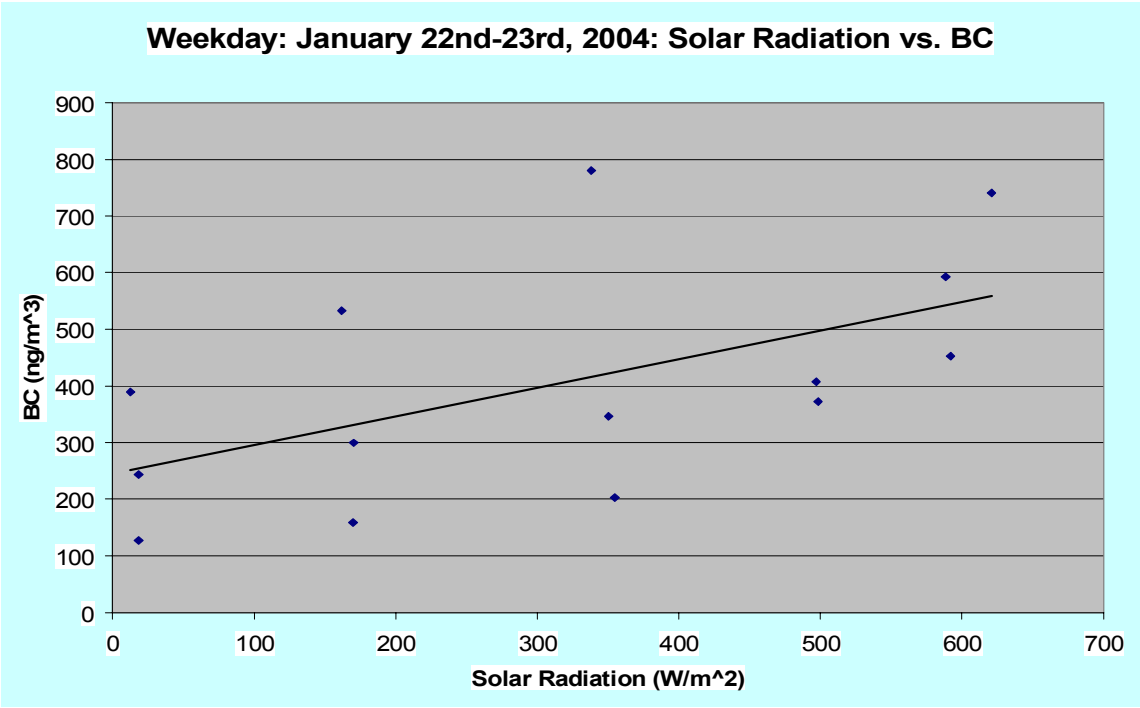

Figure 232. January 2004 Weekdays Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

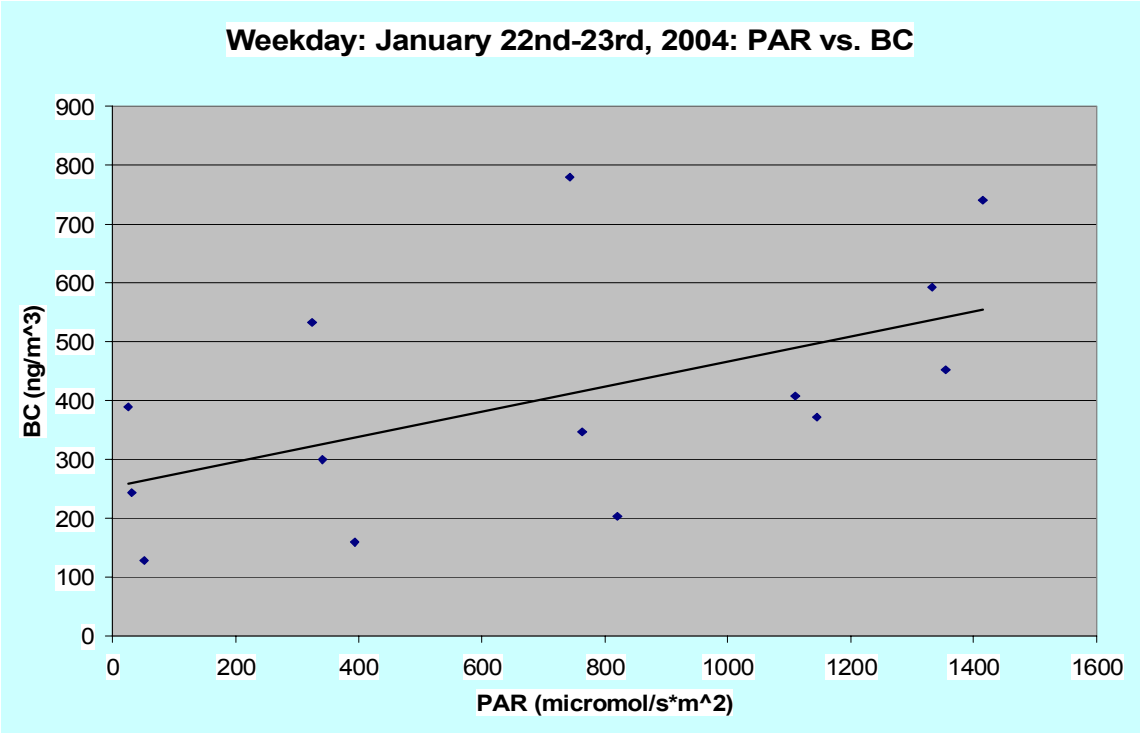

Figure 233. January 2004 Weekdays PAR (micromol/s*m^2) vs. BC Concentrations (ng/m^3)

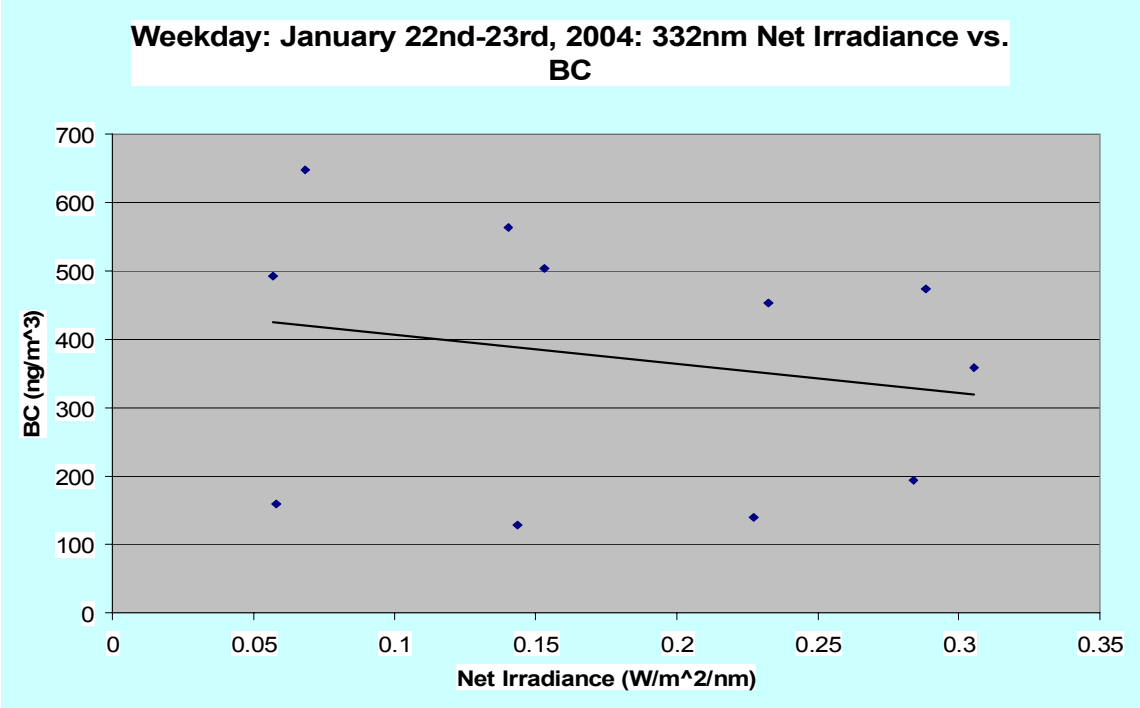

Figure 234. January 2004 Weekdays 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

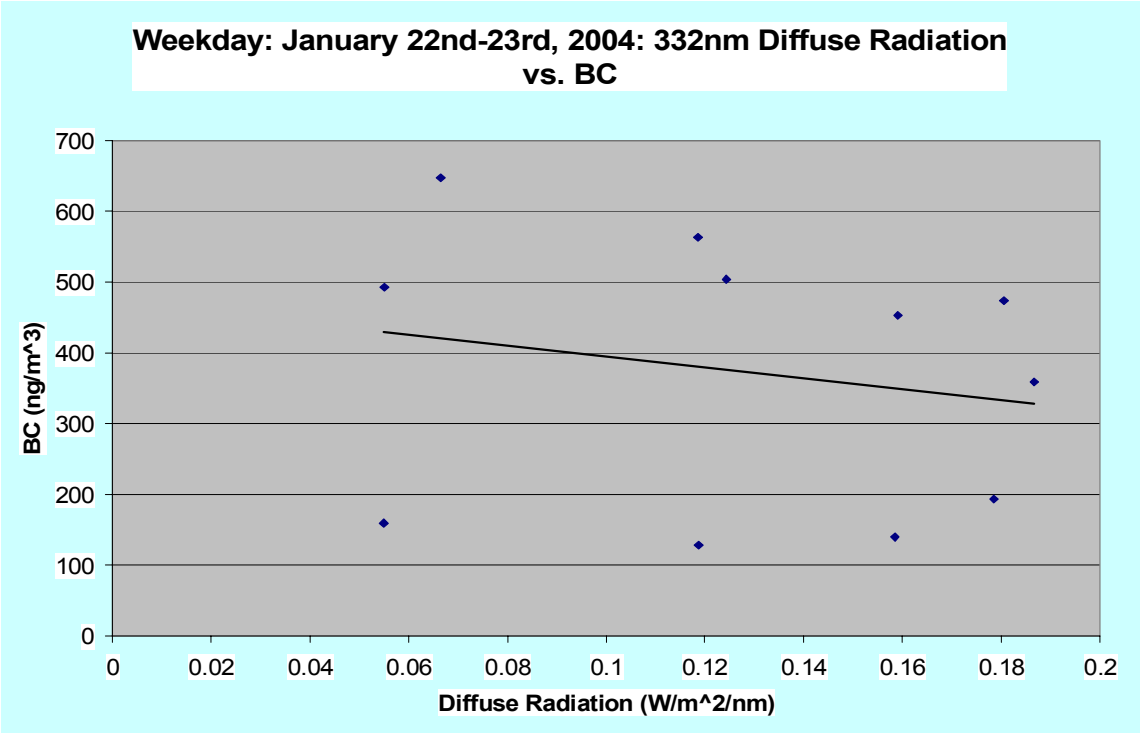

Figure 235. January 2004 Weekdays 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

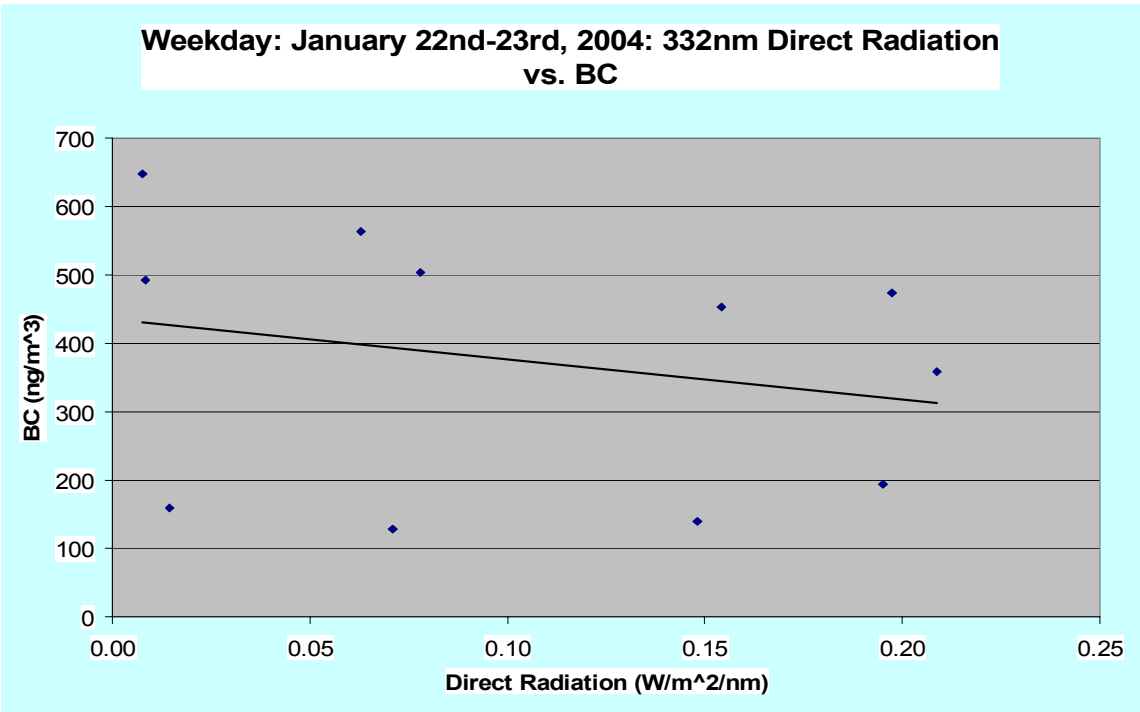

Figure 236. January 2004 Weekdays 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

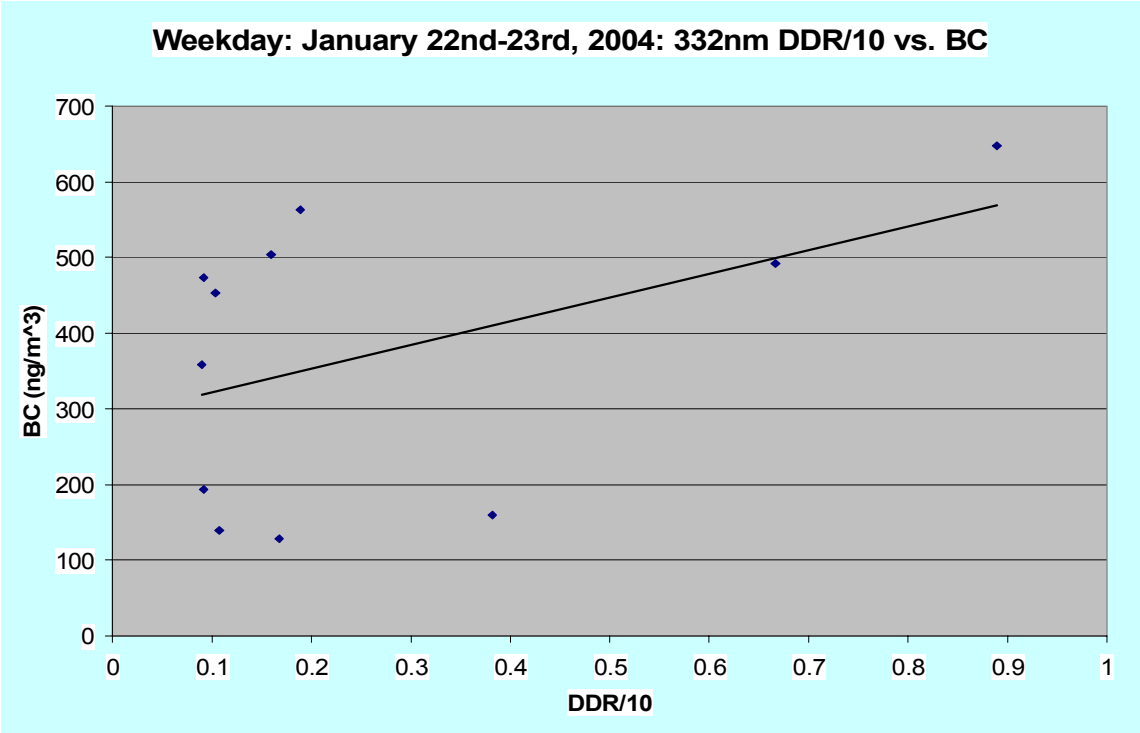

Figure 237. January 2004 Weekdays 332nm DDR/10 s. BC Concentrations (ng/m^3)

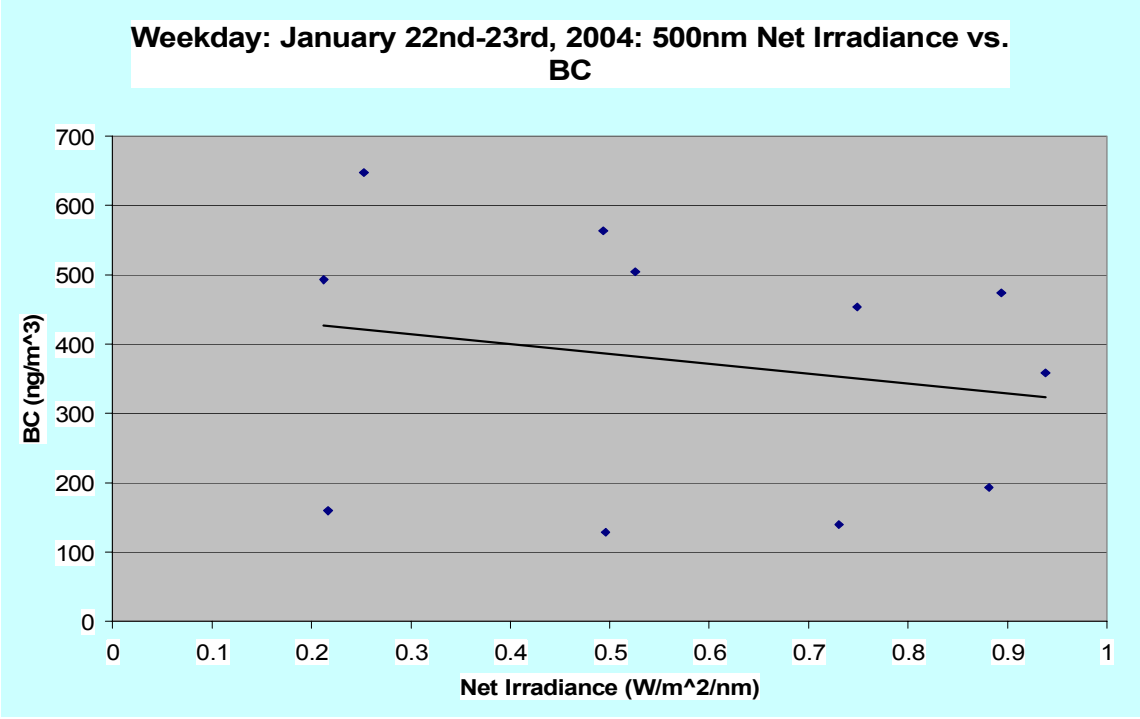

Figure 238. January 2004 Weekdays 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

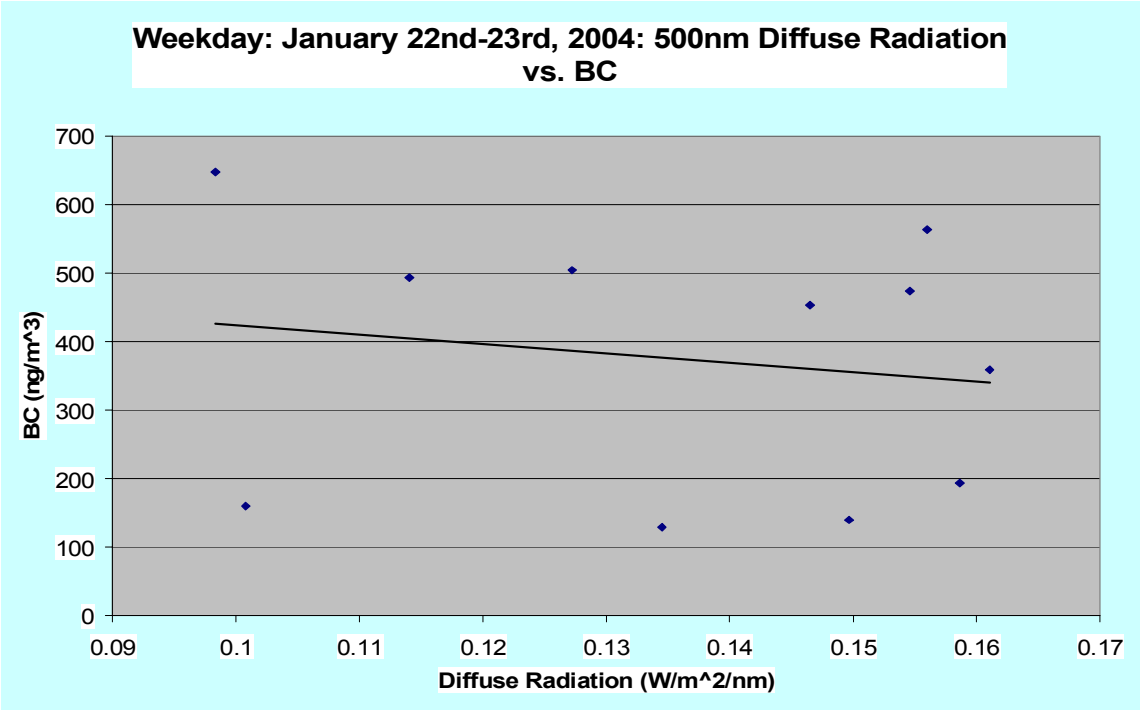

Figure 239. January 2004 Weekdays 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

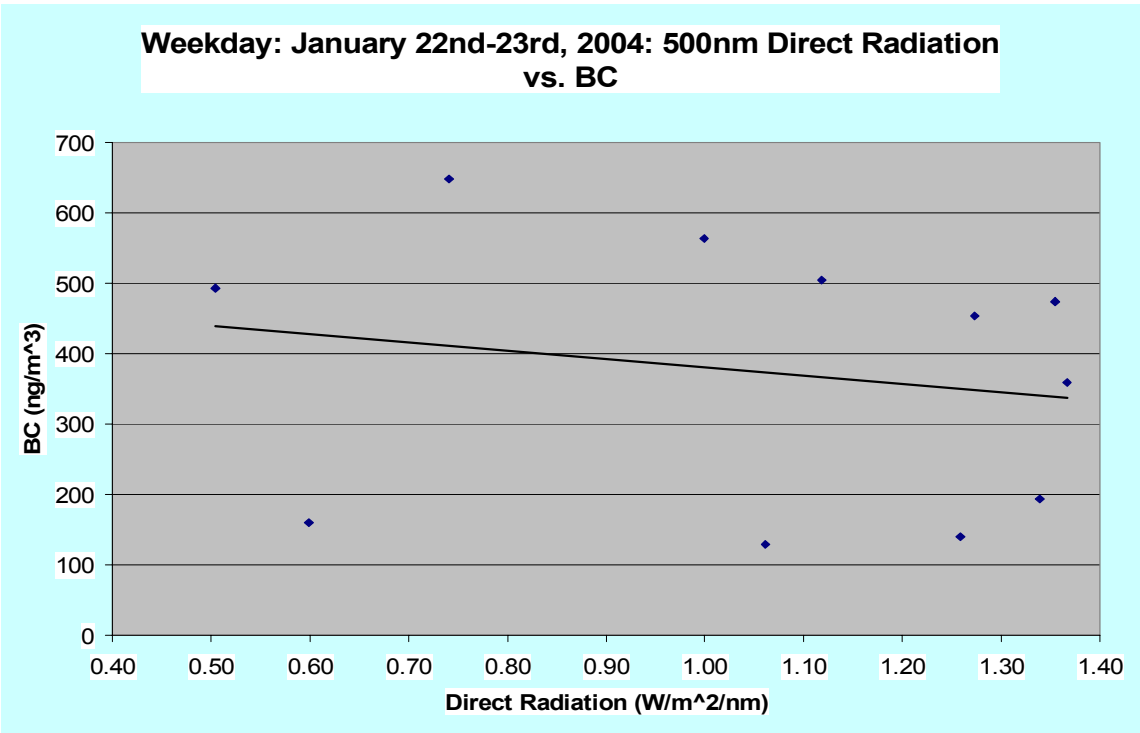

Figure 240. January 2004 Weekdays 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

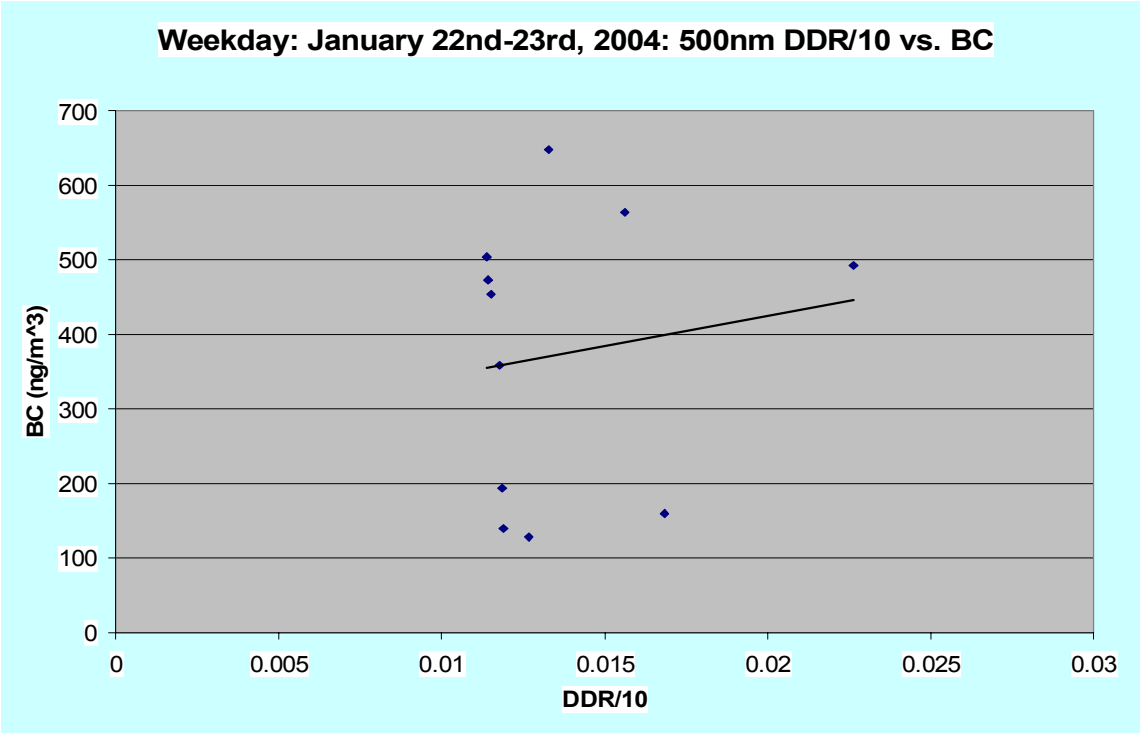

Figure 241. January 2004 Weekdays 500nm DDR/10 vs. BC Concentrations (ng/m^3)

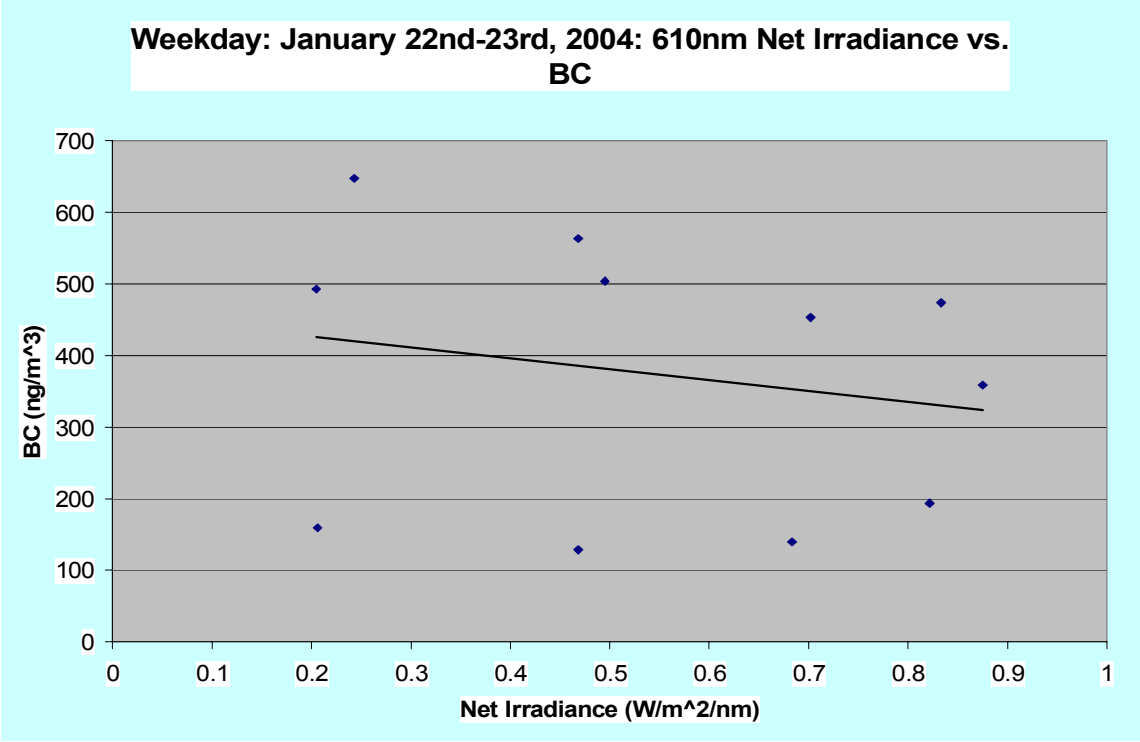

Figure 242. January 2004 Weekdays 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

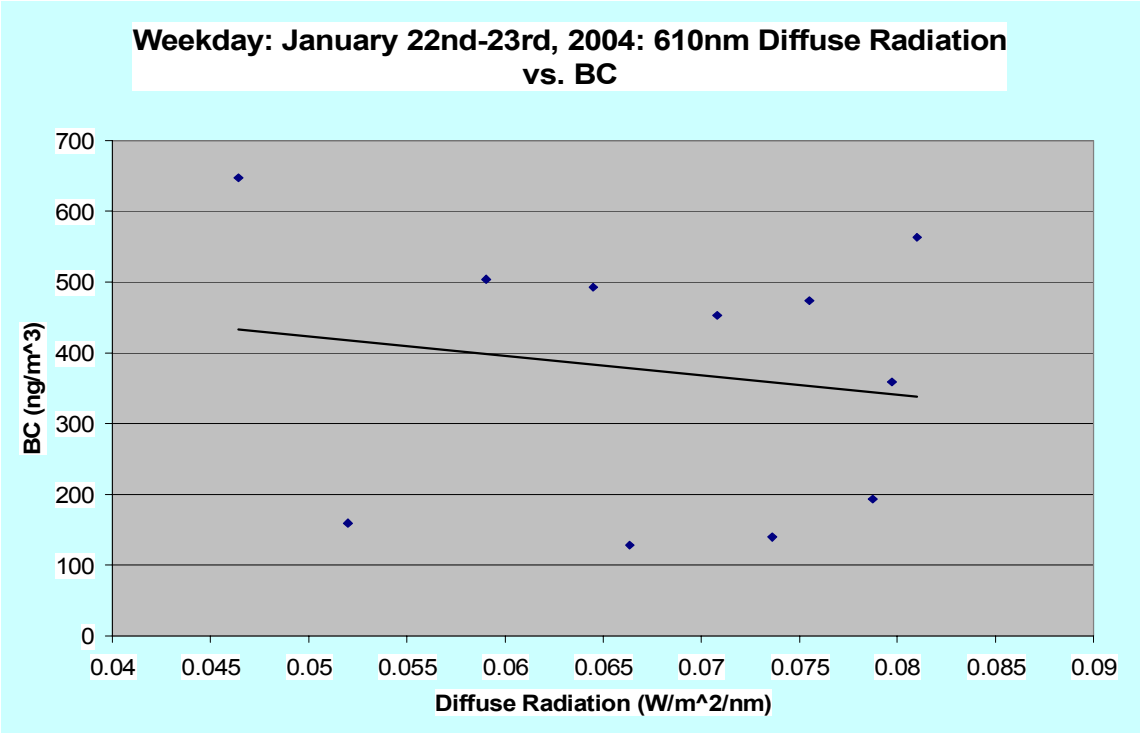

Figure 243. January 2004 Weekdays 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

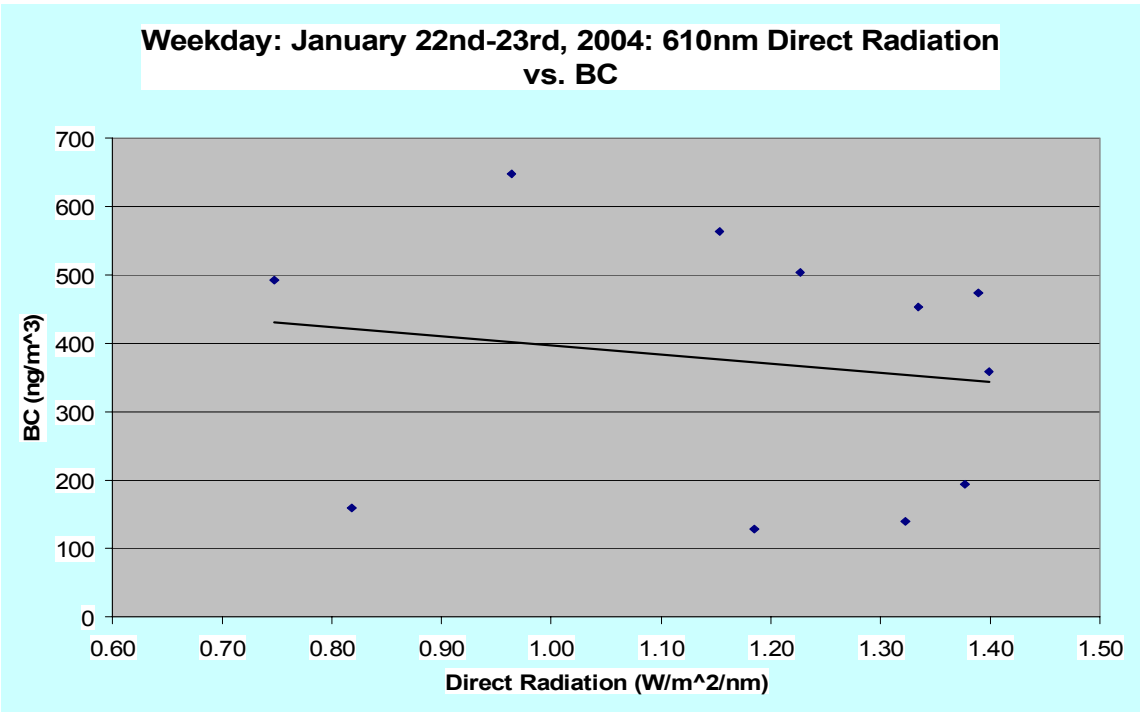

Figure 244. January 2004 Weekdays 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

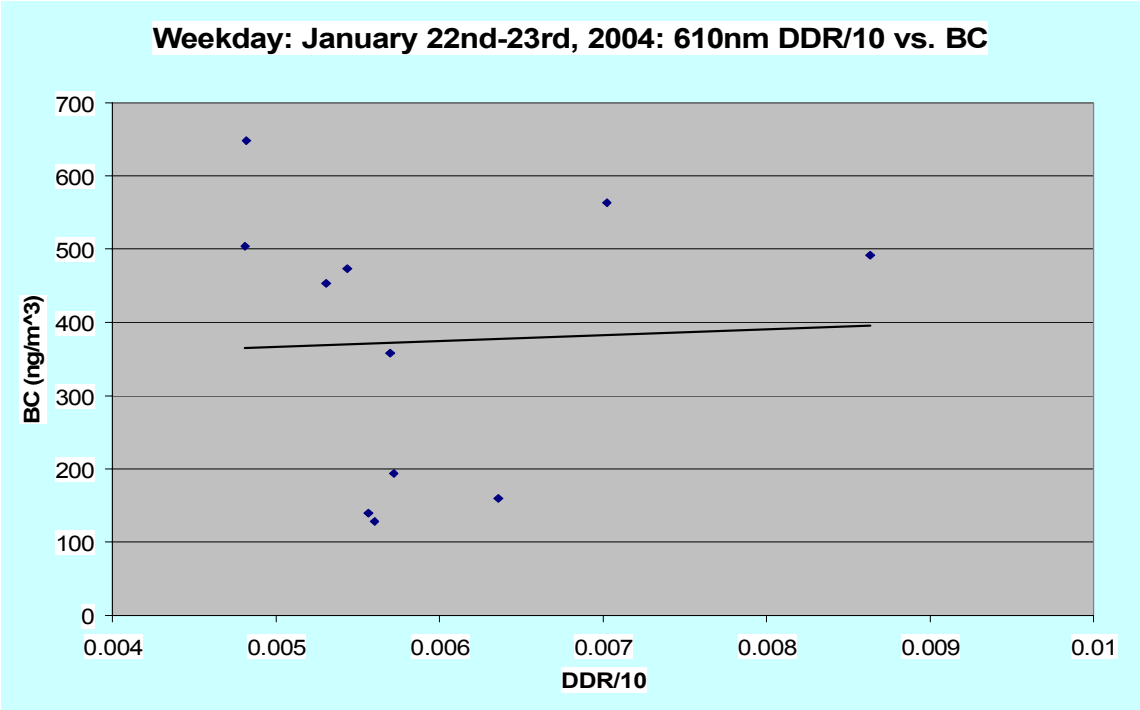

Figure 245. January 2004 Weekdays 610nm DDR/10 vs. BC Concentrations (ng/m^3)

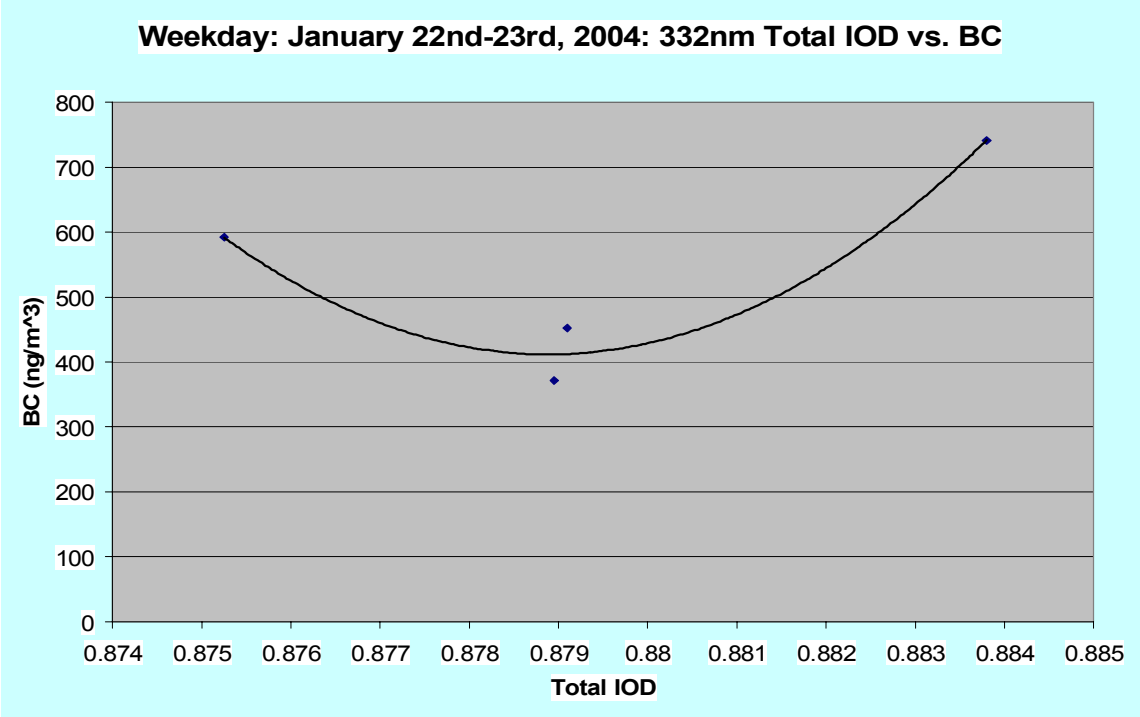

Figure 246. January 2004 Weekdays 332nm Total IOD vs. BC Concentrations (ng/m^3)

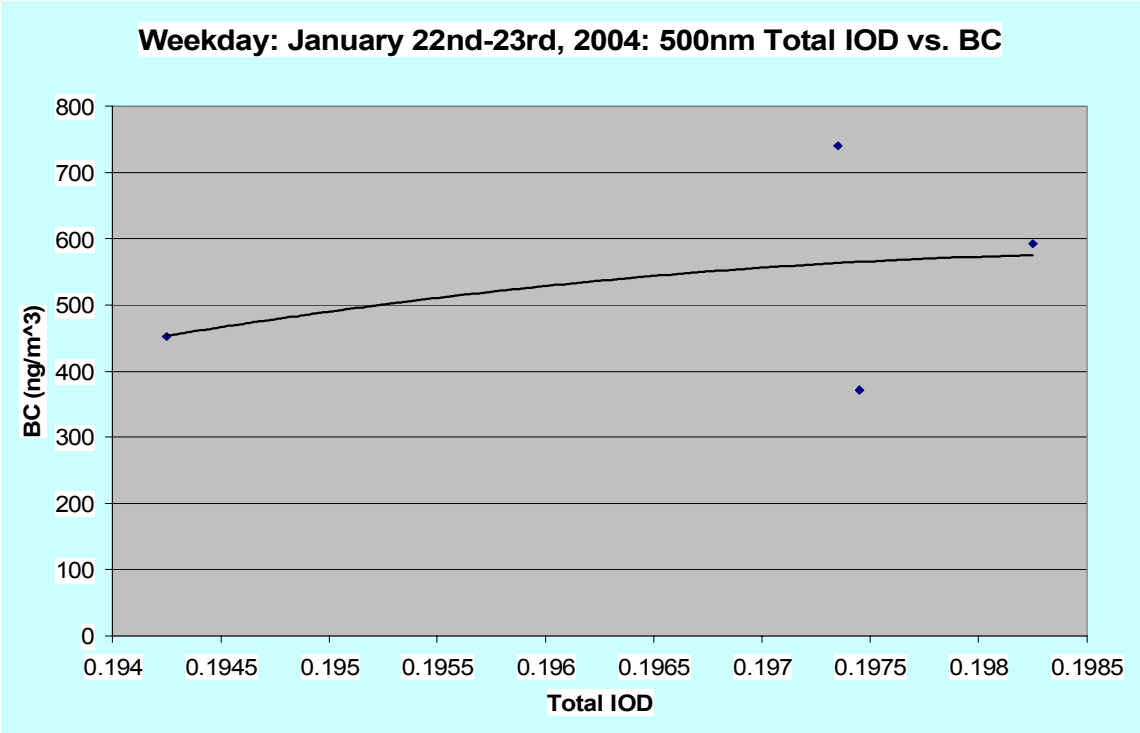

Figure 247. January 2004 Weekdays 500nm Total IOD vs. BC Concentrations (ng/m^3)

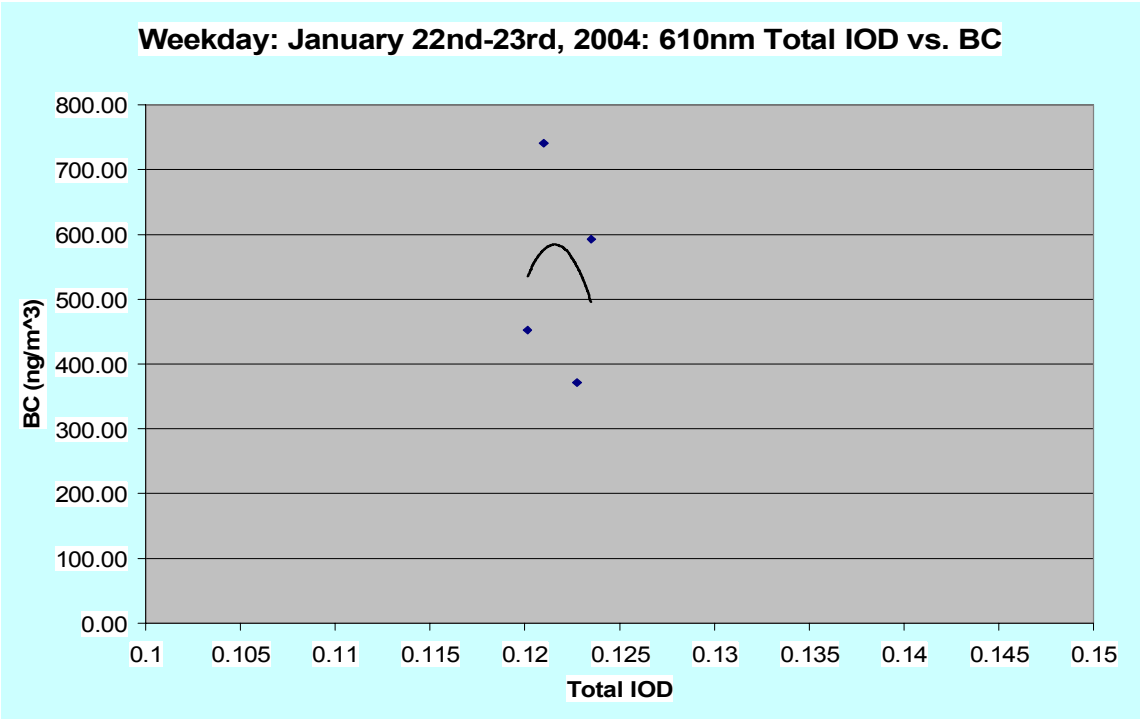

Figure 248. January 2004 Weekdays 610nm Total IOD vs. BC Concentrations (ng/m^3)

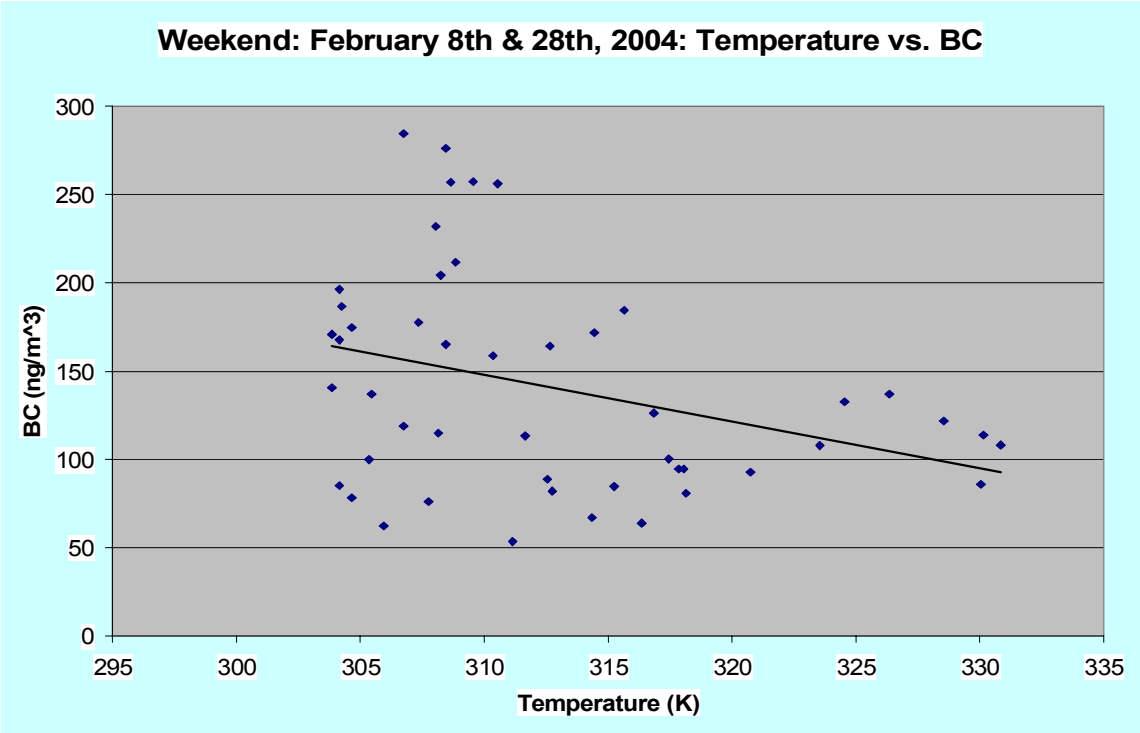

Figure 249. February 2004 Weekend Temperature (K) vs. BC Concentrations (ng/m^3)

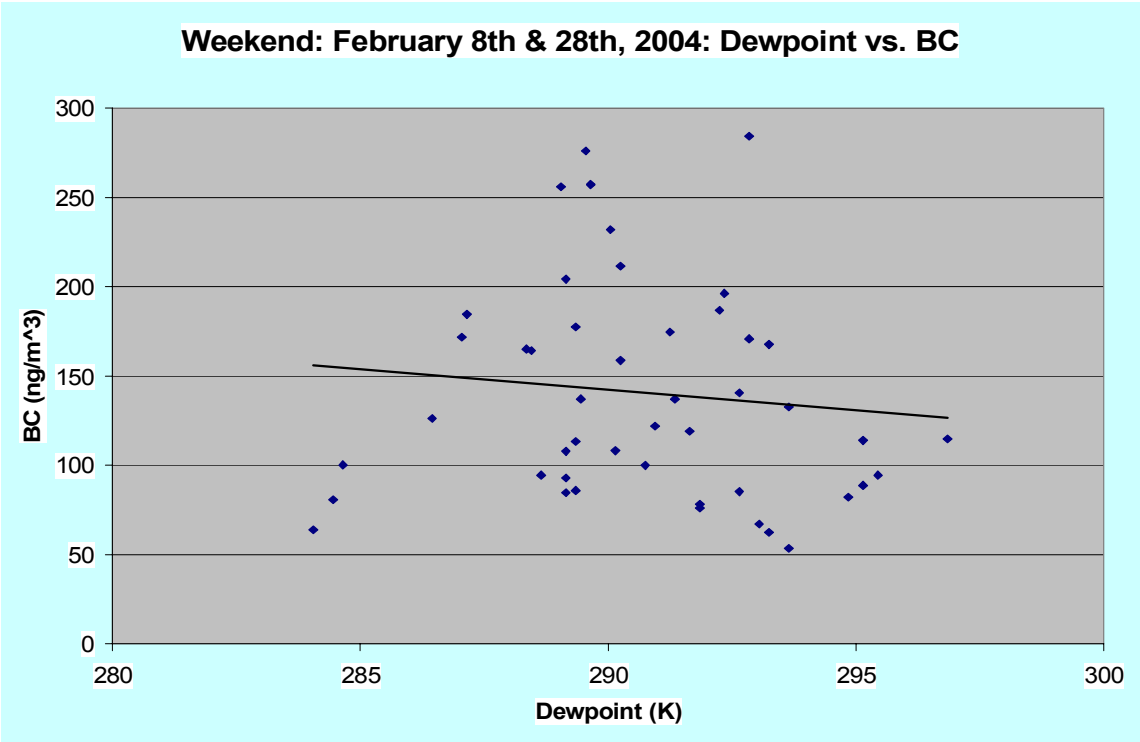

Figure 250. February 2004 Weekend Dewpoint (K) vs. BC Concentrations (ng/m^3)

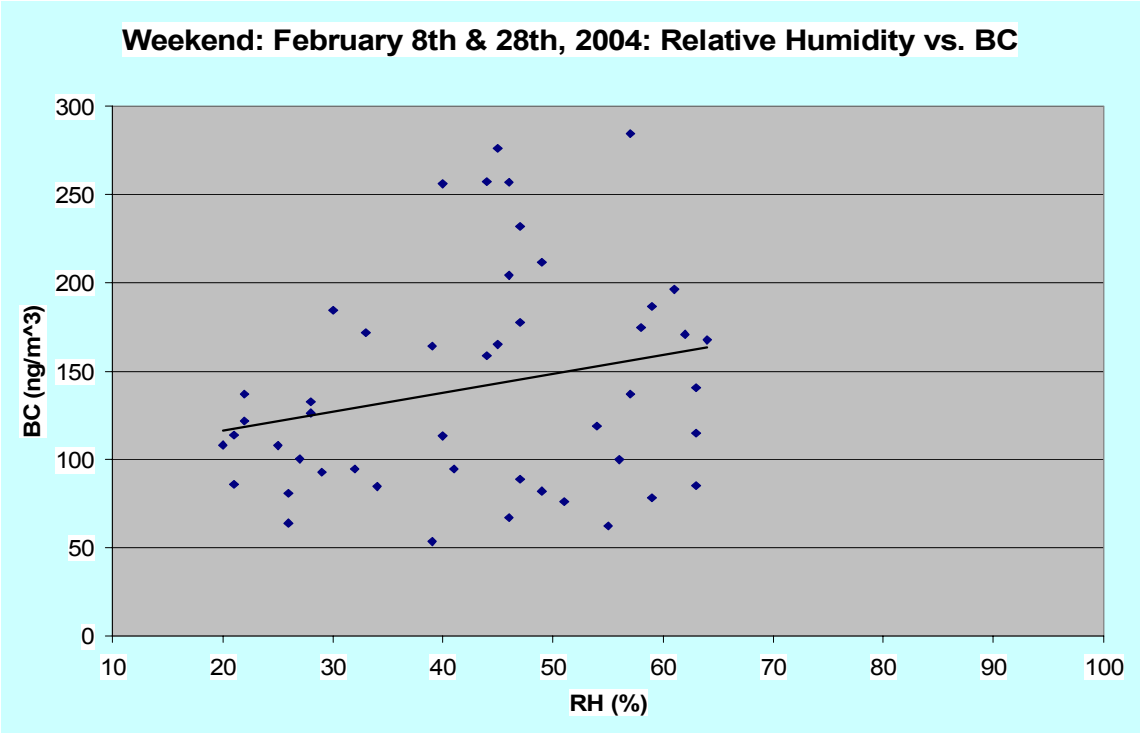

Figure 251. February 2004 Weekend Relative Humidity (%) vs. BC Concentrations (ng/m^3)

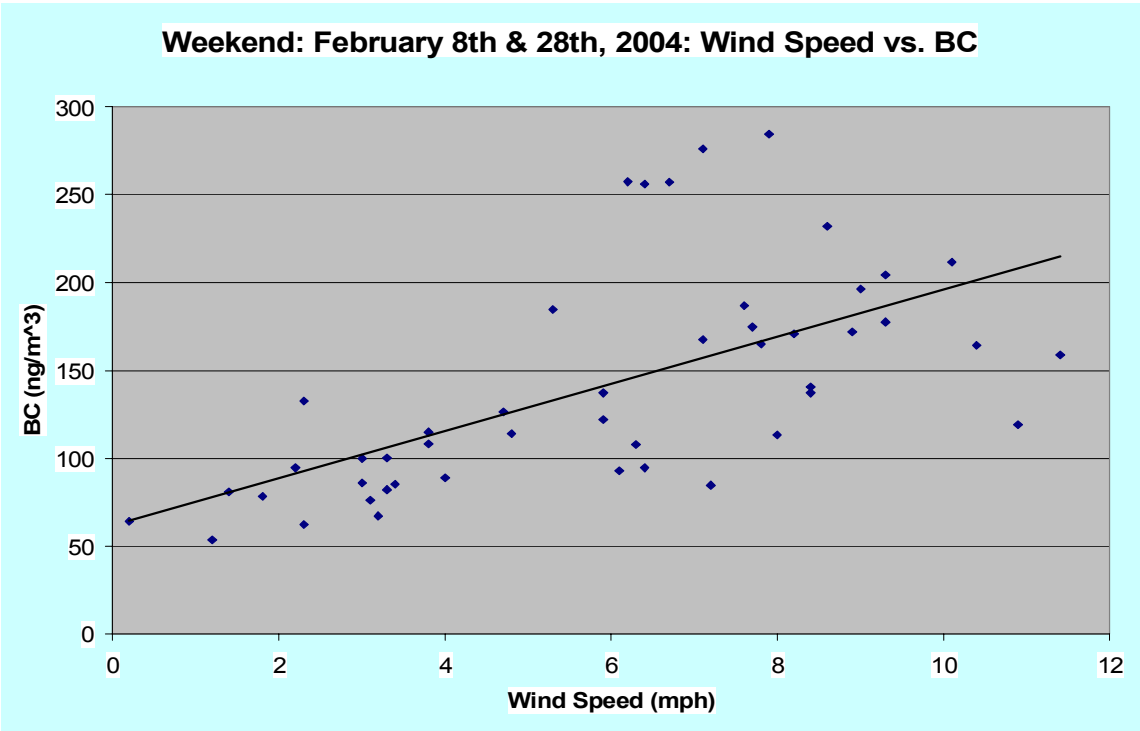

Figure 252. February 2004 Weekend Wind Speed (mph) vs. BC Concentrations (ng/m^3)

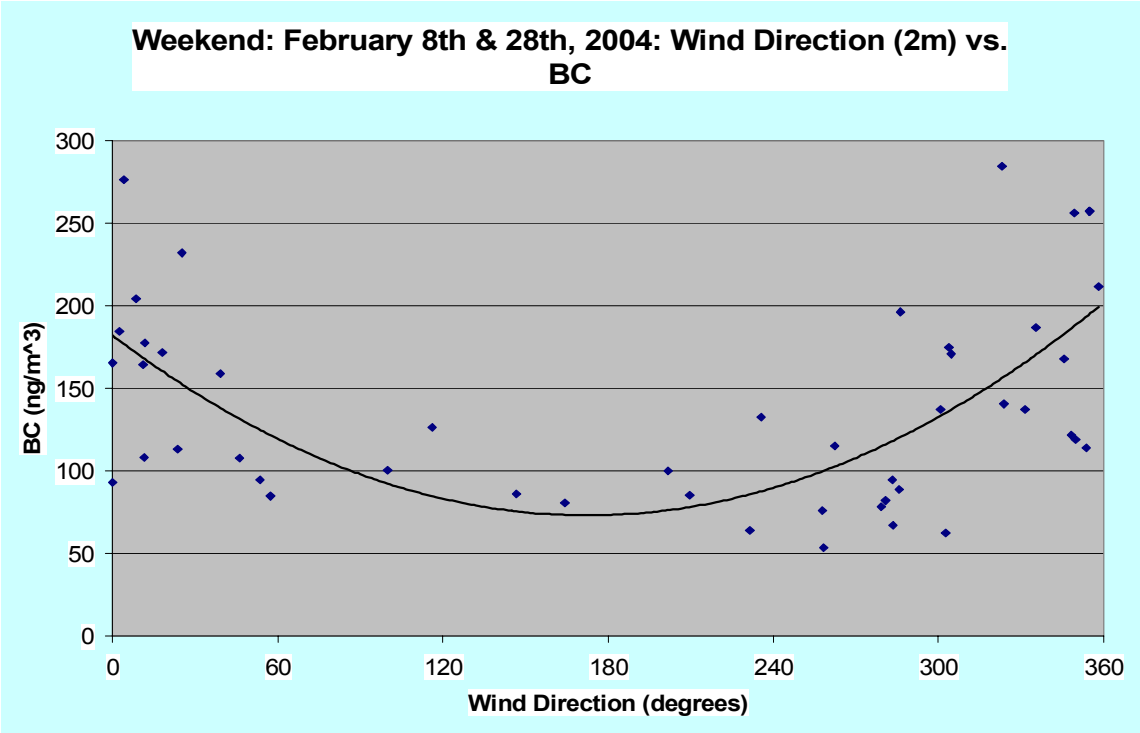

Figure 253. February 2004 Weekend Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

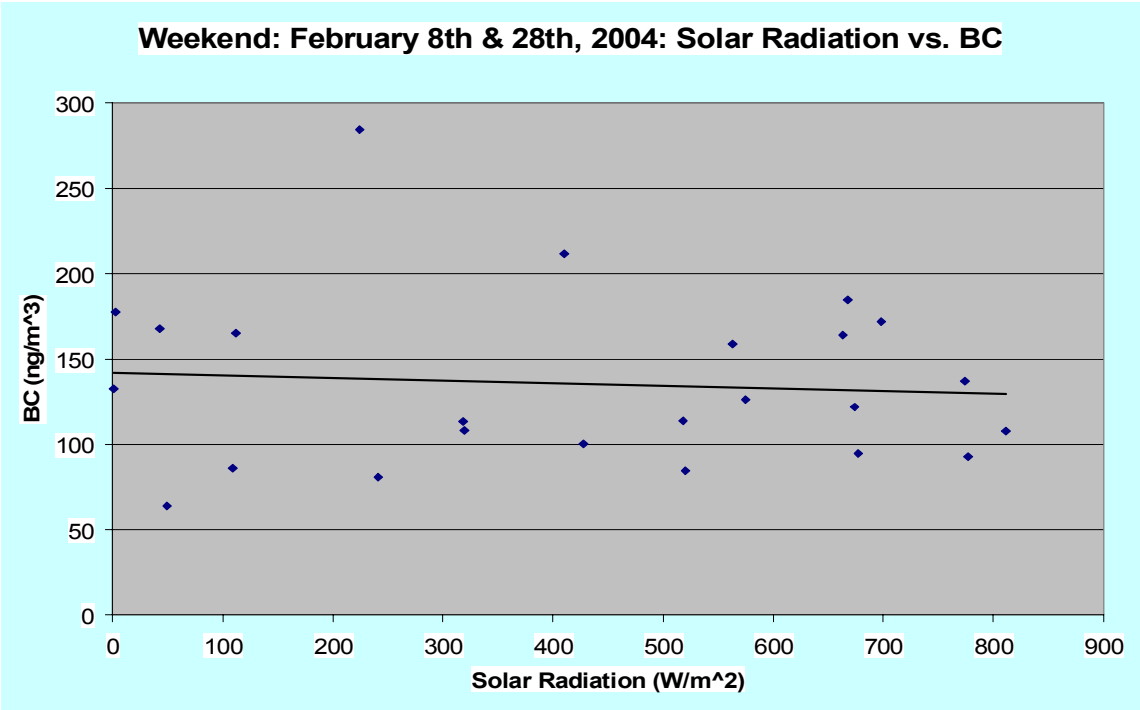

Figure 254. February 2004 Weekend Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

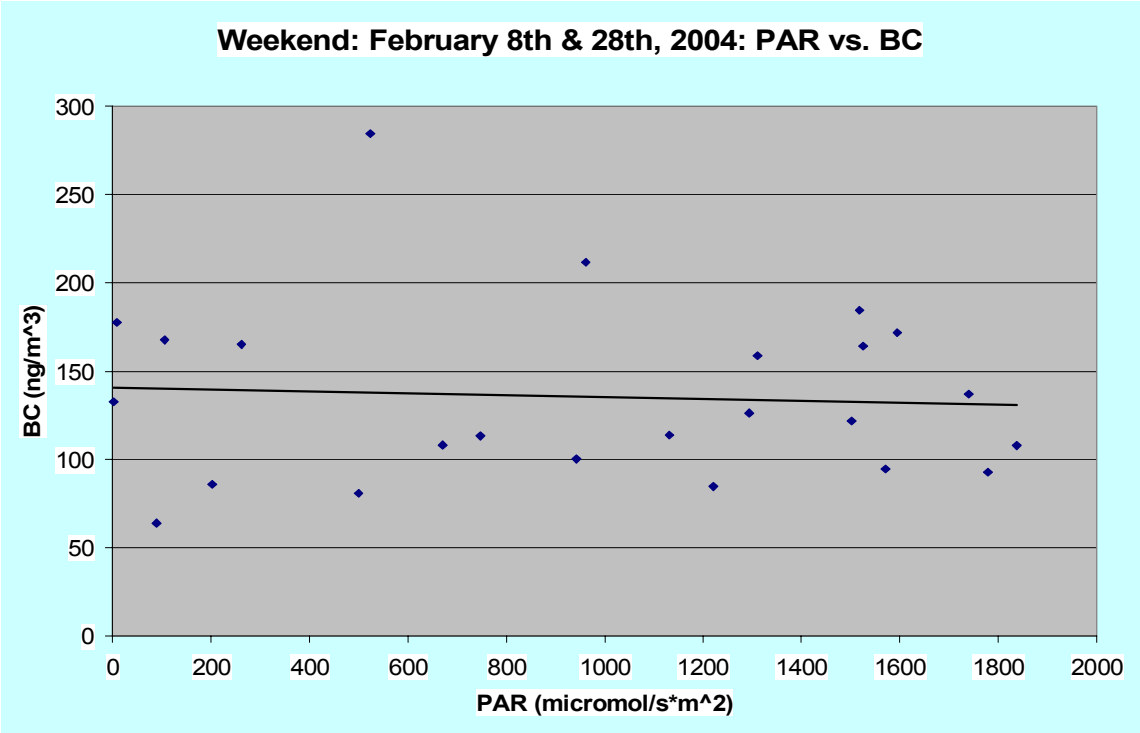

Figure 255. February 2004 Weekend PAR (micromole/s*m^2) vs. BC Concentrations (ng/m^3)

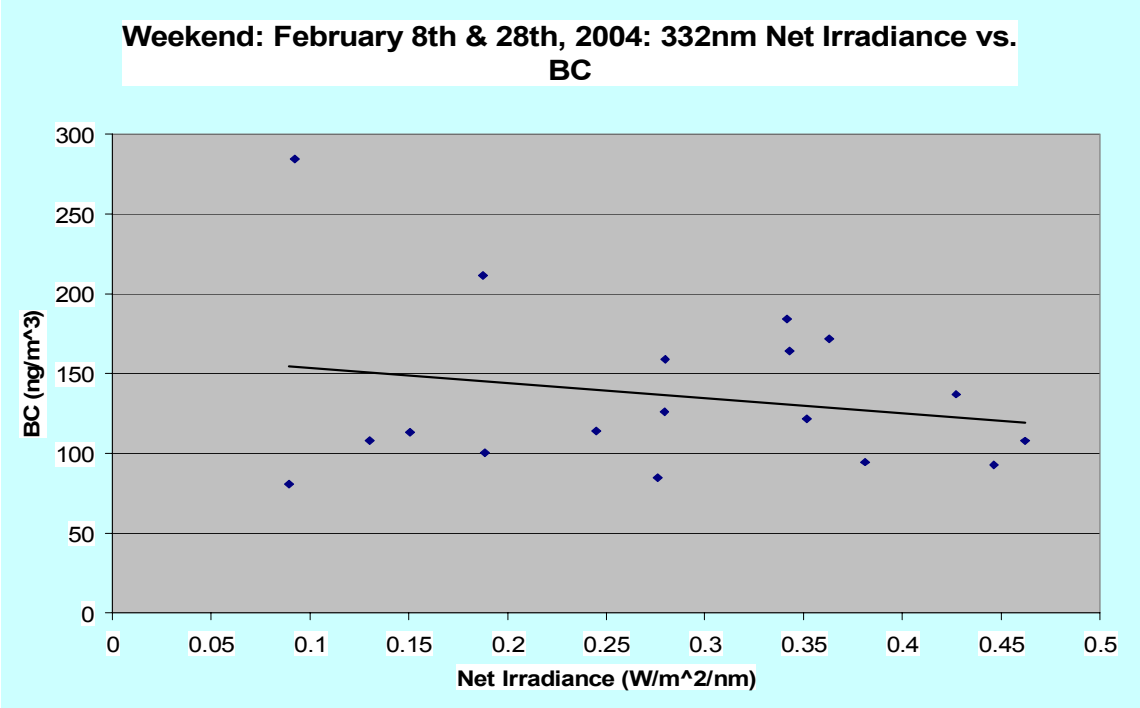

Figure 256. February 2004 Weekend 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

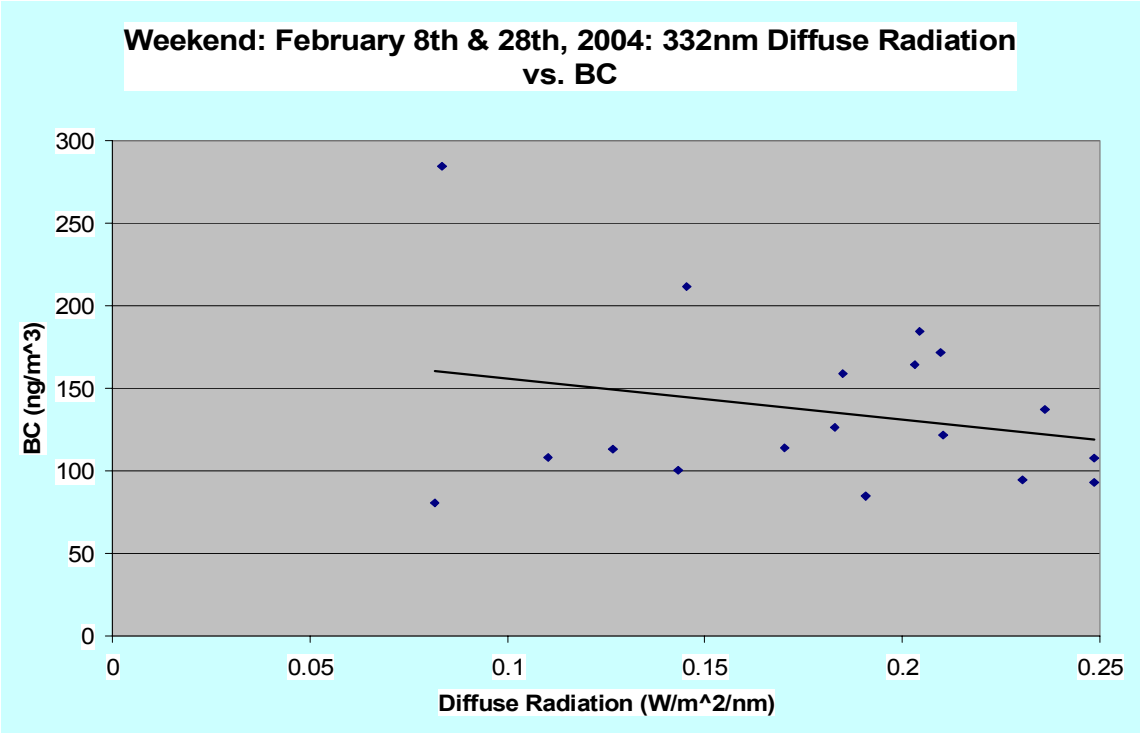

Figure 257. February 2004 Weekend 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

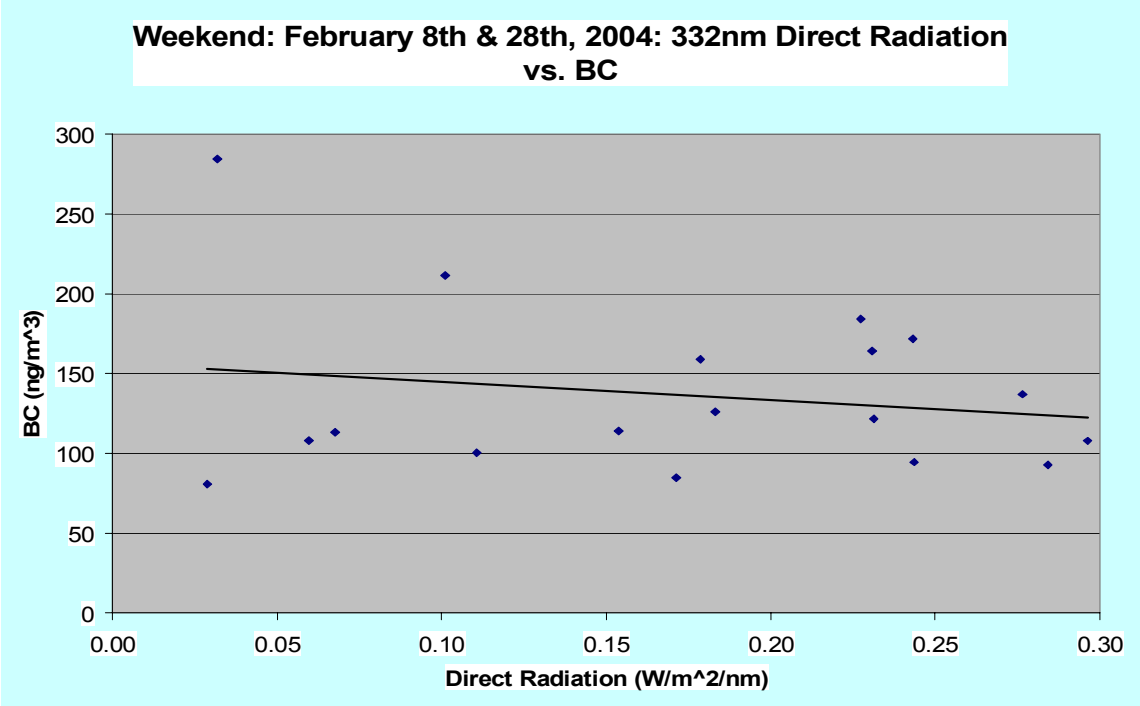

Figure 258. February 2004 Weekend 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

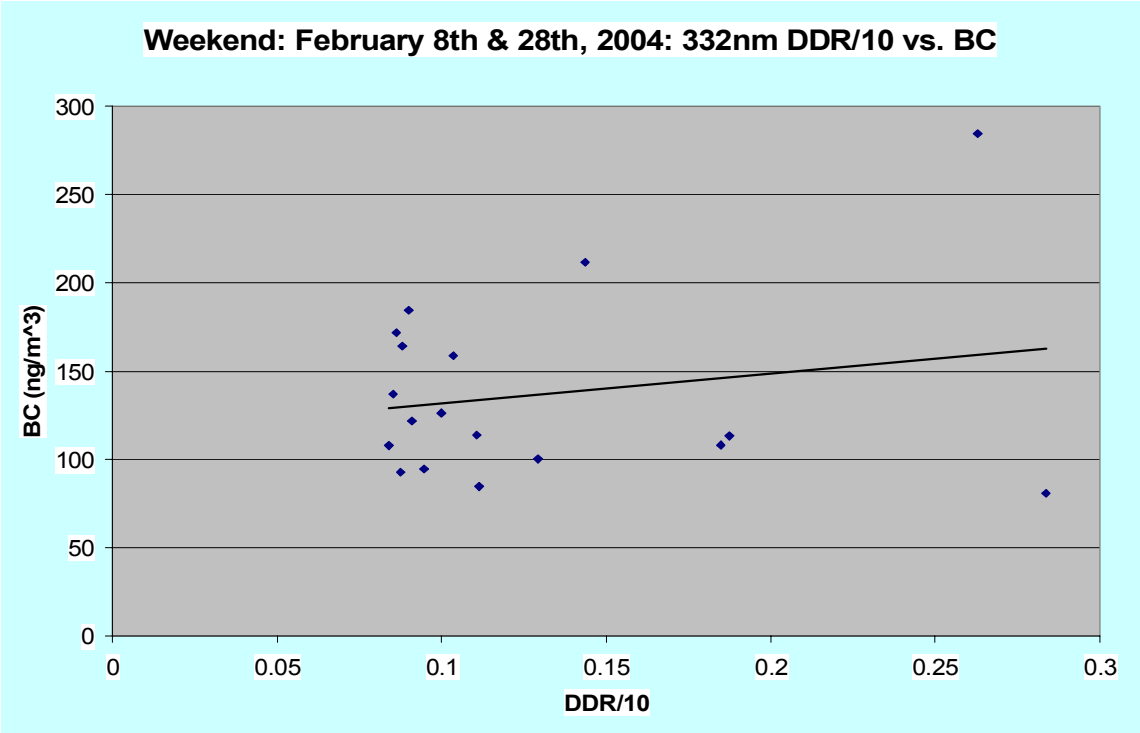

Figure 259. February 2004 Weekend 332nm DDR/10 vs. BC Concentrations (ng/m^3)

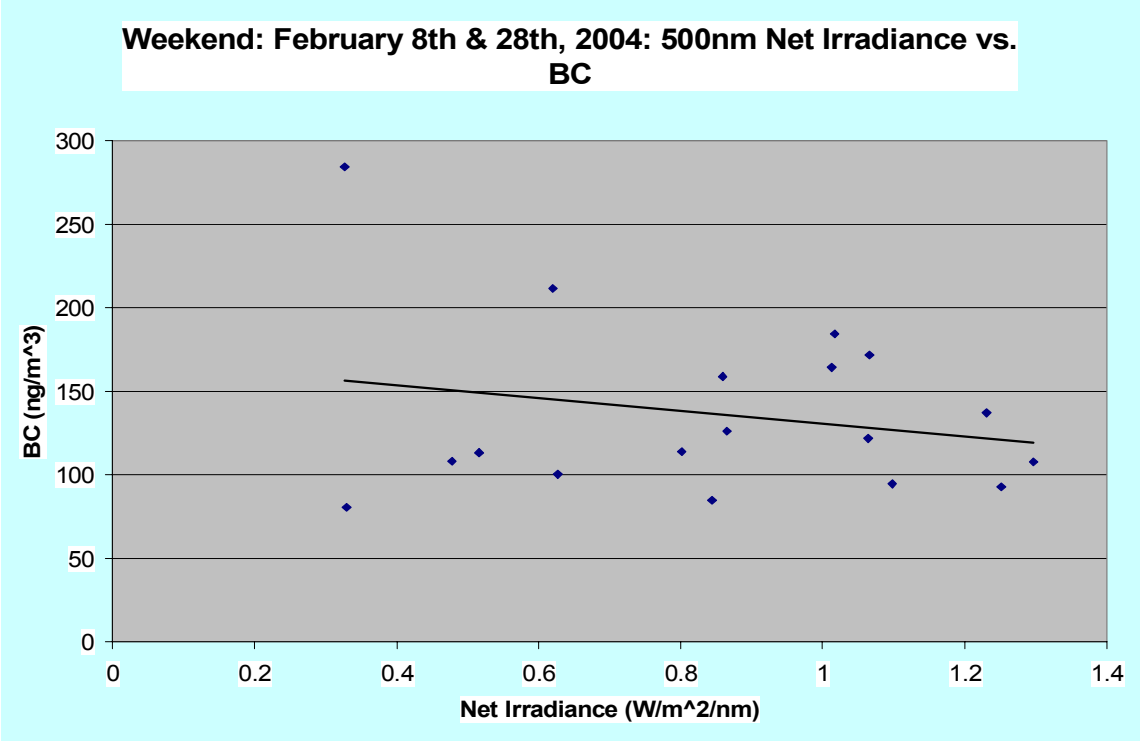

Figure 260. February 2004 Weekend 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

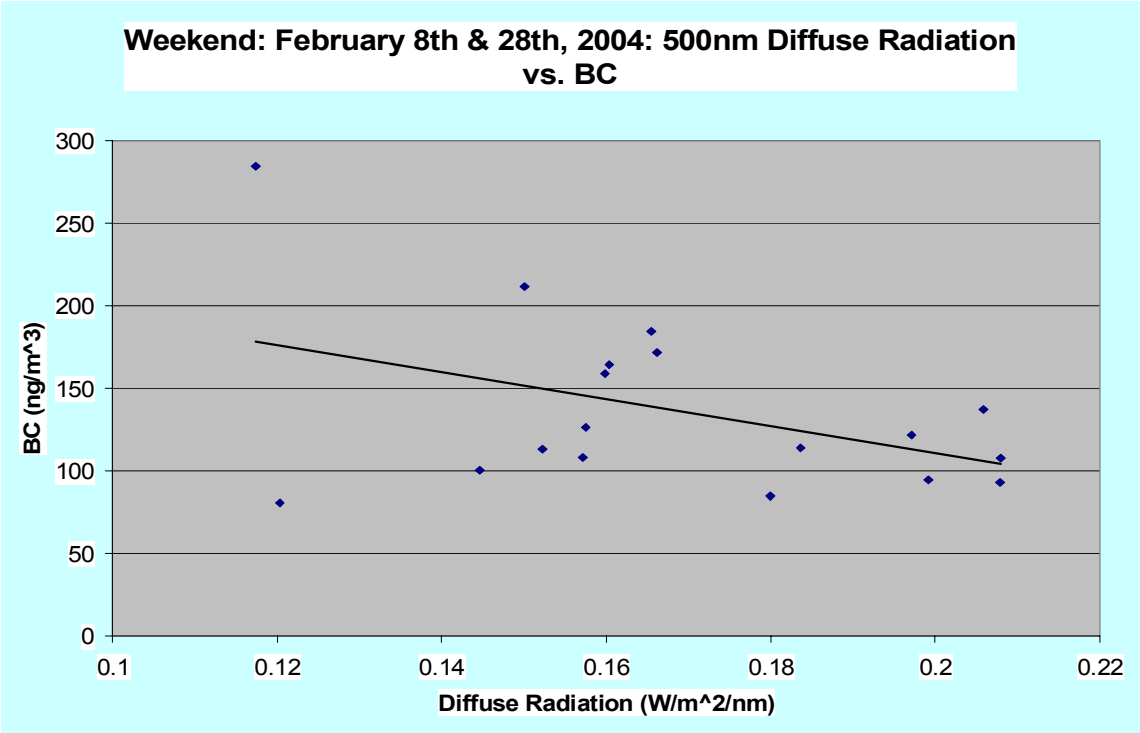

Figure 261. February 2004 Weekend 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

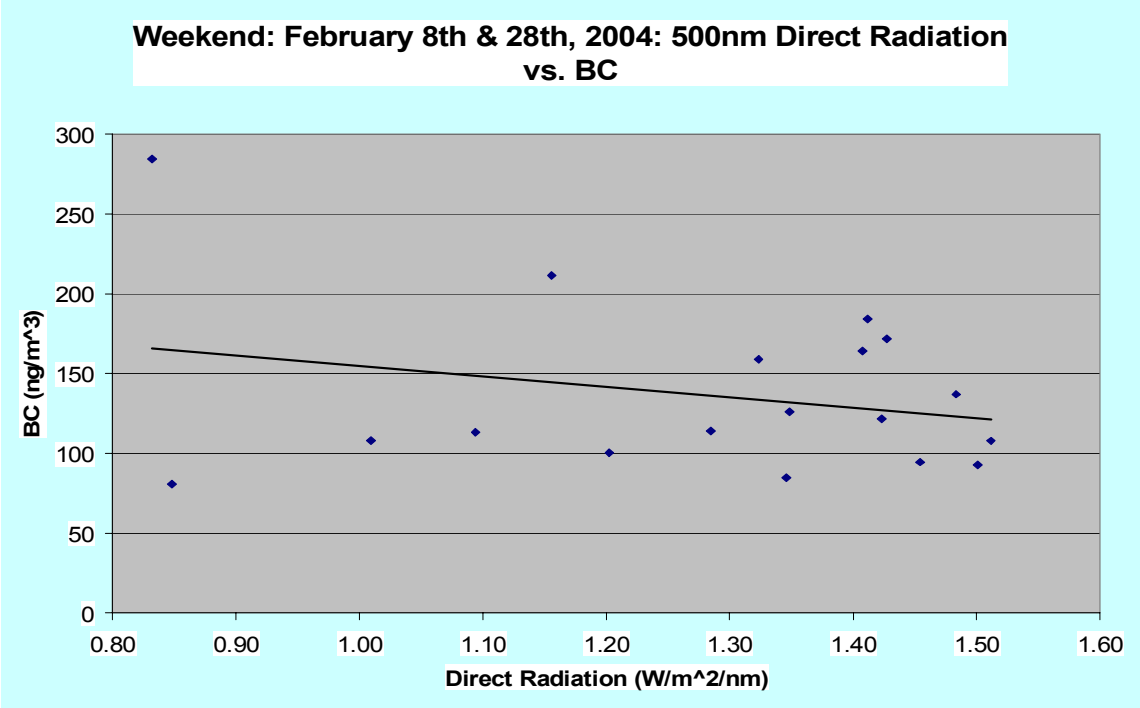

Figure 262. February 2004 Weekend 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

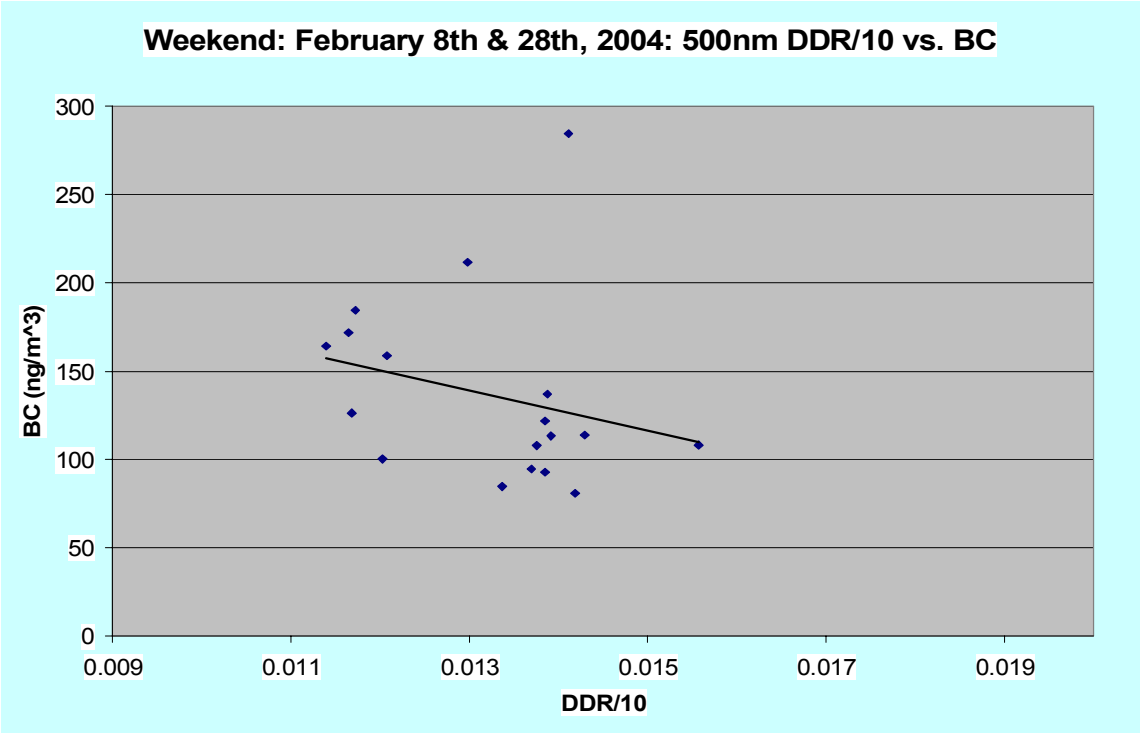

Figure 263. February 2004 Weekend 500nm DDR/10 vs. BC Concentrations (ng/m^3)

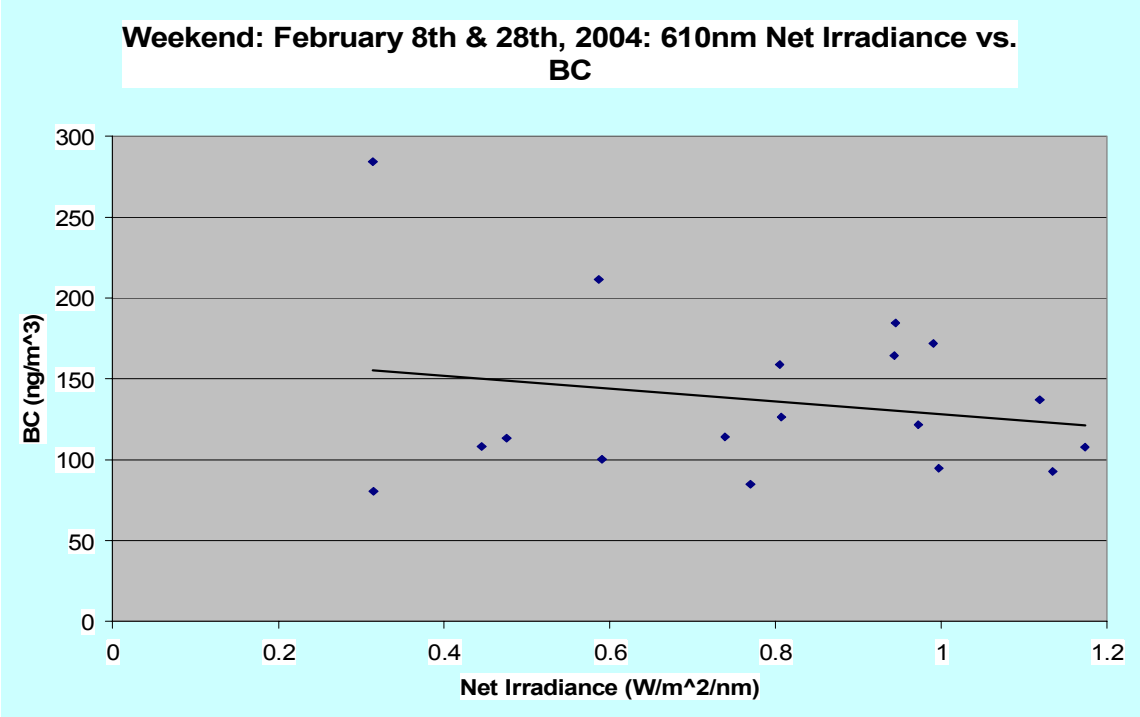

Figure 264. February 2004 Weekend 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

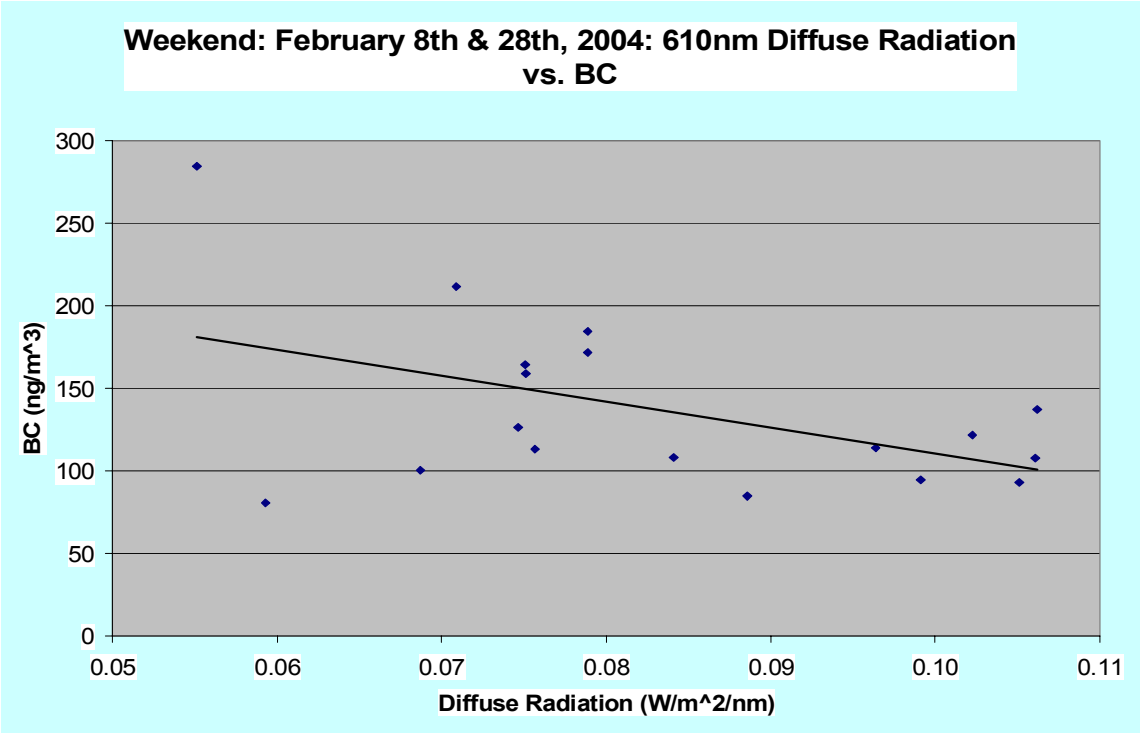

Figure 265. February 2004 Weekend 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

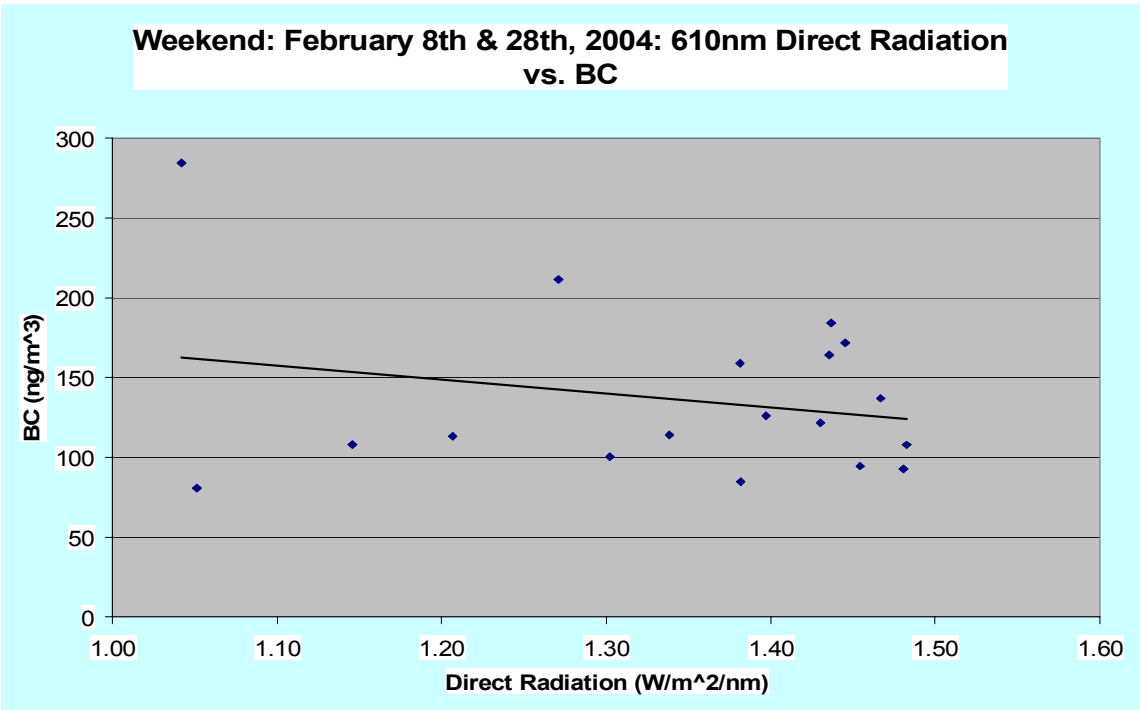

Figure 266. February 2004 Weekend 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

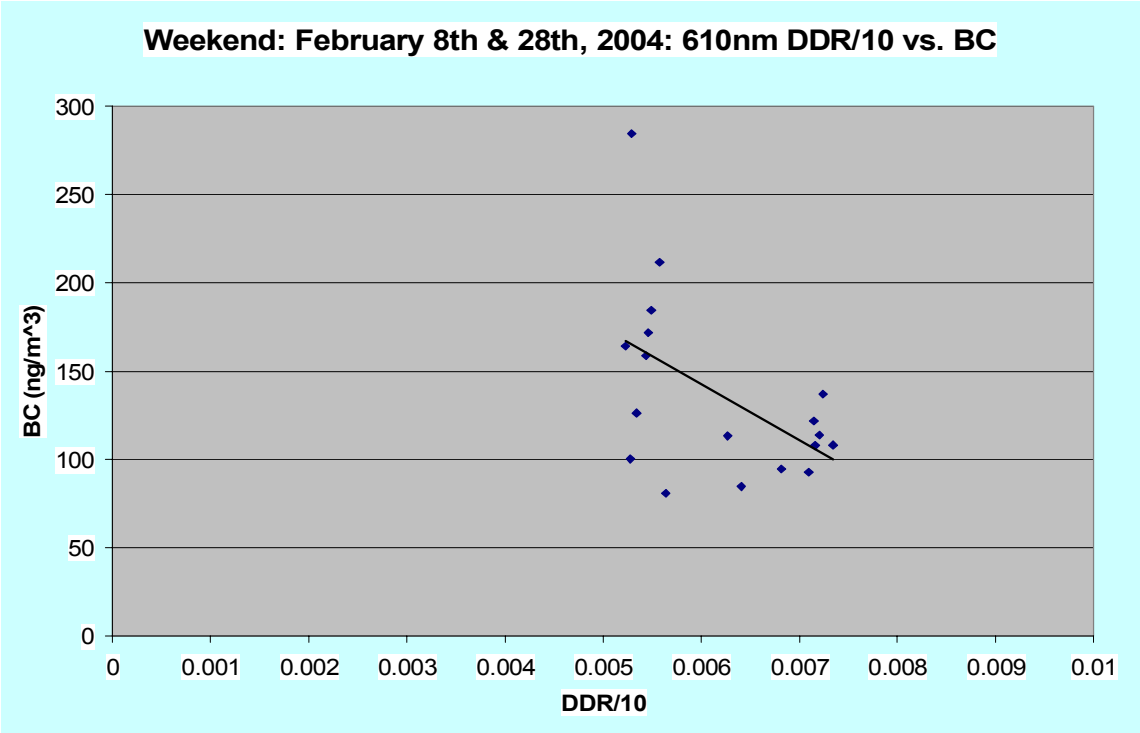

Figure 267. February 2004 Weekend 610nm DDR/10 vs. BC Concentrations (ng/m^3)

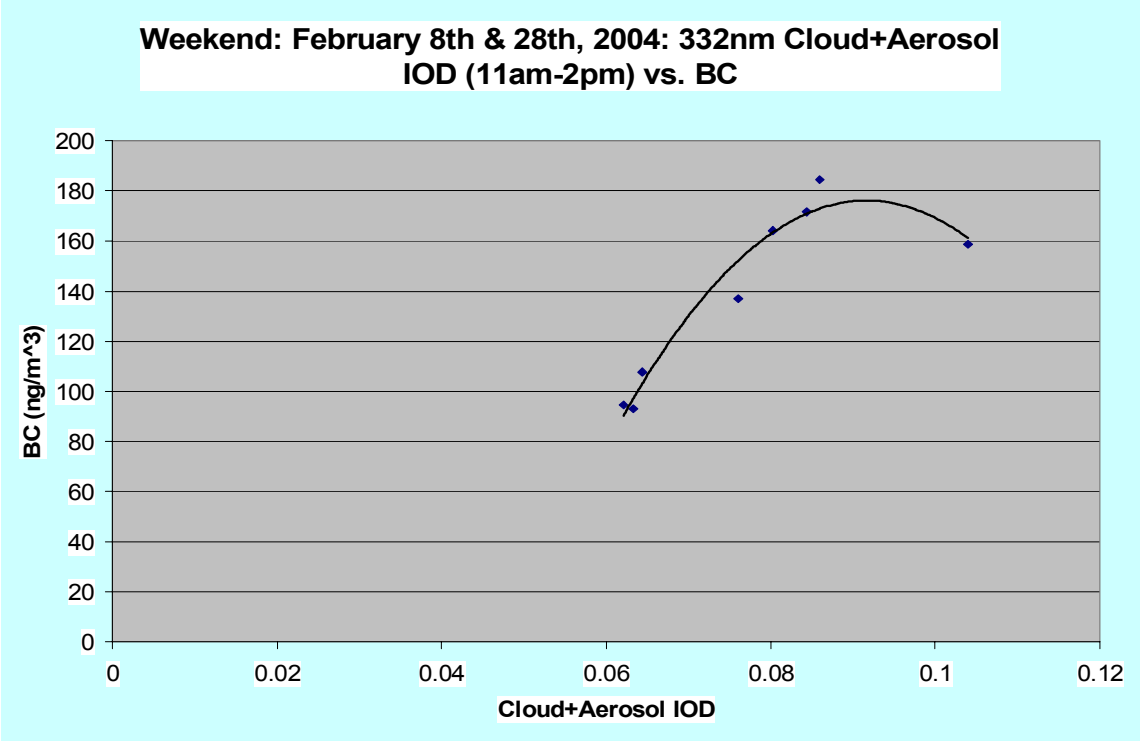

Figure 268. February 2004 Weekend 332nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

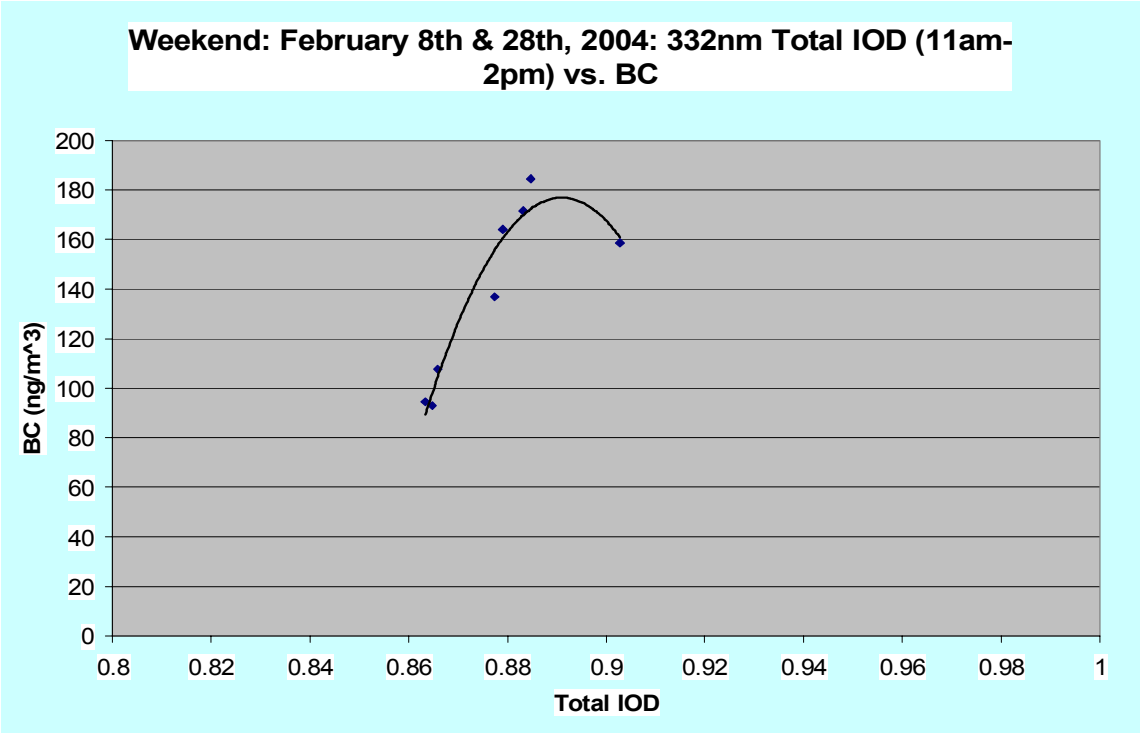

Figure 269. February 2004 Weekend 332nm Total IOD vs. BC Concentrations (ng/m^3)

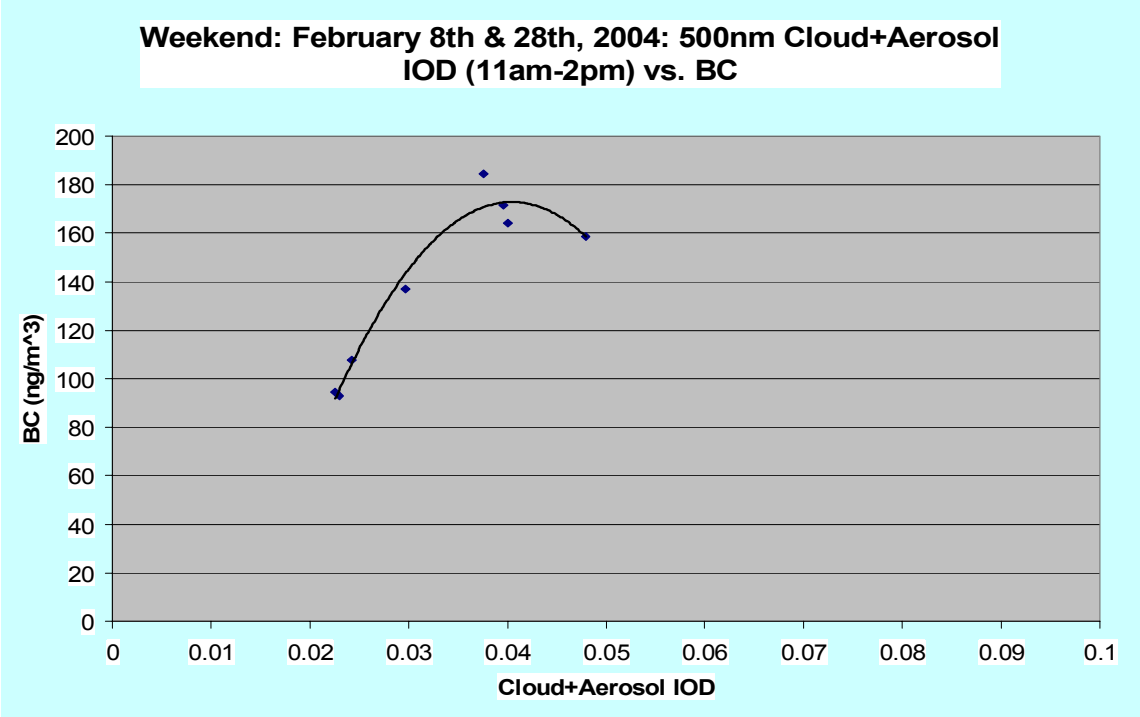

Figure 270. February 2004 Weekend 332nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

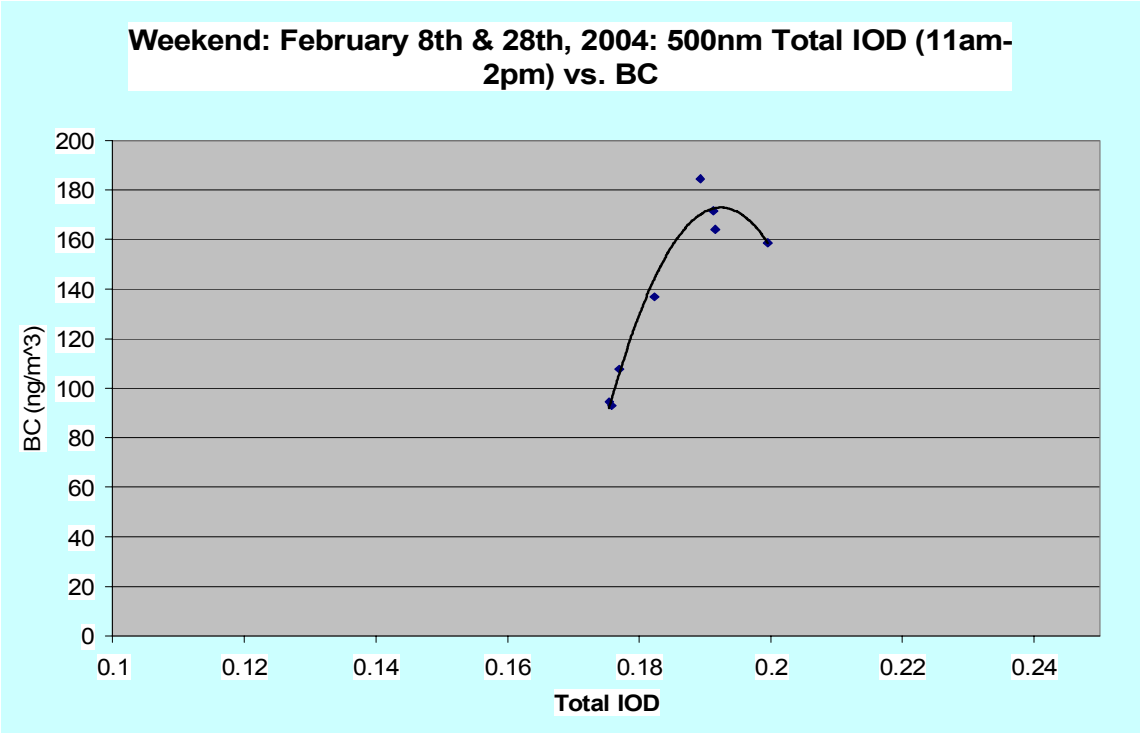

Figure 271. February 2004 Weekend 500nm Total IOD vs. BC Concentrations (ng/m^3)

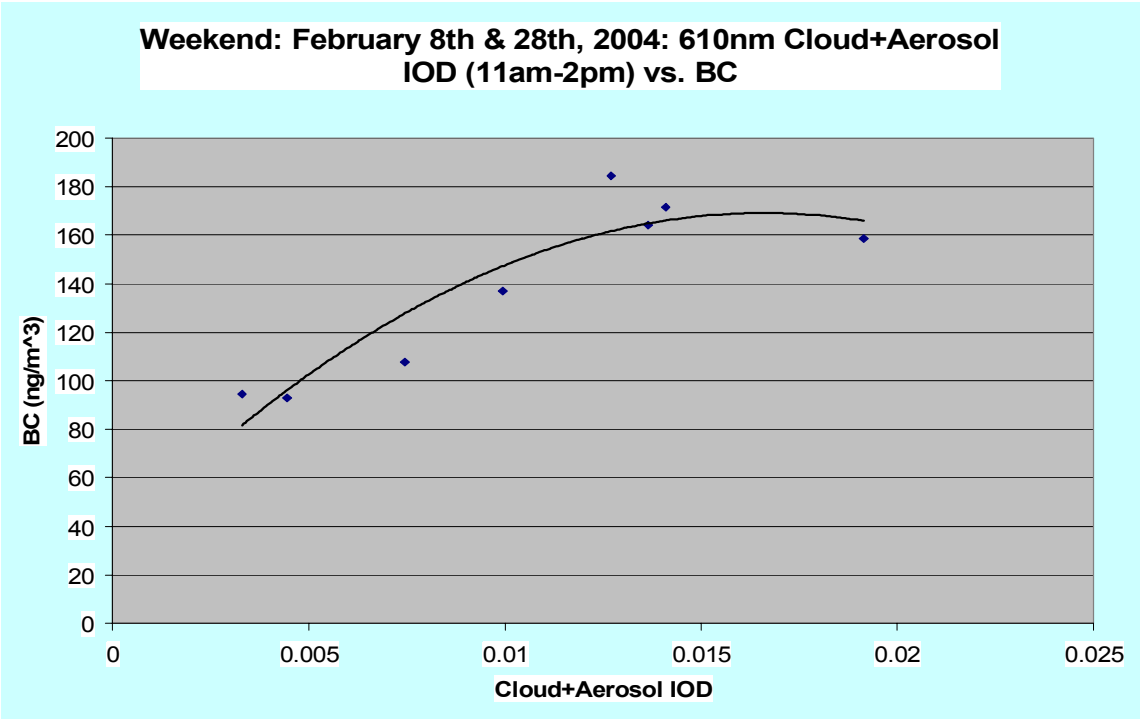

Figure 272. February 2004 Weekend 610nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

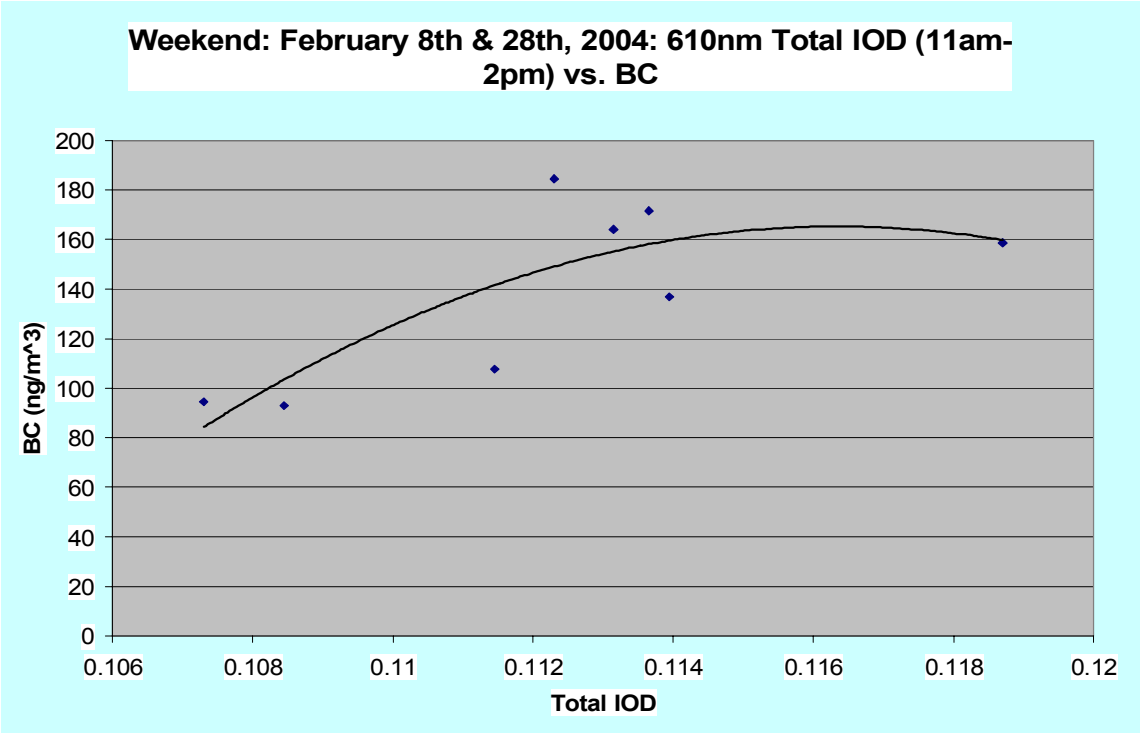

Figure 273. February 2004 Weekend 610nm Total IOD vs. BC Concentrations (ng/m^3)

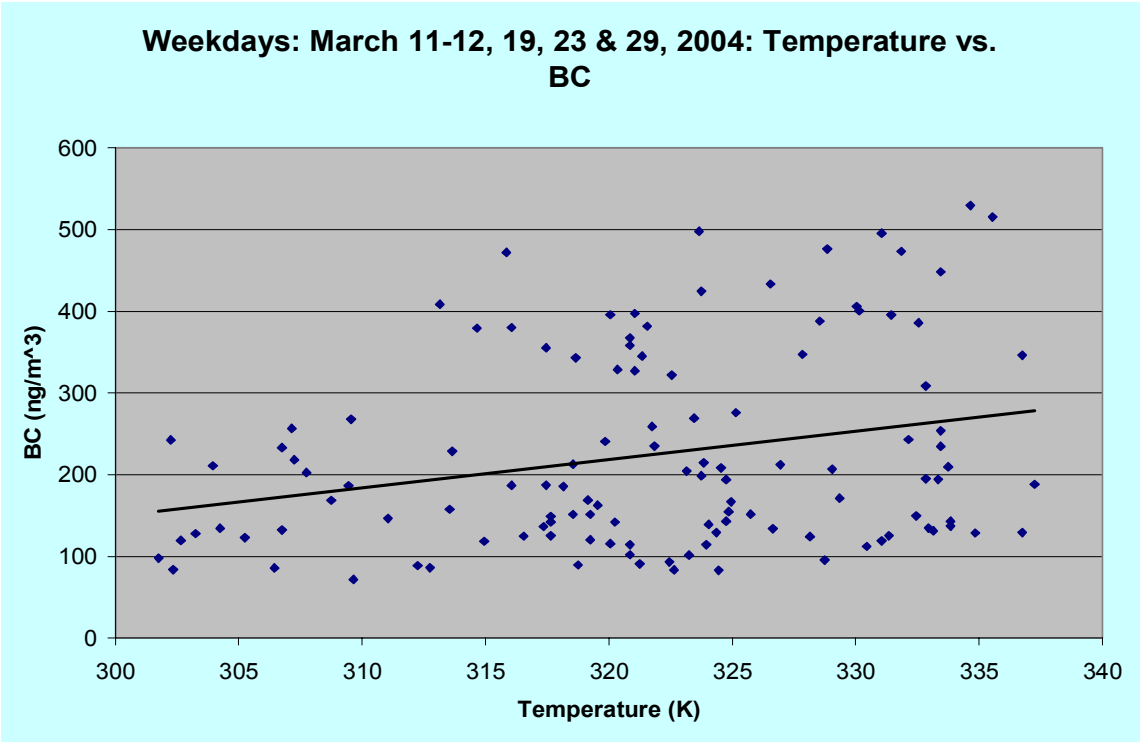

Figure 274. March 2004 Weekdays Temperature (K) vs. BC Concentrations (ng/m^3)

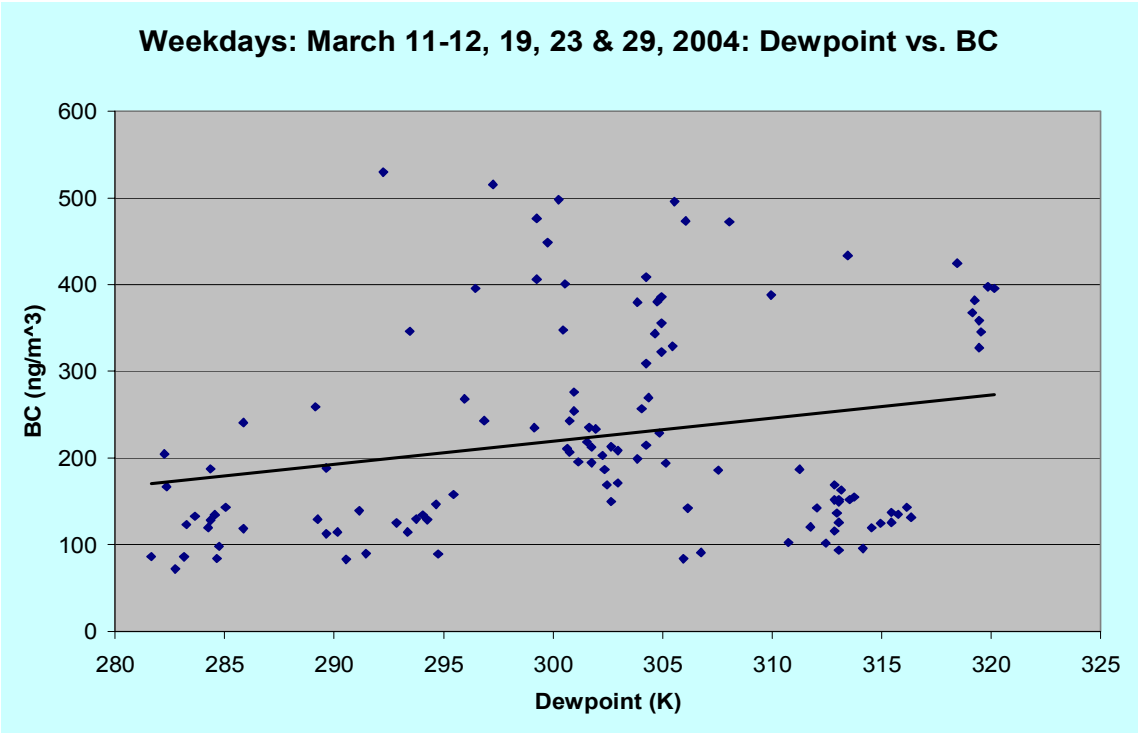

Figure 275. March 2004 Weekdays Dewpoint (K) vs. BC Concentrations (ng/m^3)

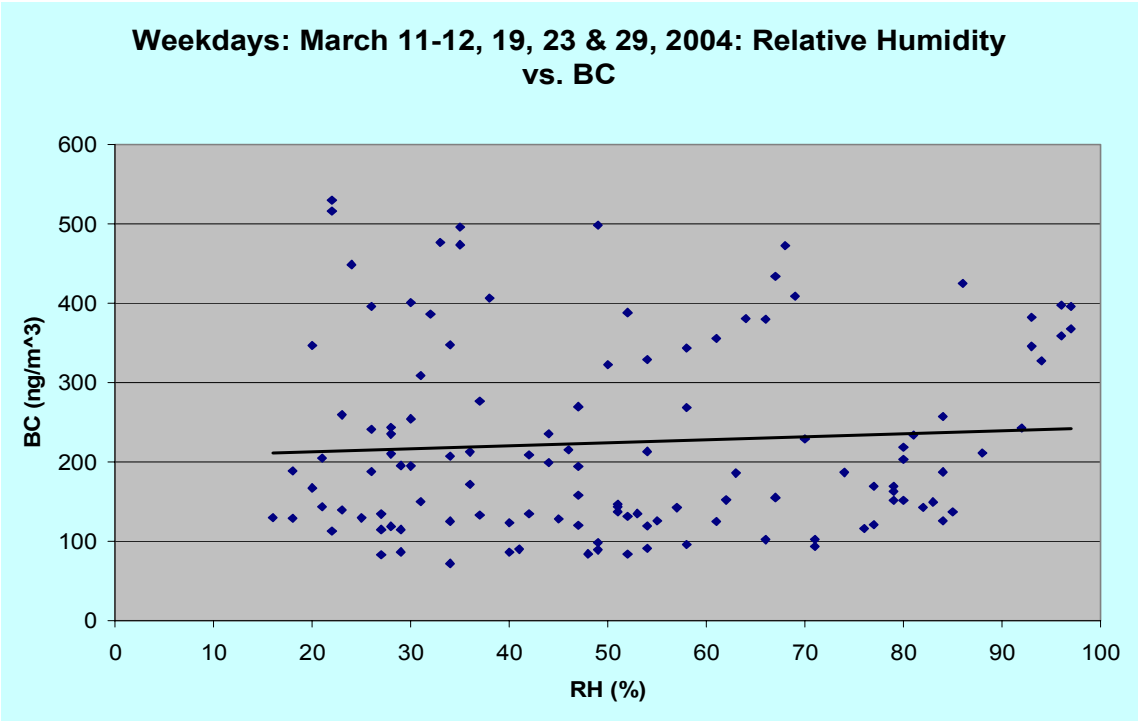

Figure 276. March 2004 Weekdays Relative Humidity (%) vs. BC Concentrations (ng/m^3)

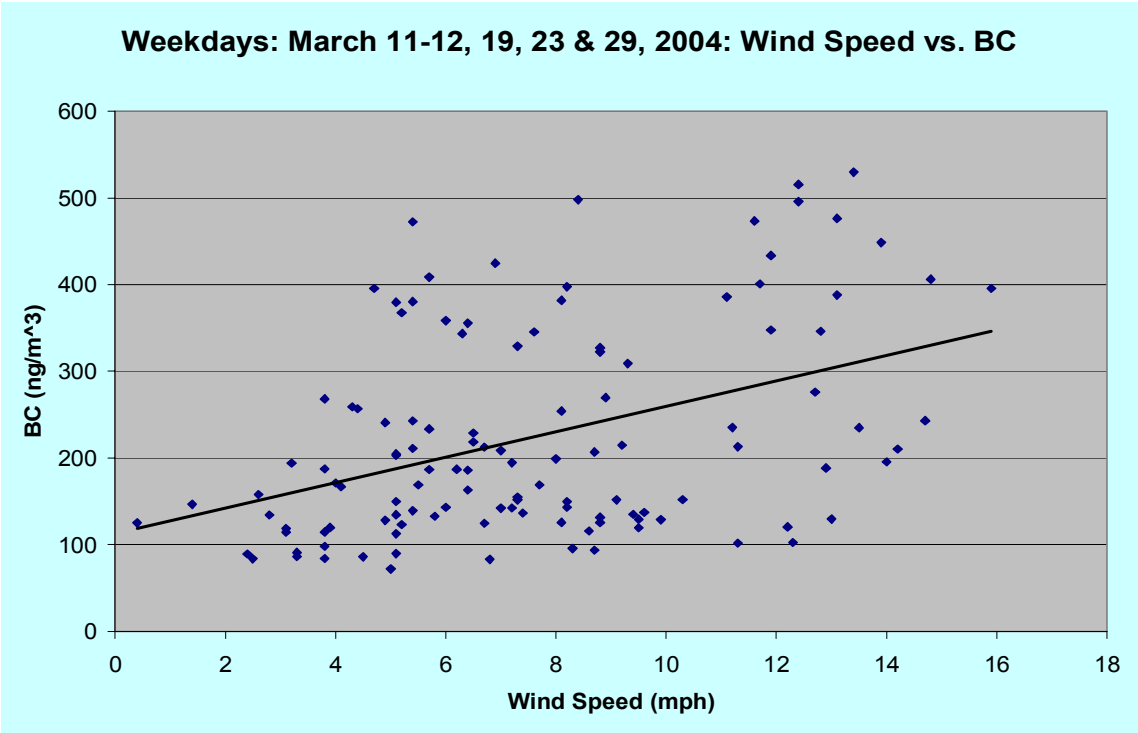

Figure 277. March 2004 Weekdays Wind Speed (mph) vs. BC Concentrations (ng/m^3)

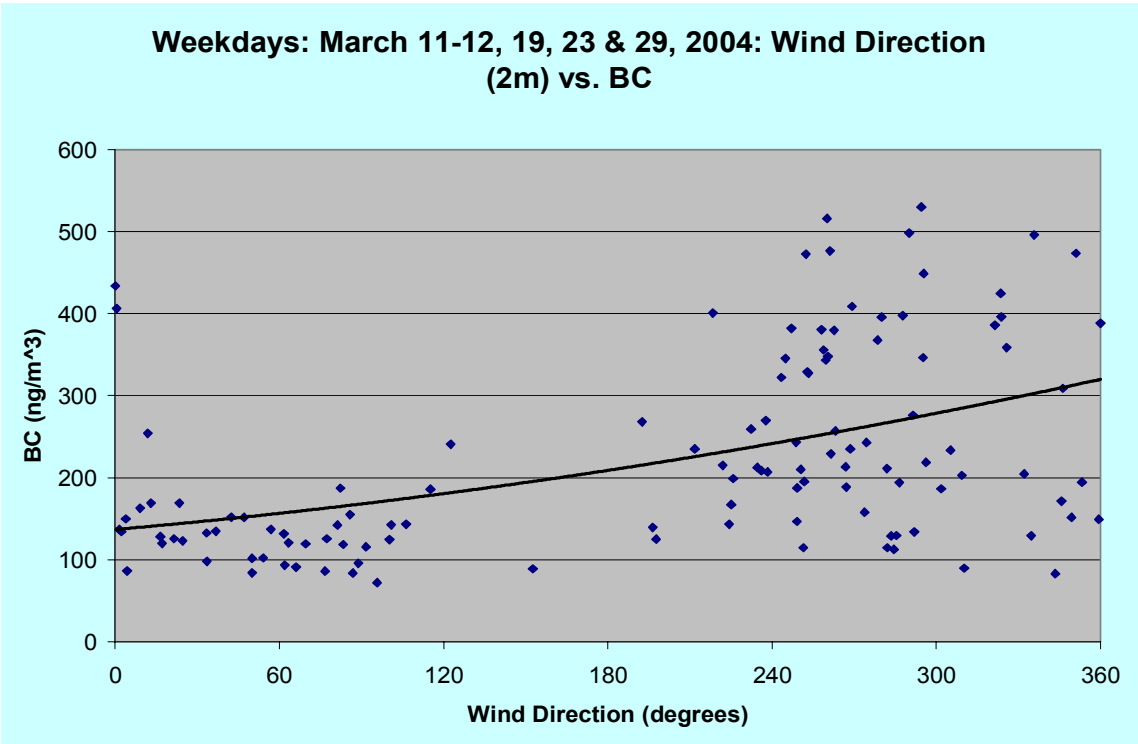

Figure 278. March 2004 Weekdays Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

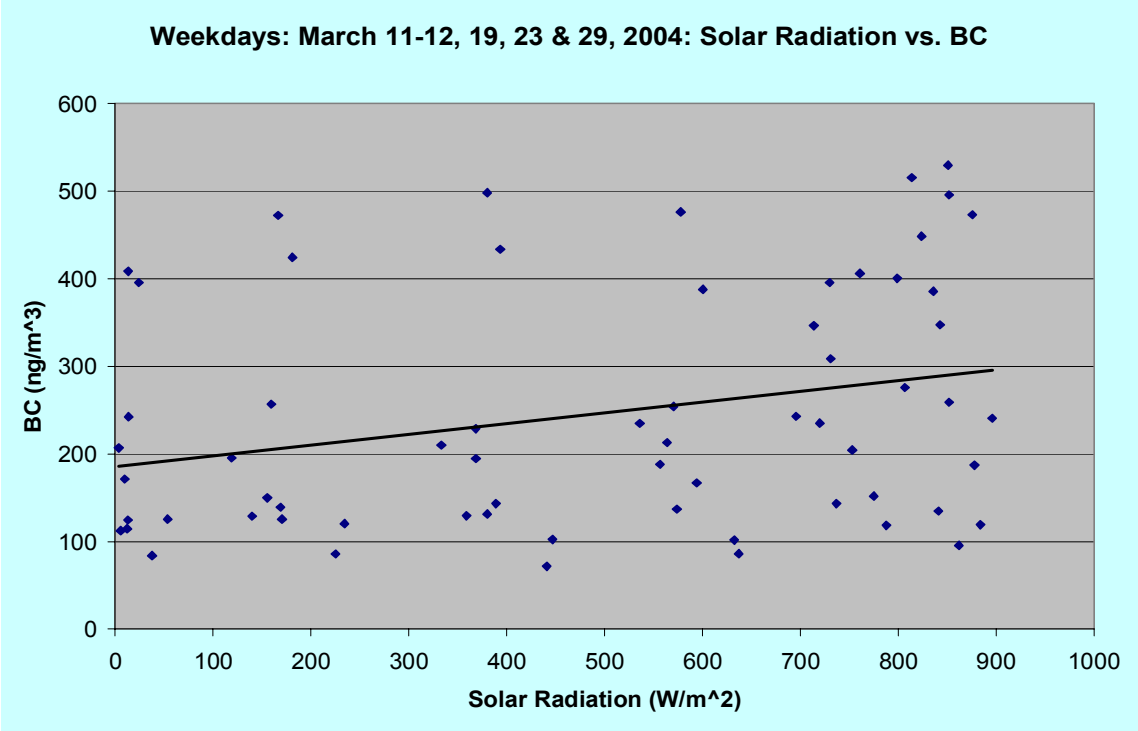

Figure 279. March 2004 Weekdays Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

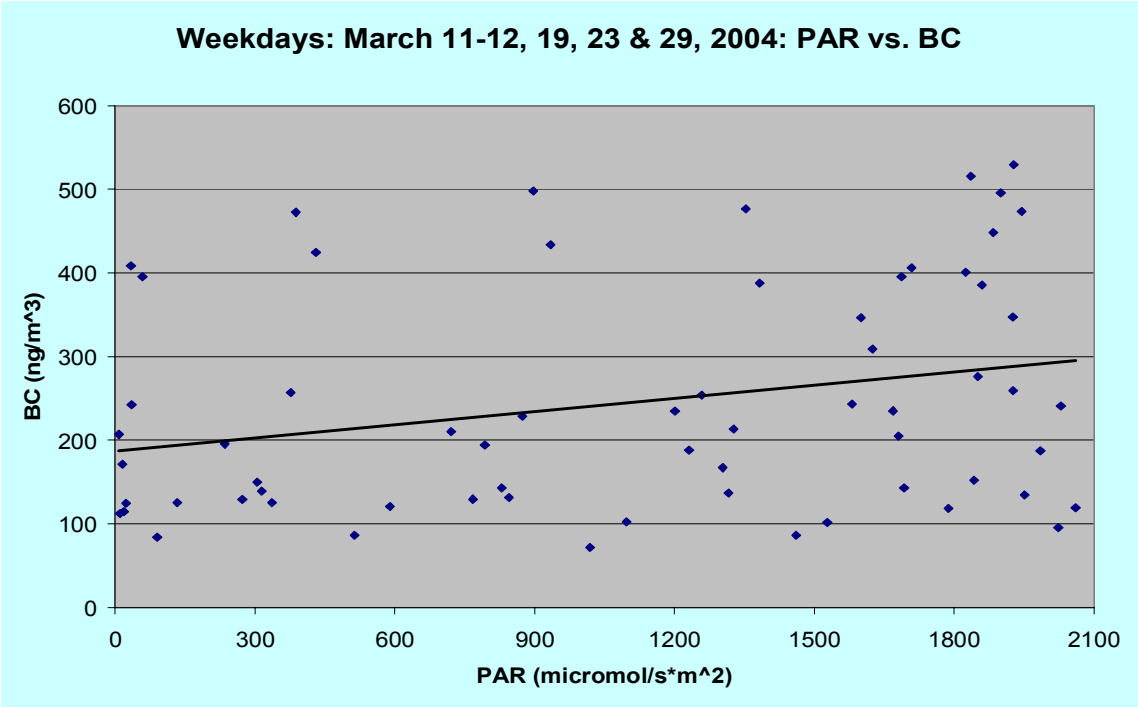

Figure 280. March 2004 Weekdays PAR (micromole/s*m^2) vs. BC Concentrations (ng/m^3)

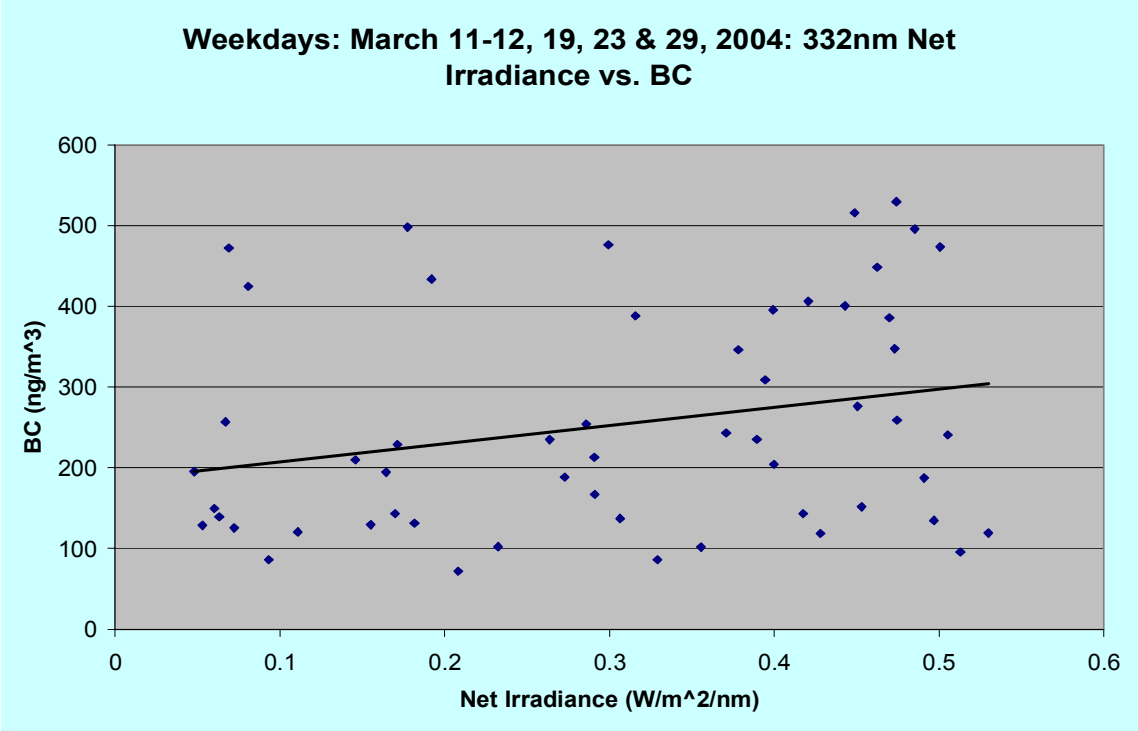

Figure 281. March 2004 Weekdays 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

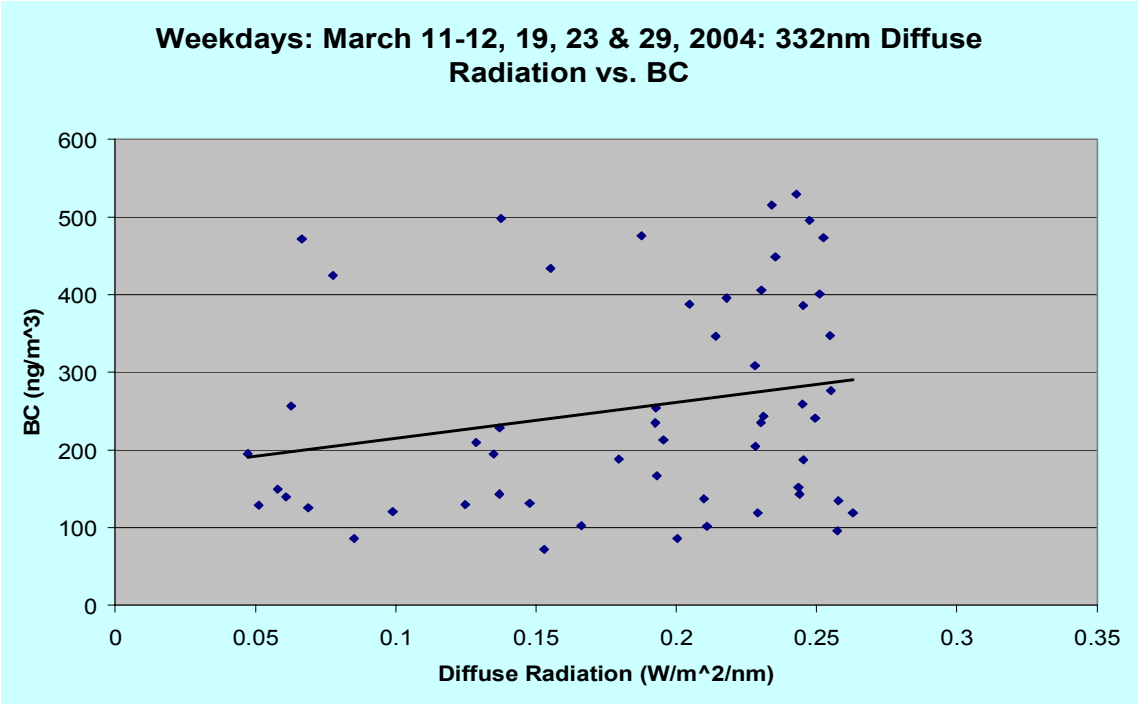

Figure 282. March 2004 Weekdays 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

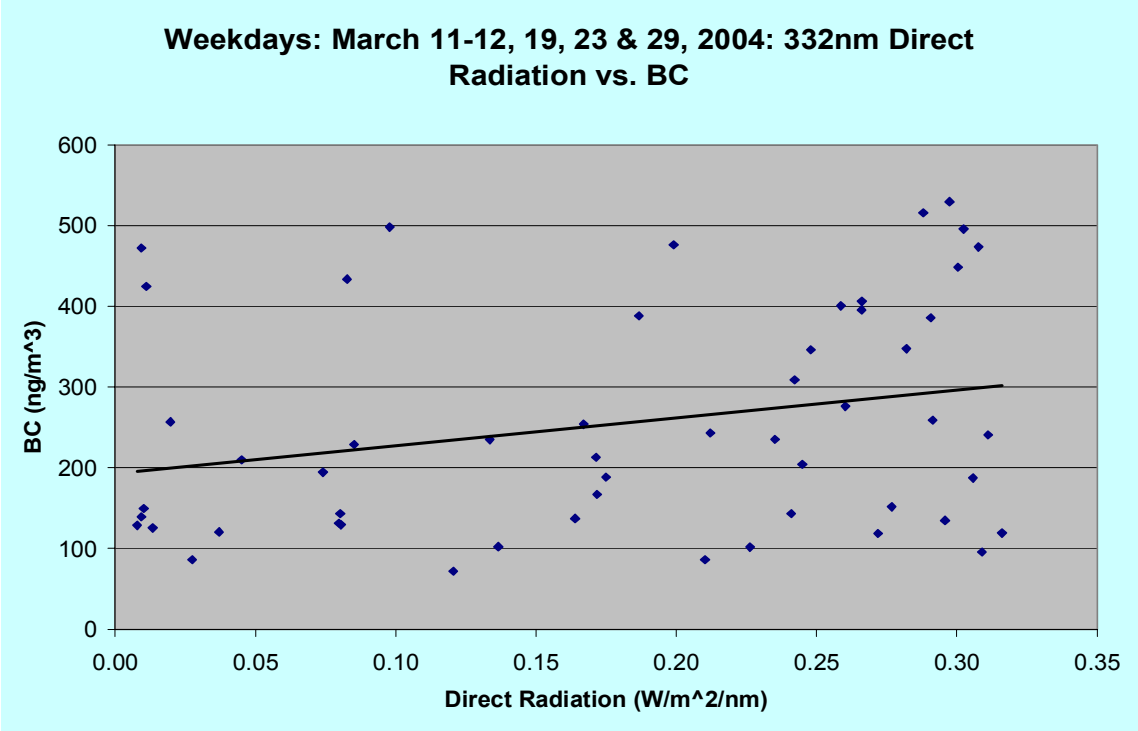

Figure 283. March 2004 Weekdays 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

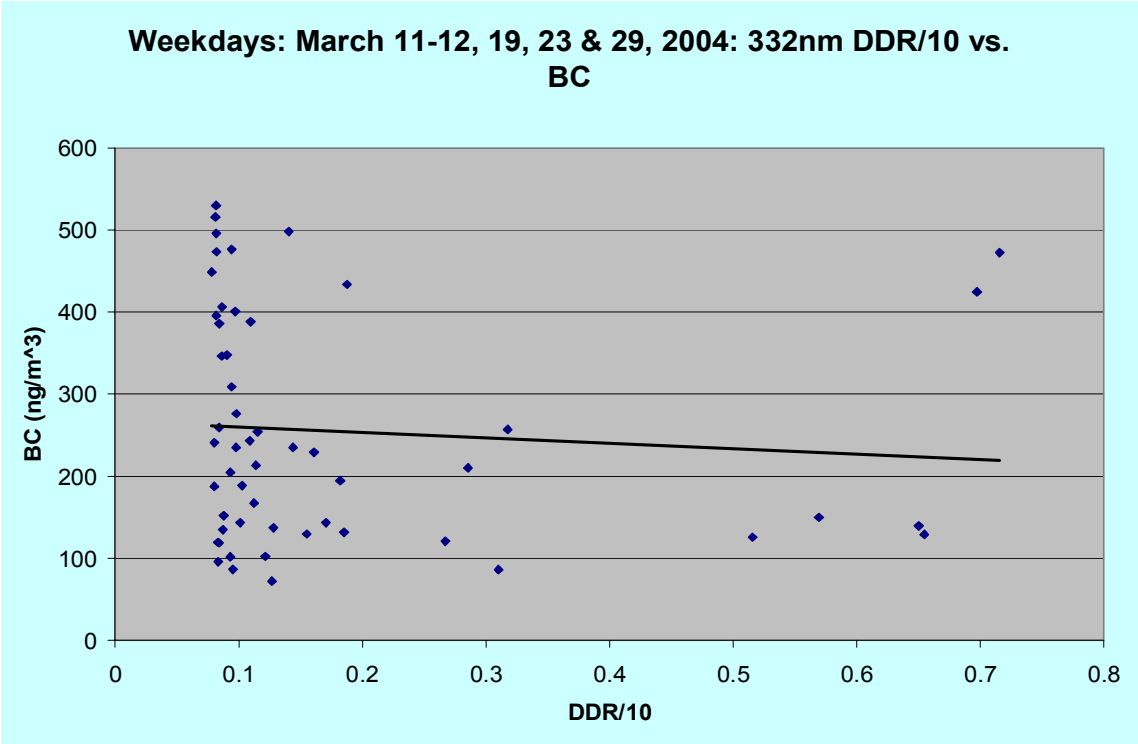

Figure 284. March 2004 Weekdays 332nm DDR/10 vs. BC Concentrations (ng/m^3)

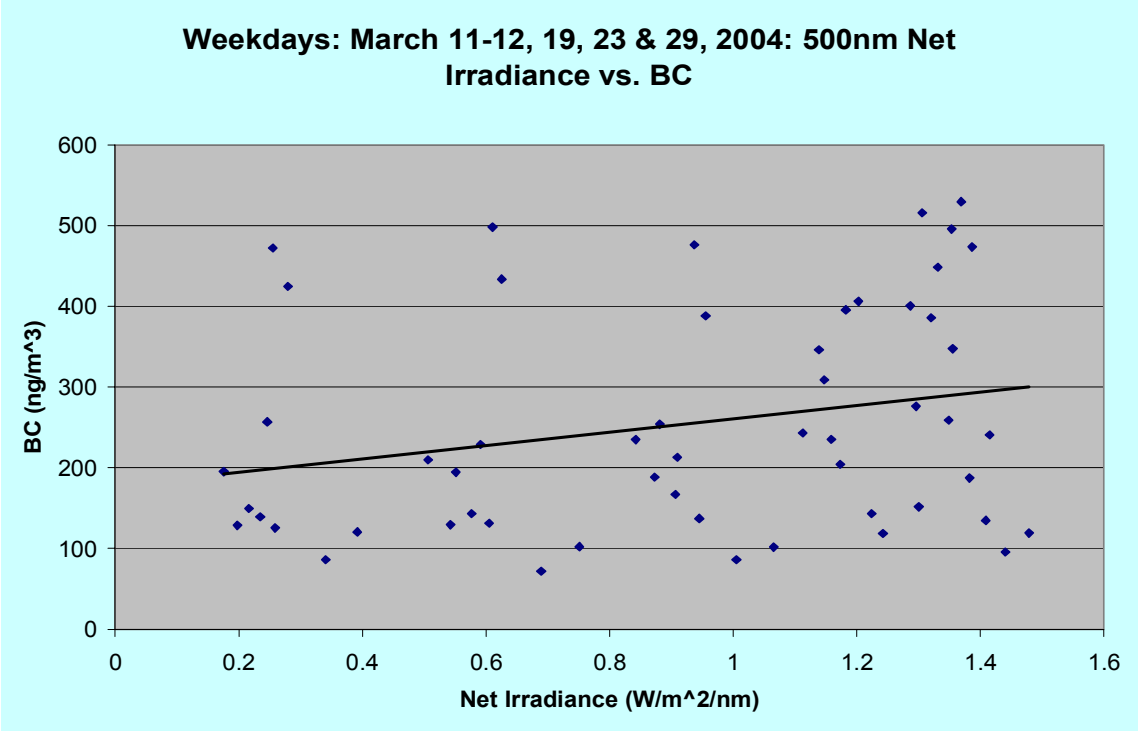

Figure 285. March 2004 Weekdays 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

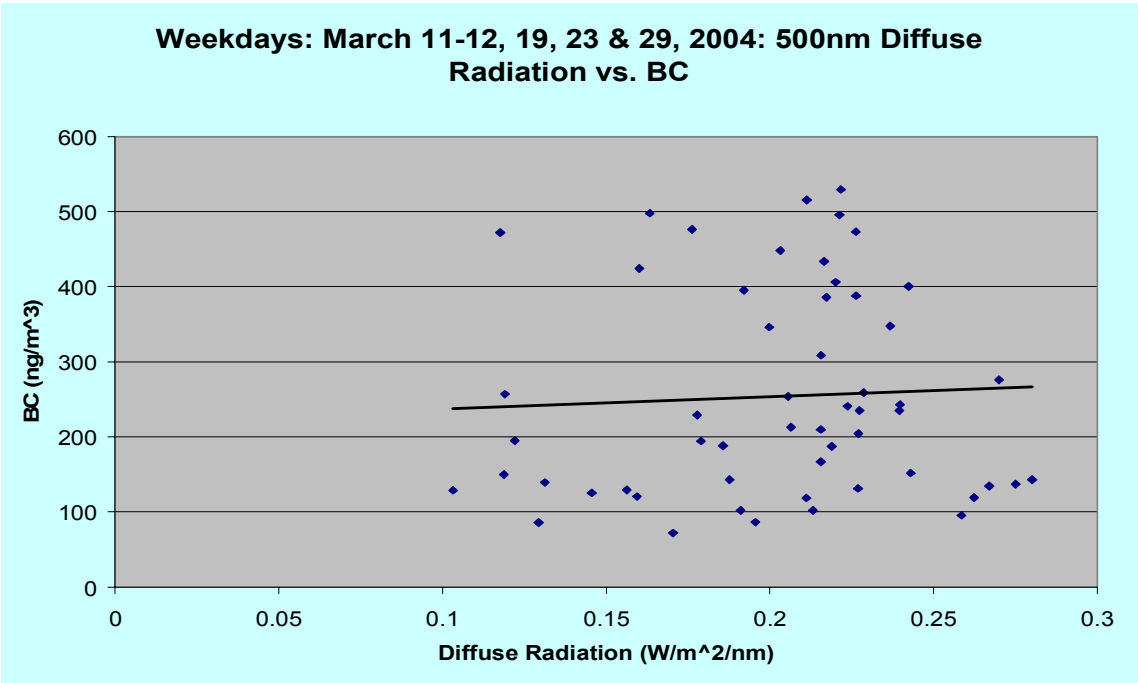

Figure 286. March 2004 Weekdays 500nm Diffuse Radiation W/m^2/nm) vs. BC Concentrations (ng/m^3)

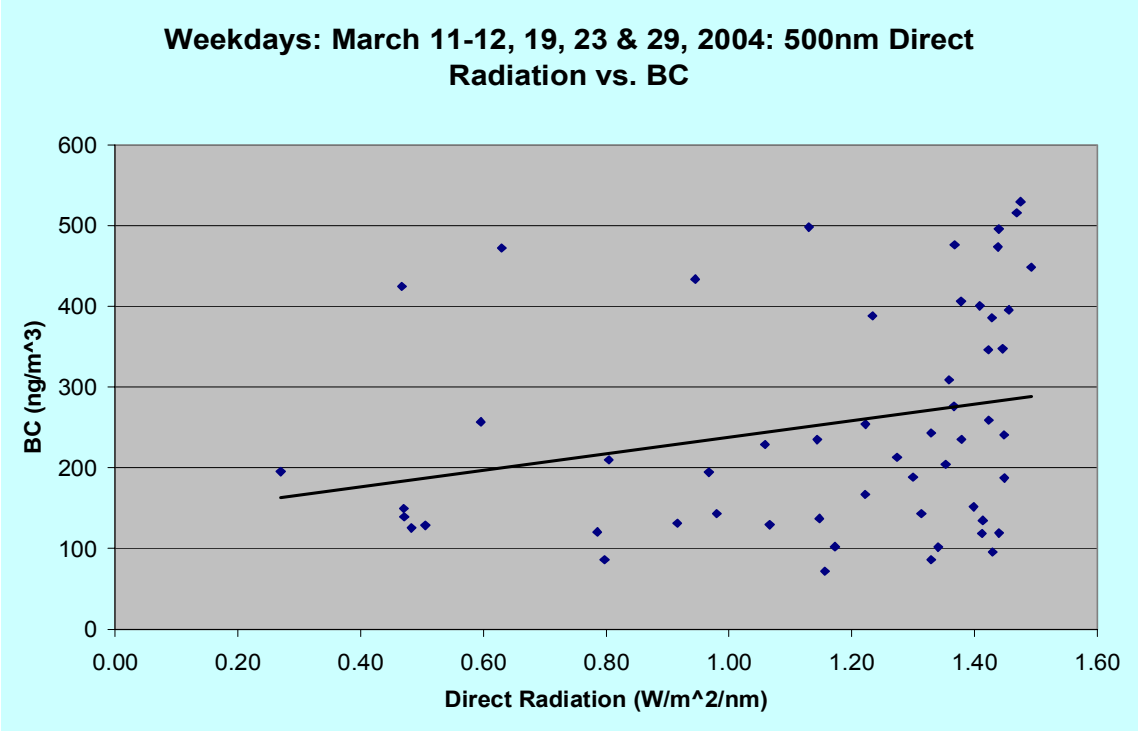

Figure 287. March 2004 Weekdays 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

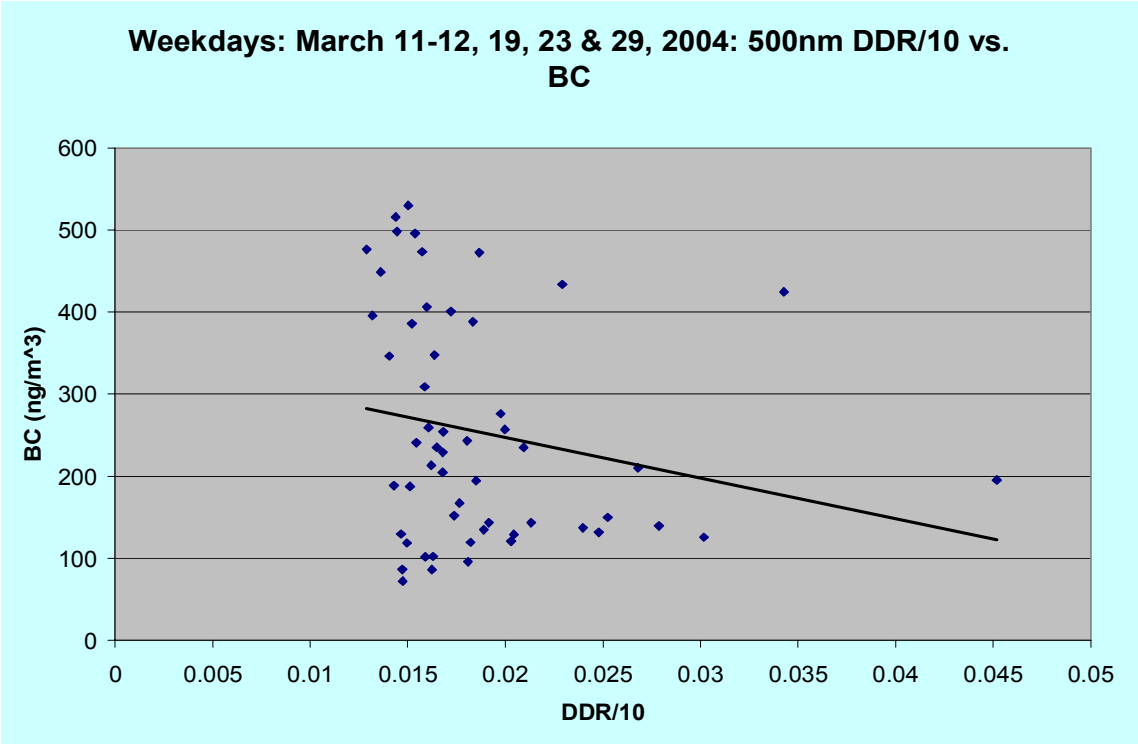

Figure 288. March 2004 Weekdays 500nm DDR/10 vs. BC Concentrations (ng/m^3)

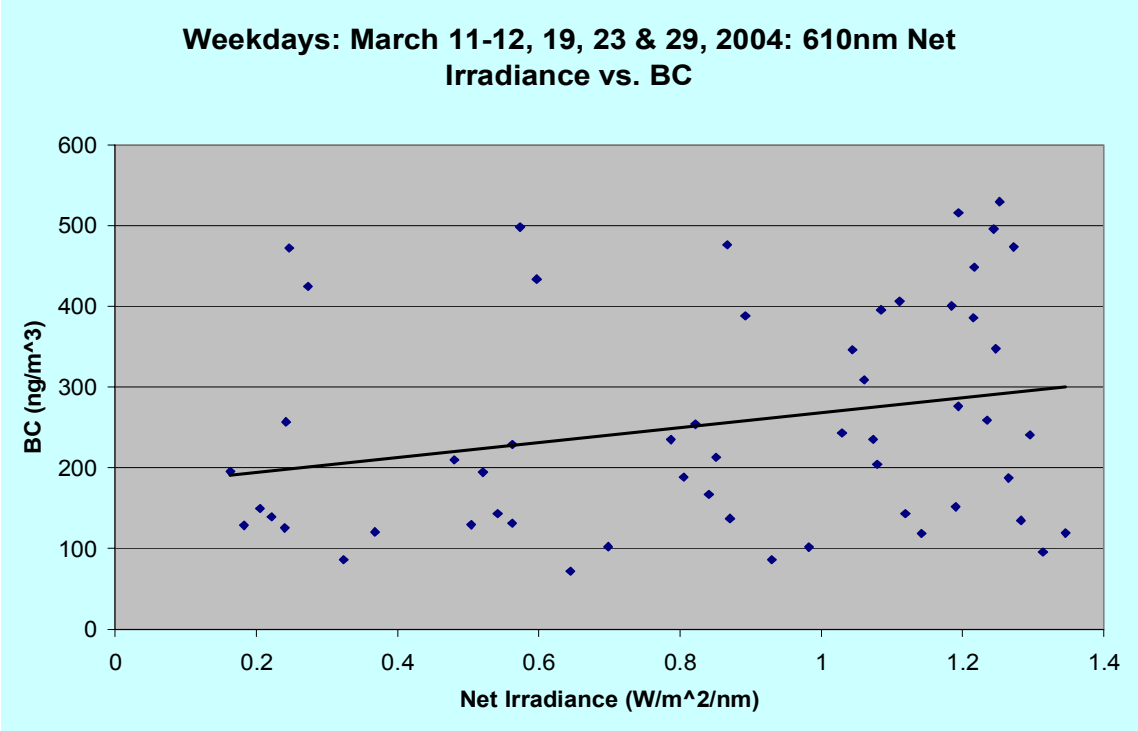

Figure 289. March 2004 Weekdays 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

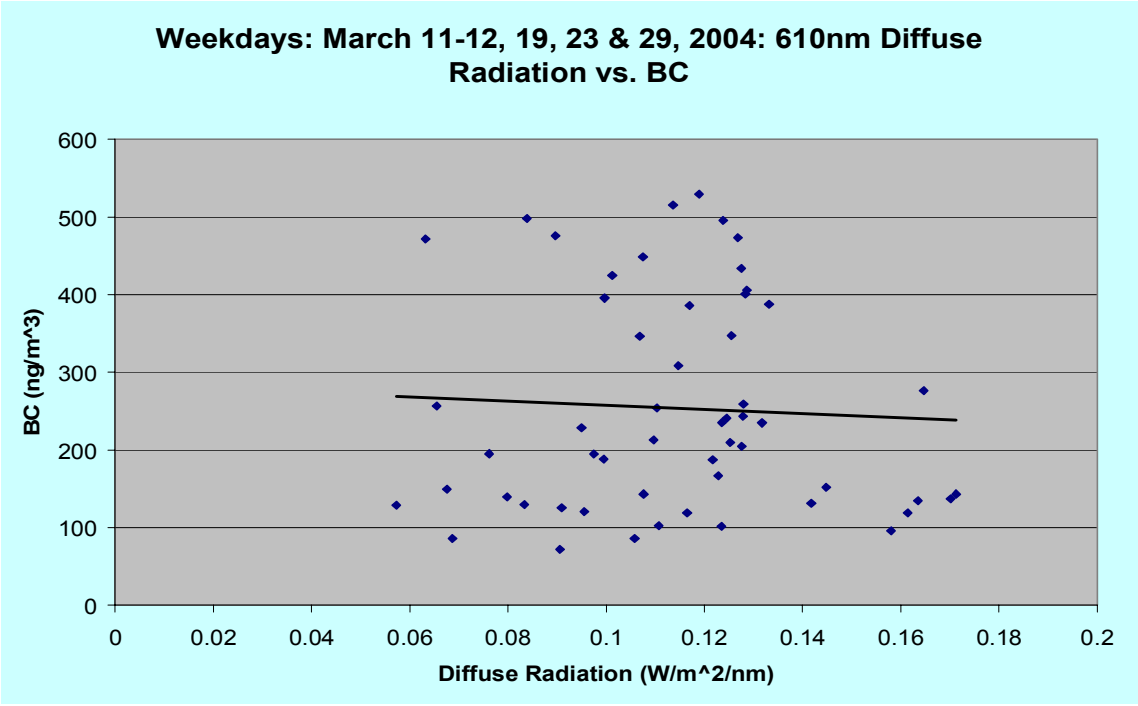

Figure 290. March 2004 Weekdays 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

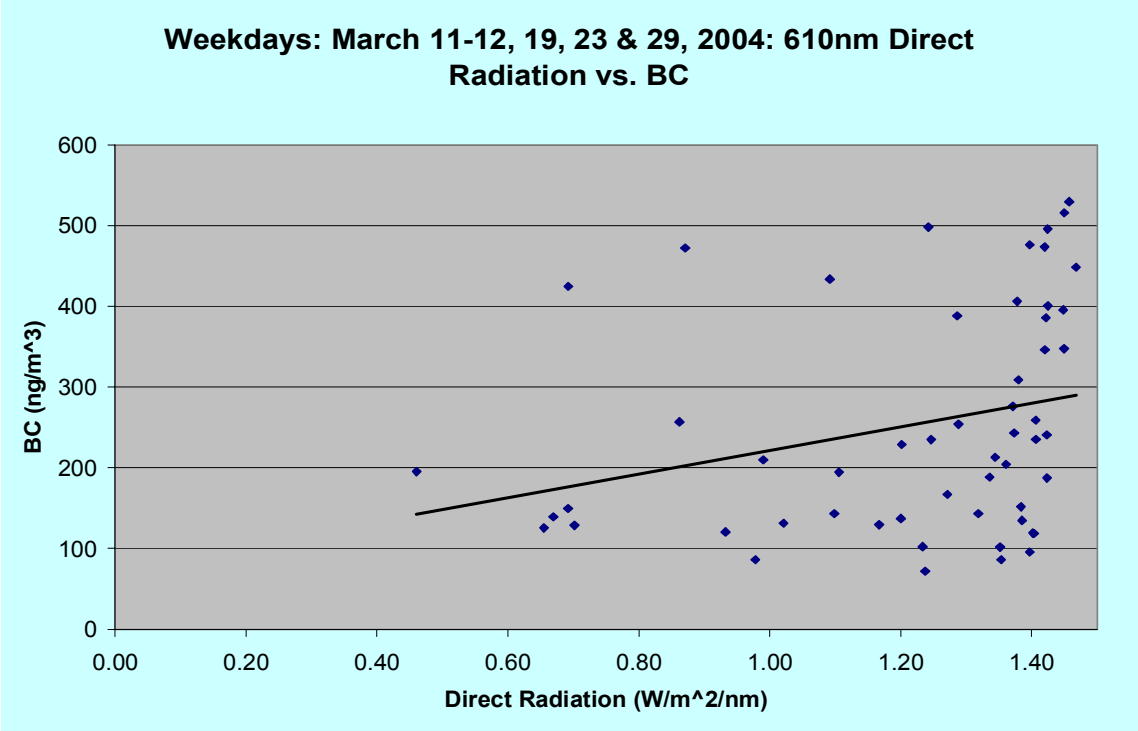

Figure 291. March 2004 Weekdays 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

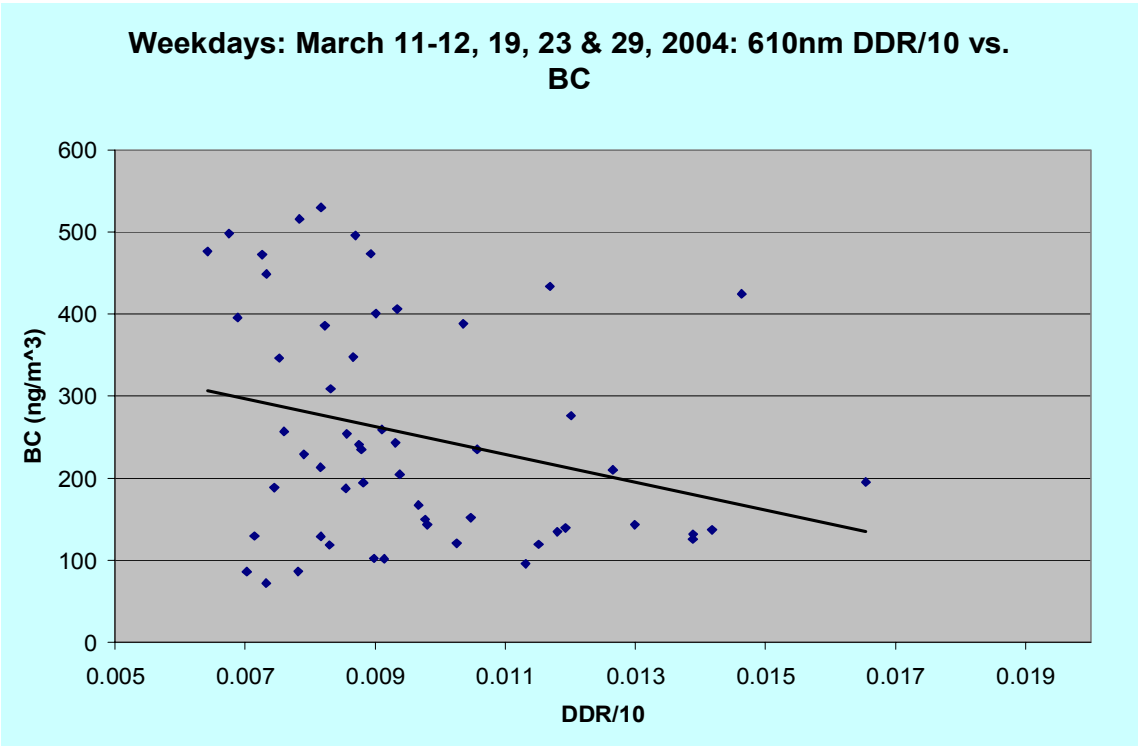

Figure 292. March 2004 Weekdays 610nm DDR/10 vs. BC Concentrations (ng/m^3)

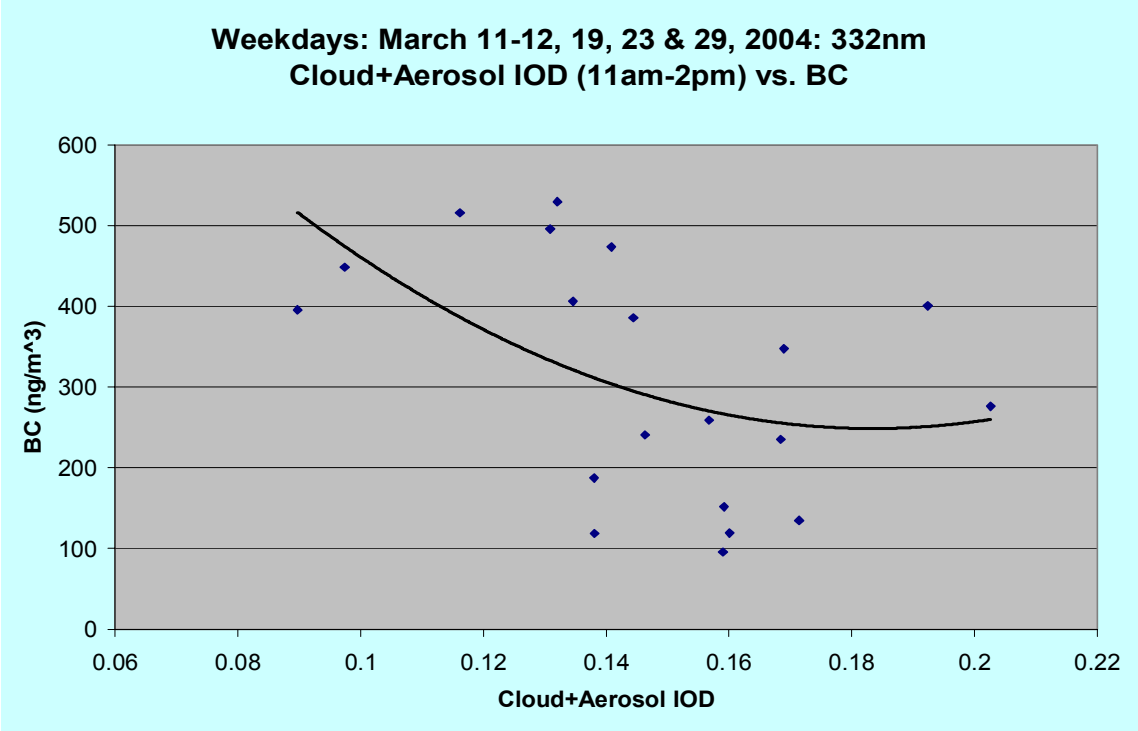

Figure 293. March 2004 Weekdays 332nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

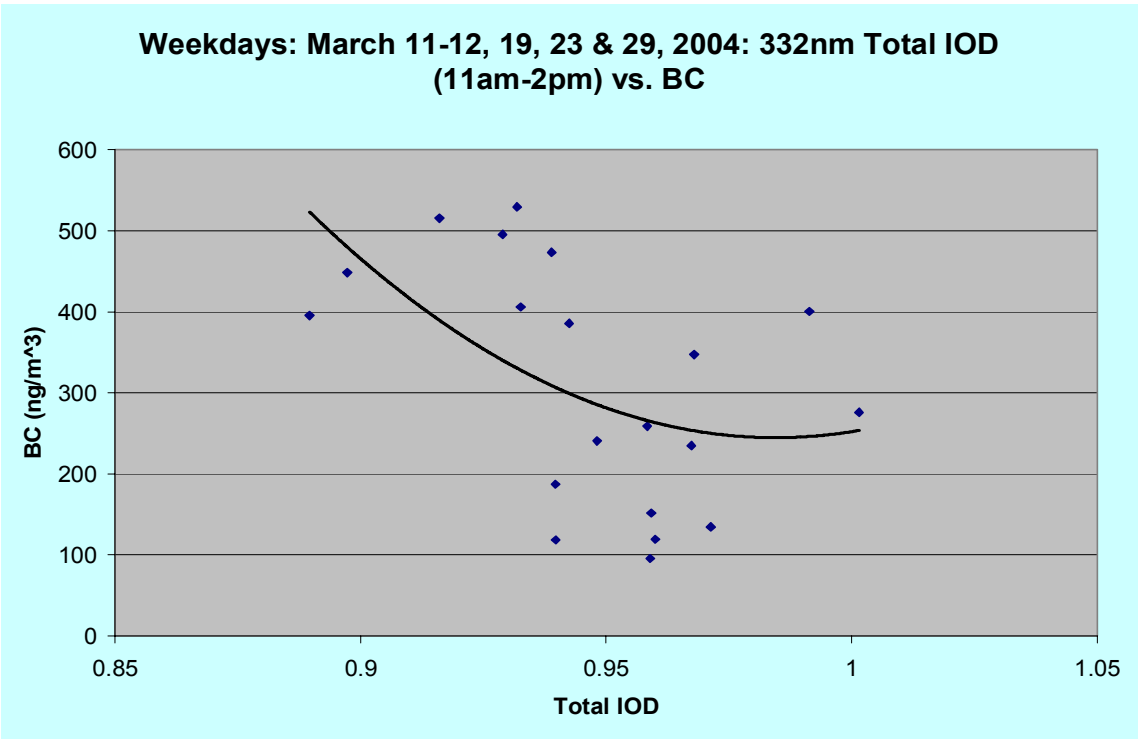

Figure 294. March 2004 Weekdays 332nm Total IOD vs. BC Concentrations (ng/m^3)

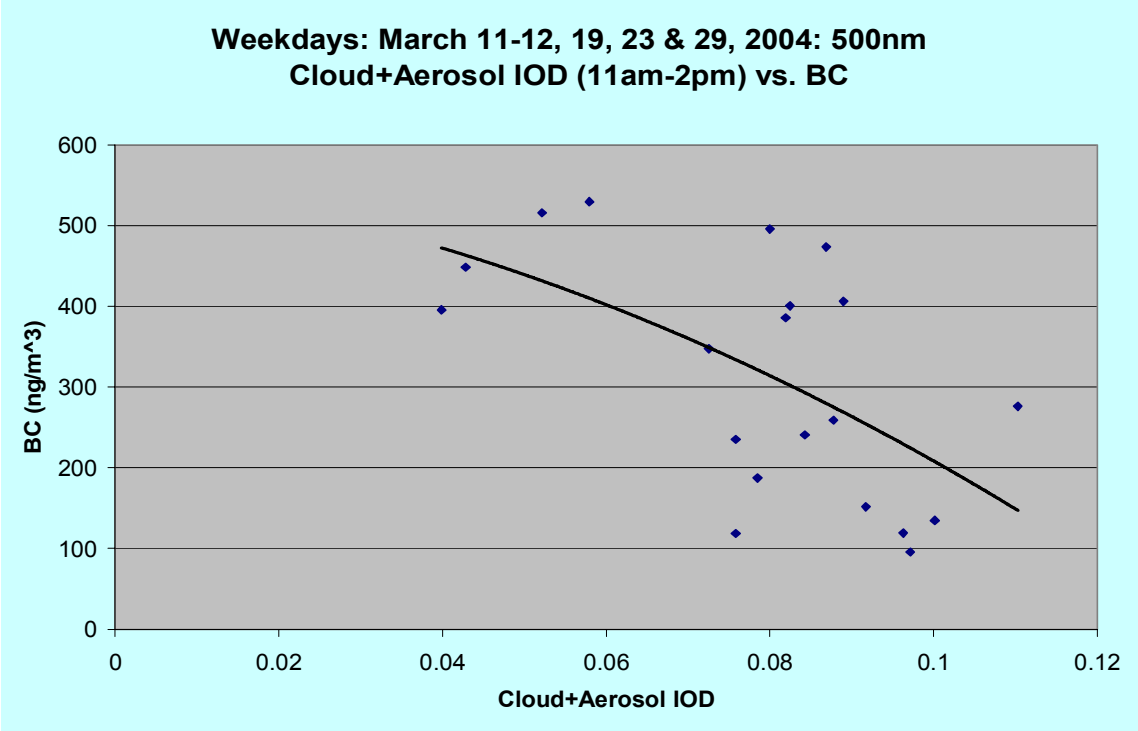

Figure 295. March 2004 Weekdays 500nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

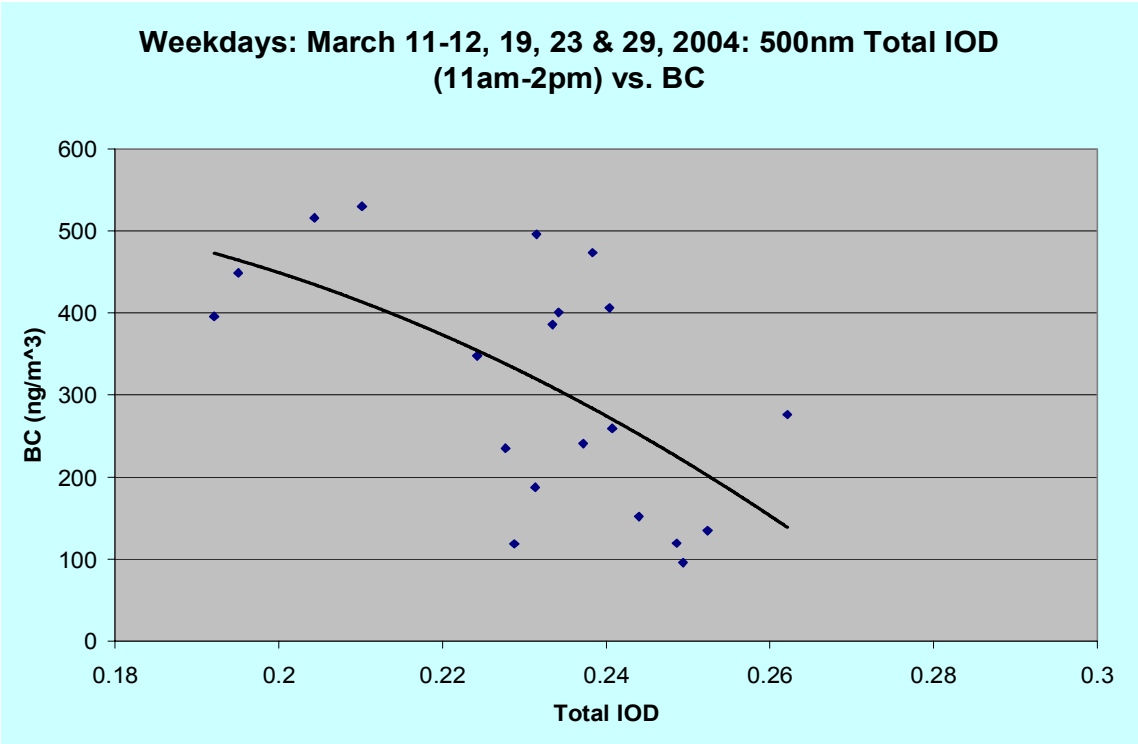

Figure 296. March 2004 Weekdays 500nm Total IOD vs. BC Concentrations (ng/m^3)

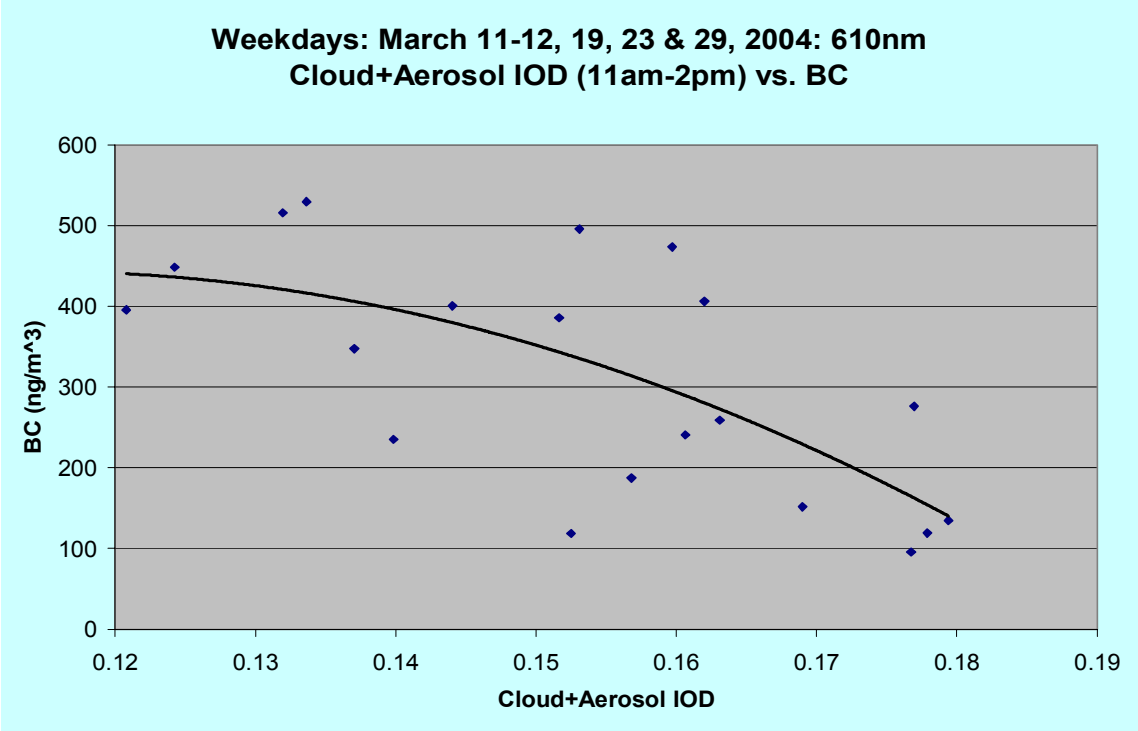

Figure 297. March 2004 Weekdays 610nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

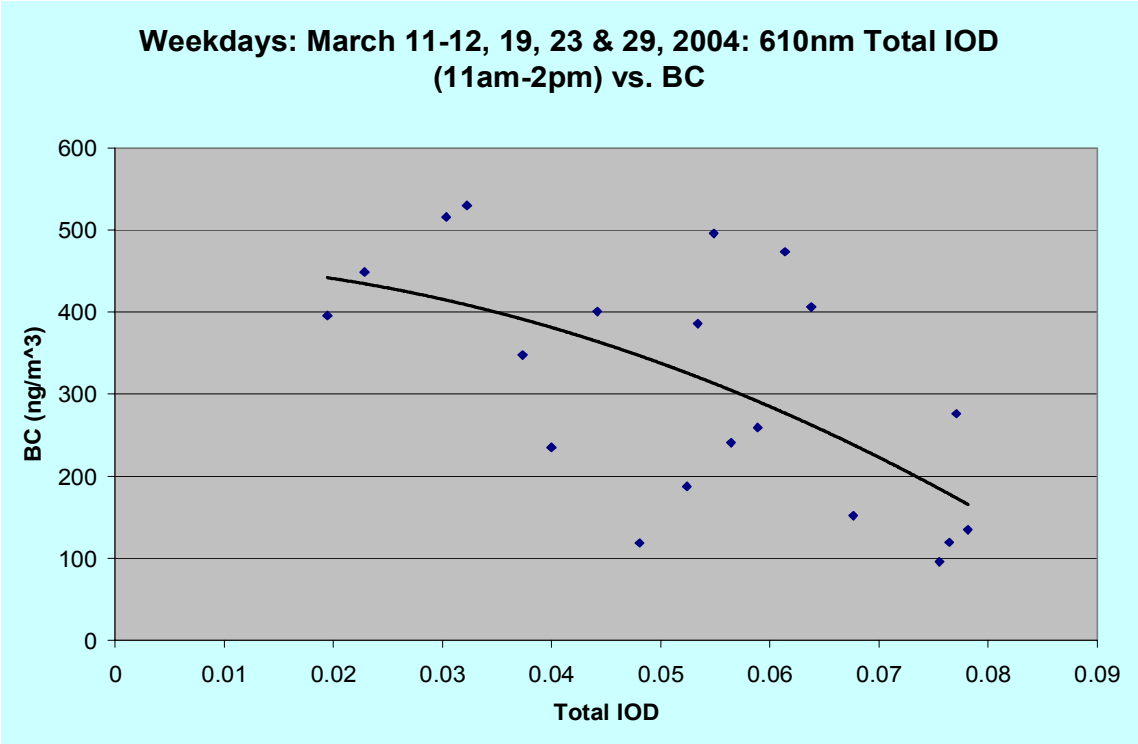

Figure 298. March 2004 Weekdays 610nm Total IOD vs. BC Concentrations (ng/m^3)

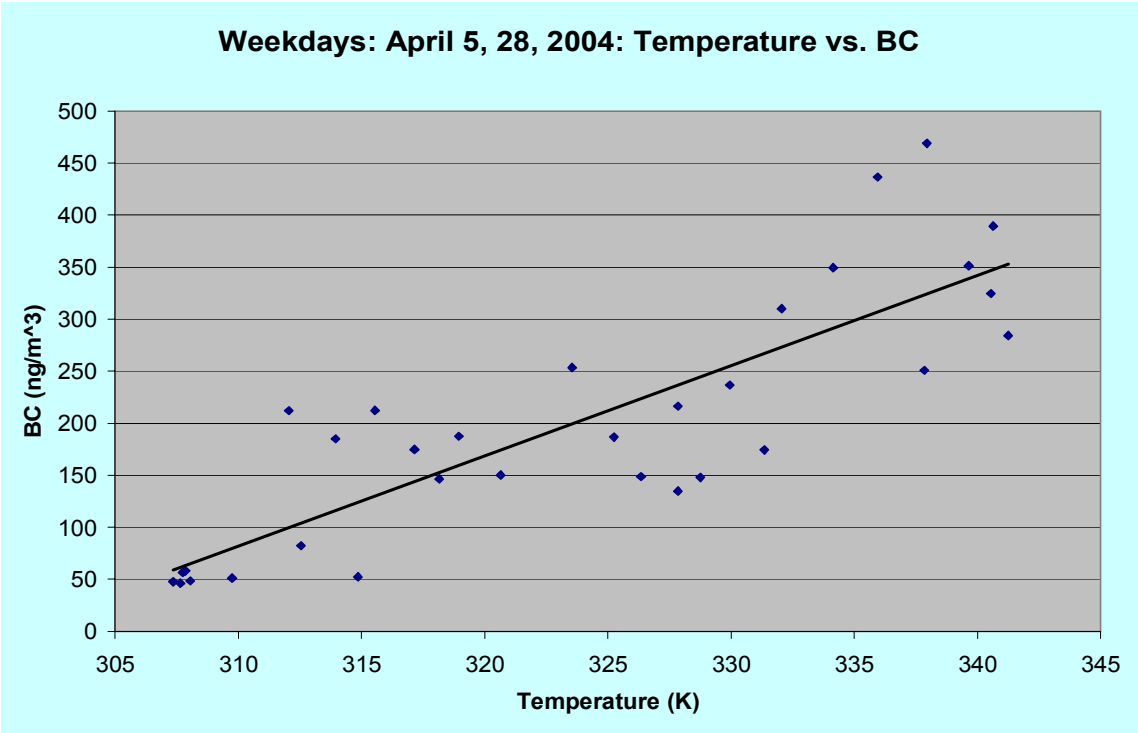

Figure 299. April 2004 Weekdays Temperature (K) vs. BC Concentrations (ng/m^3)

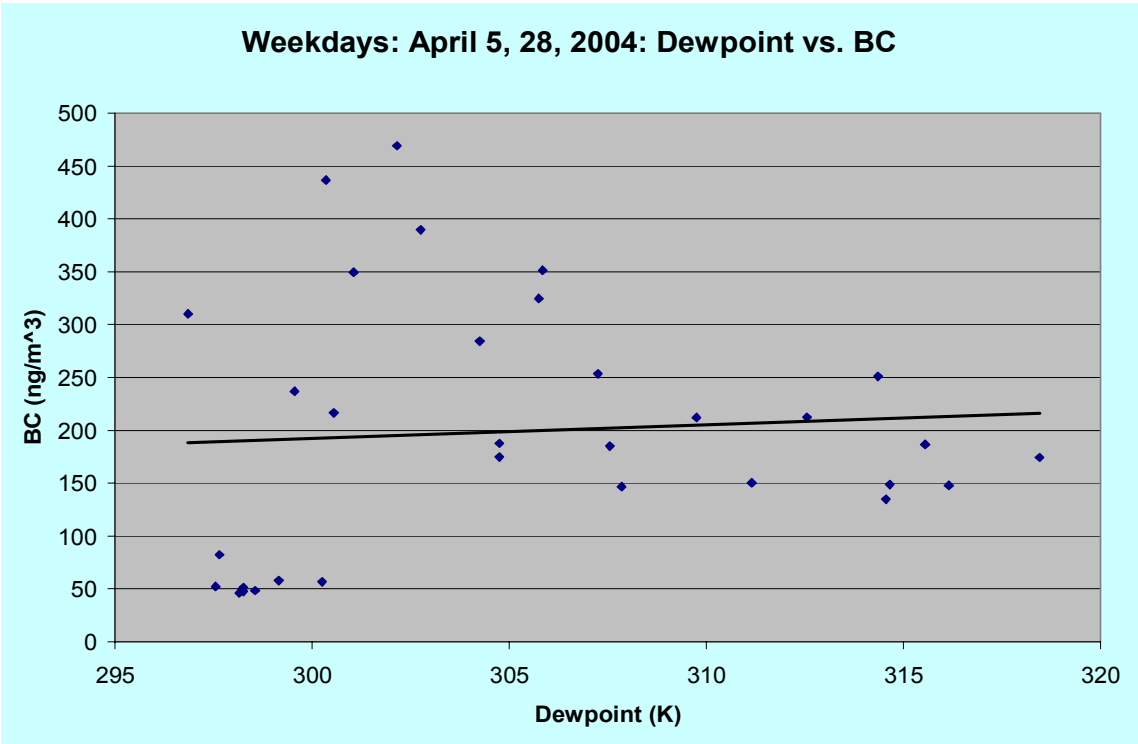

Figure 300. April 2004 Weekdays Dewpoint (K) vs. BC Concentrations (ng/m^3)

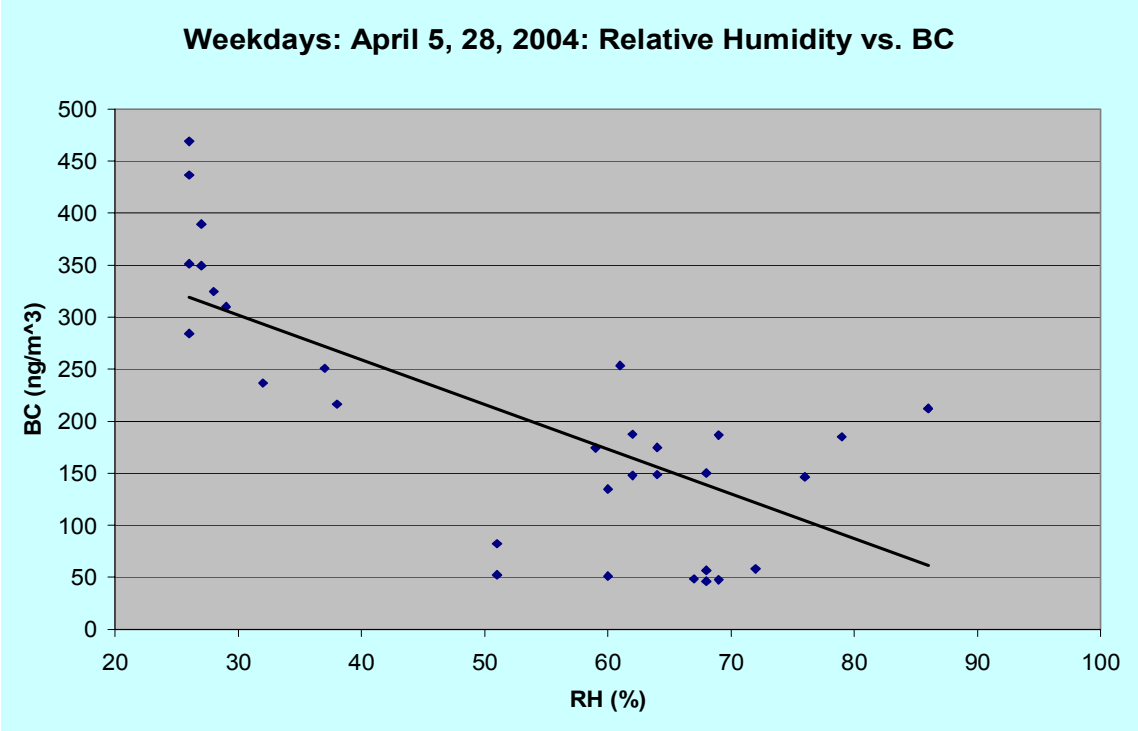

Figure 301. April 2004 Weekdays Relative Humidity (%) vs. BC Concentrations (ng/m^3)

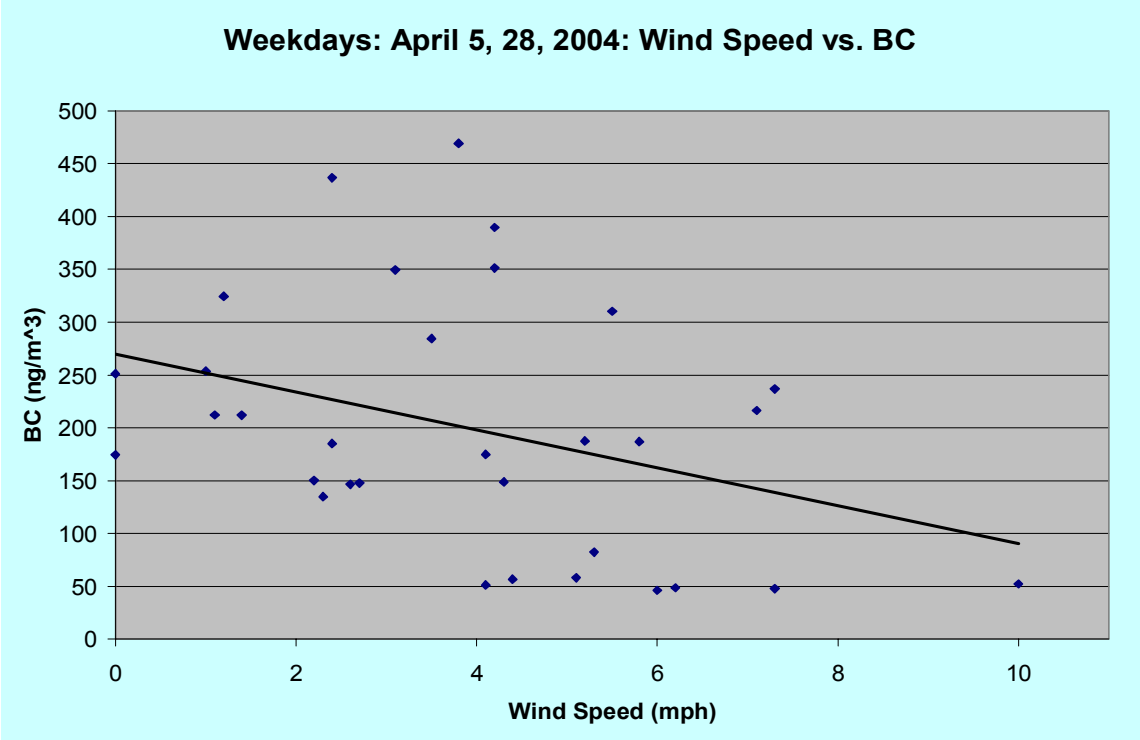

Figure 302. April 2004 Weekdays Wind Speed (mph) vs. BC Concentrations (ng/m^3)

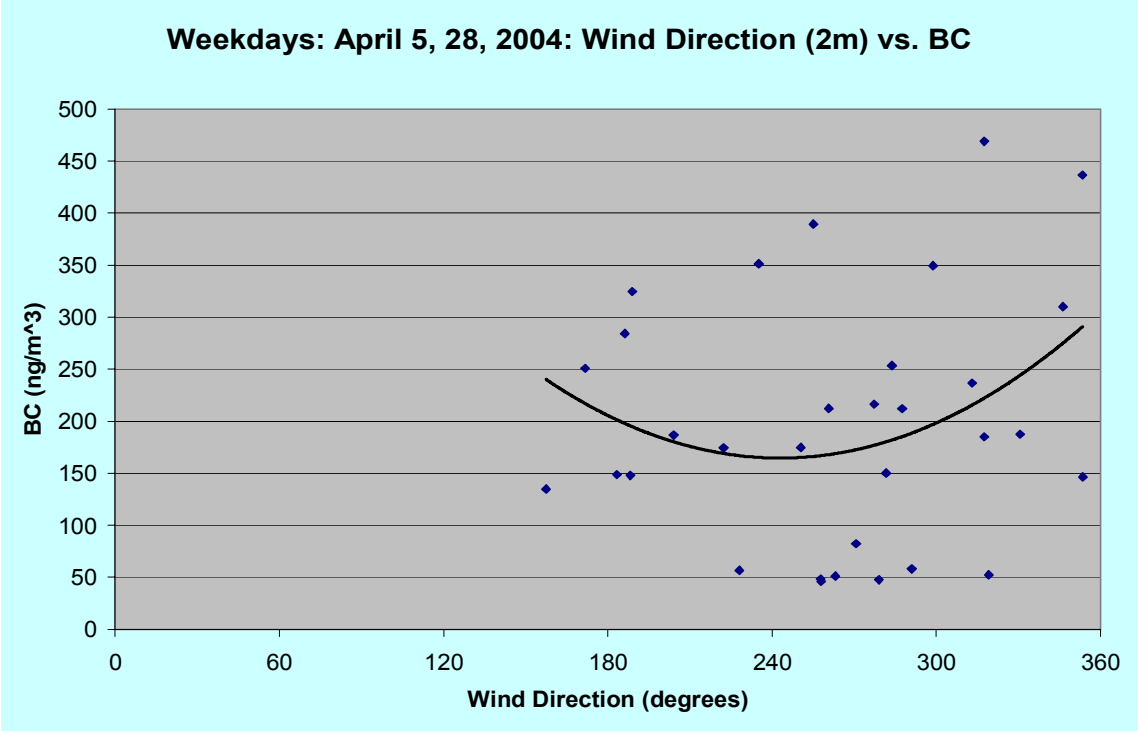

Figure 303. April 2004 Weekdays Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

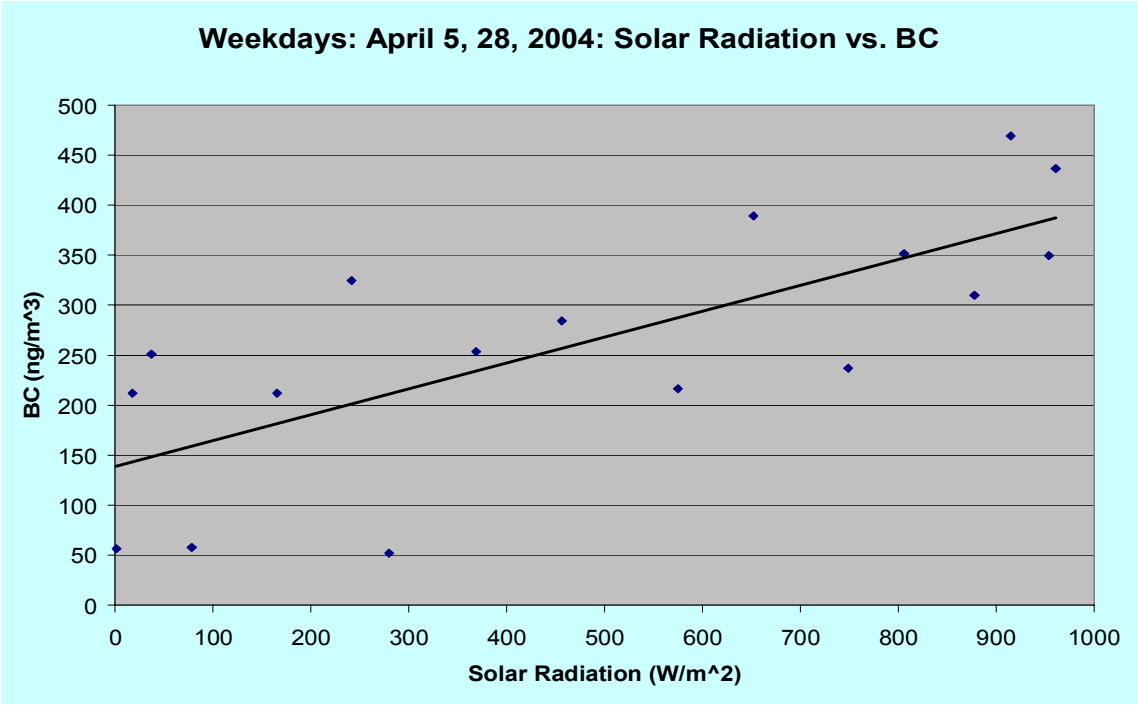

Figure 304. April 2004 Weekdays Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

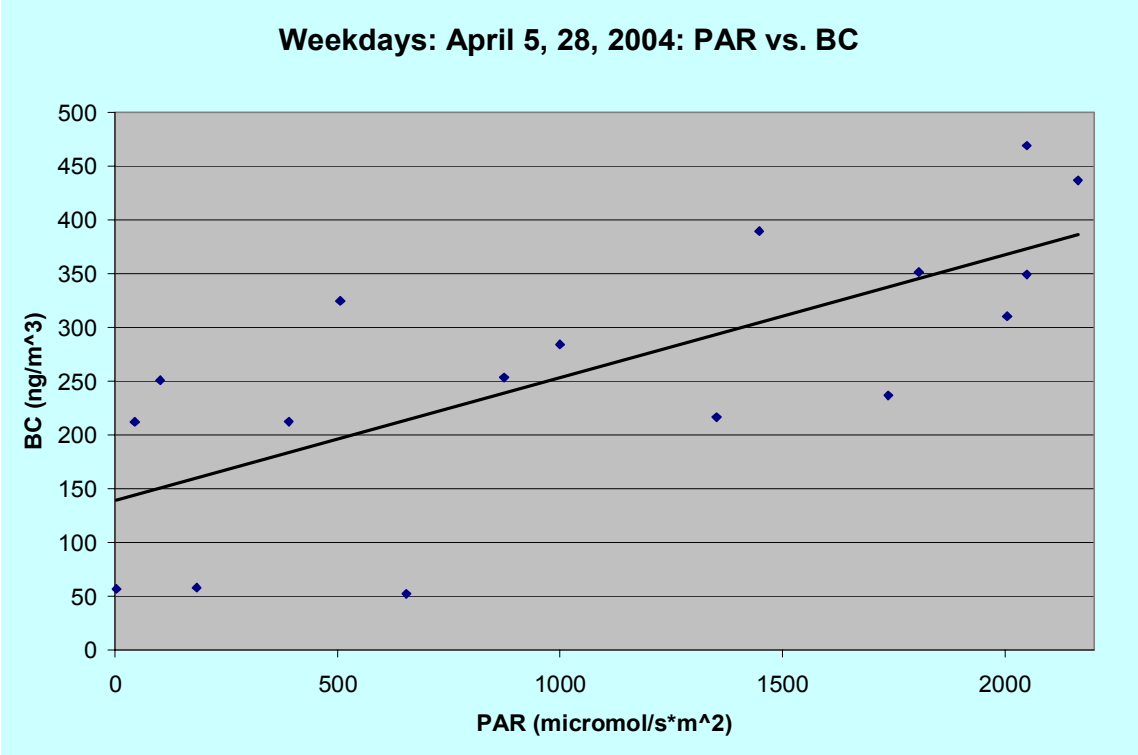

Figure 305. April 2004 Weekdays PAR (micromole/s*m^2) vs. BC Concentrations (ng/m^3)

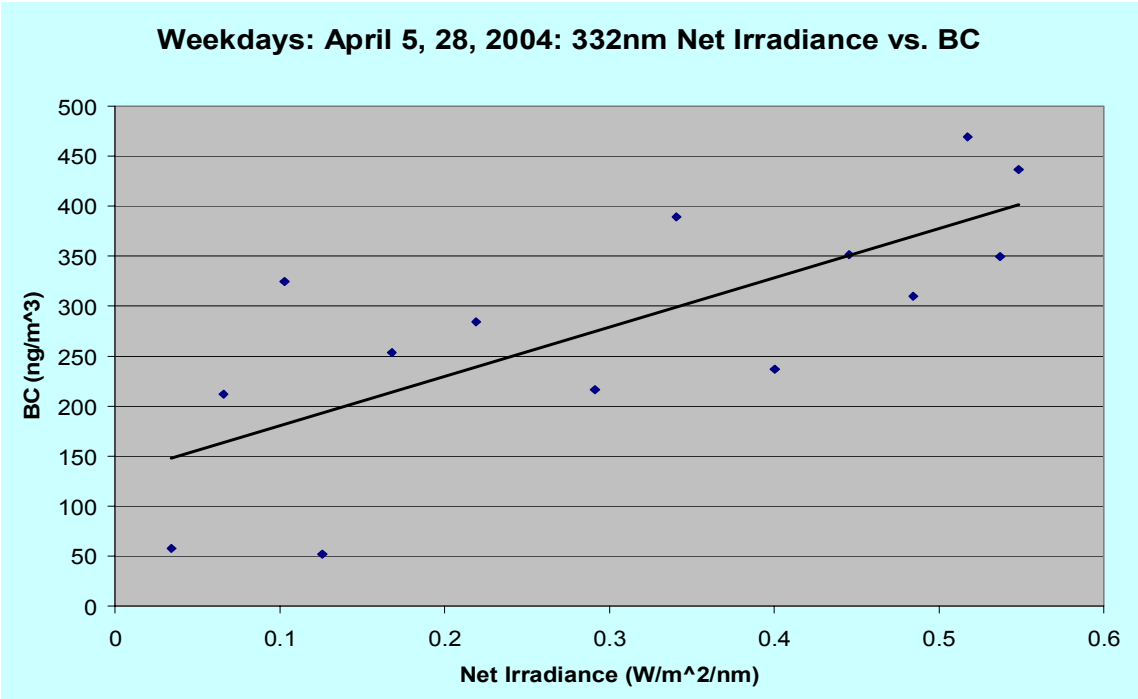

Figure 306. April 2004 Weekdays 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

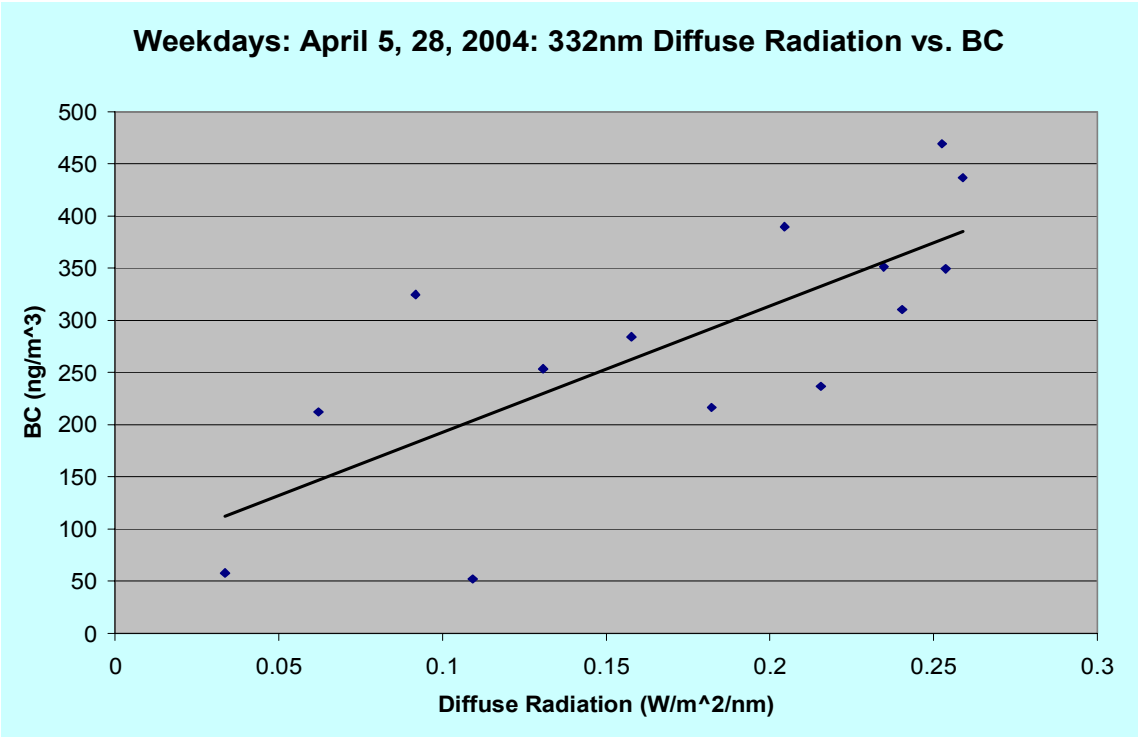

Figure 307. April 2004 Weekdays 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

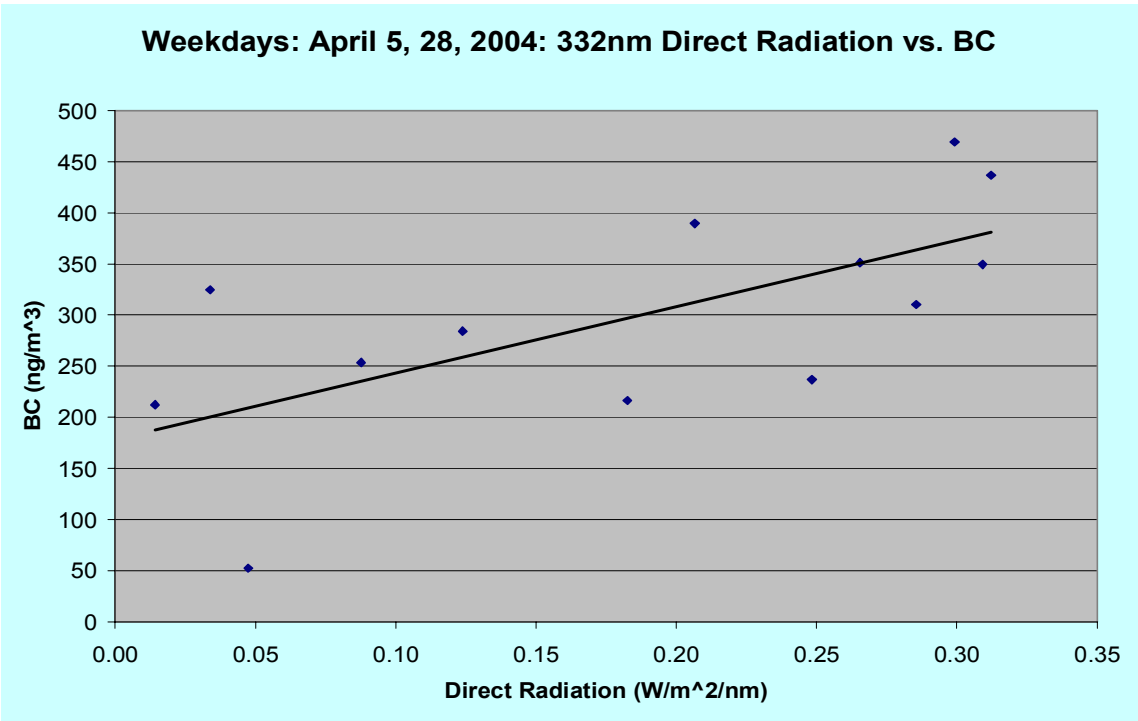

Figure 308. April 2004 Weekdays 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

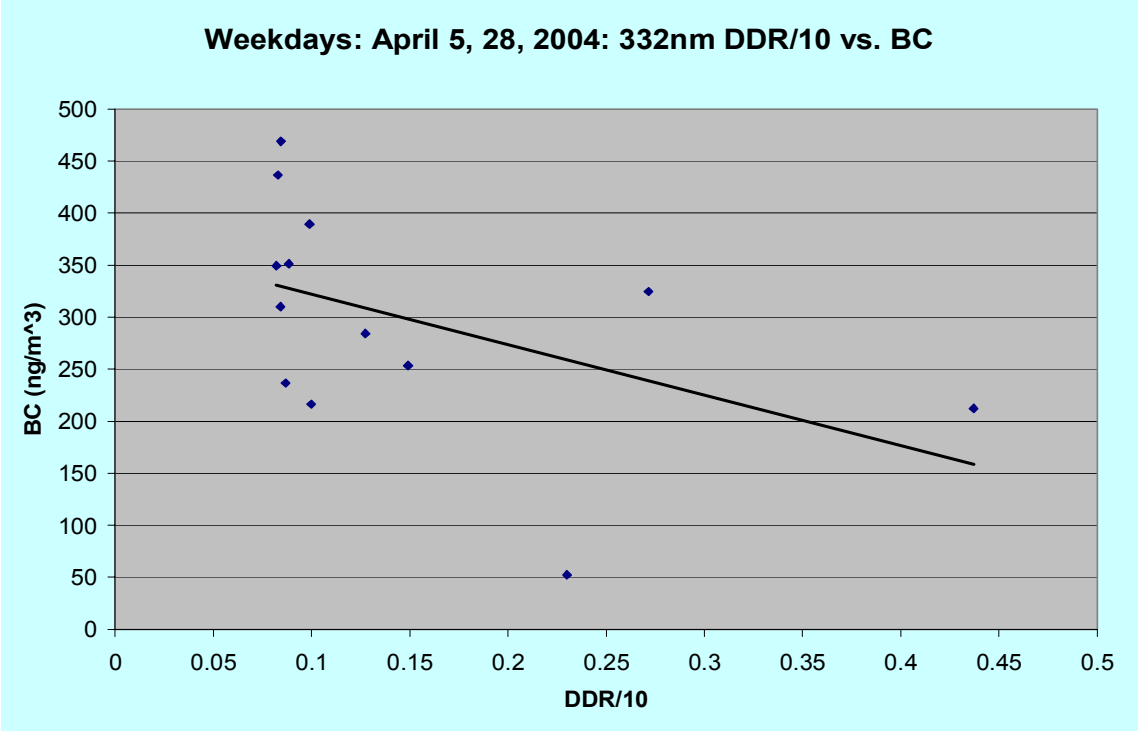

Figure 309. April 2004 Weekdays 332nm DDR/10 vs. BC Concentrations (ng/m^3)

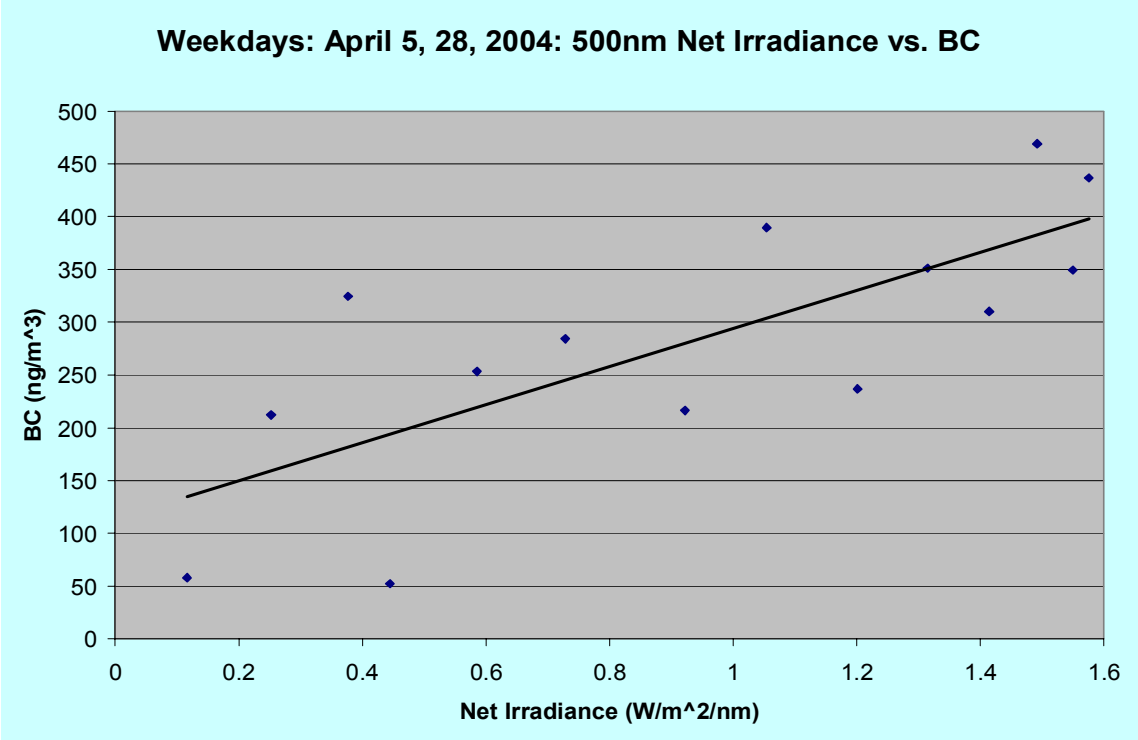

Figure 310. April 2004 Weekdays 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

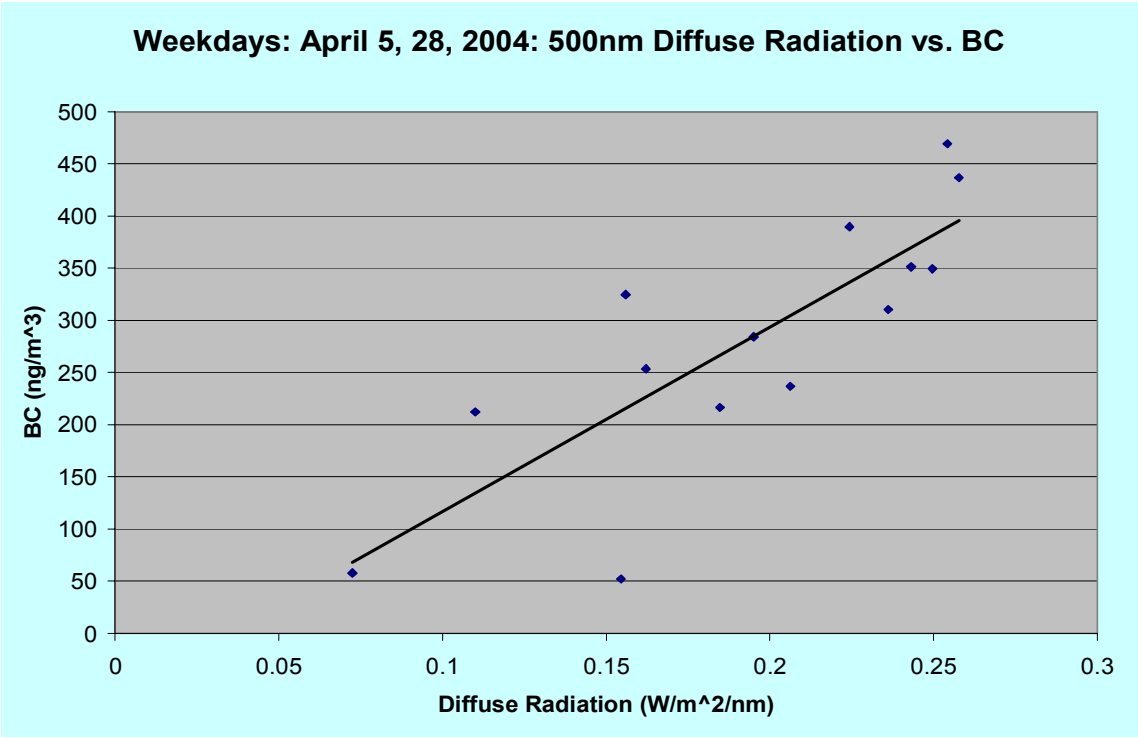

Figure 311. April 2004 Weekdays 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

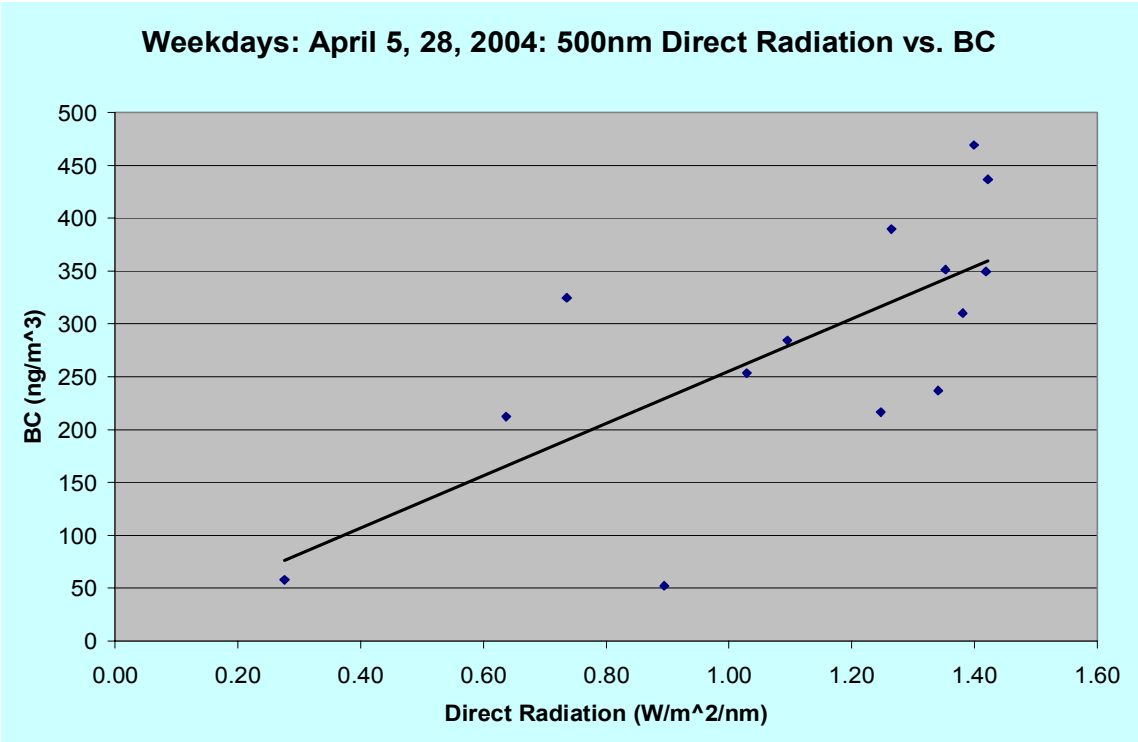

Figure 312. April 2004 Weekdays 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

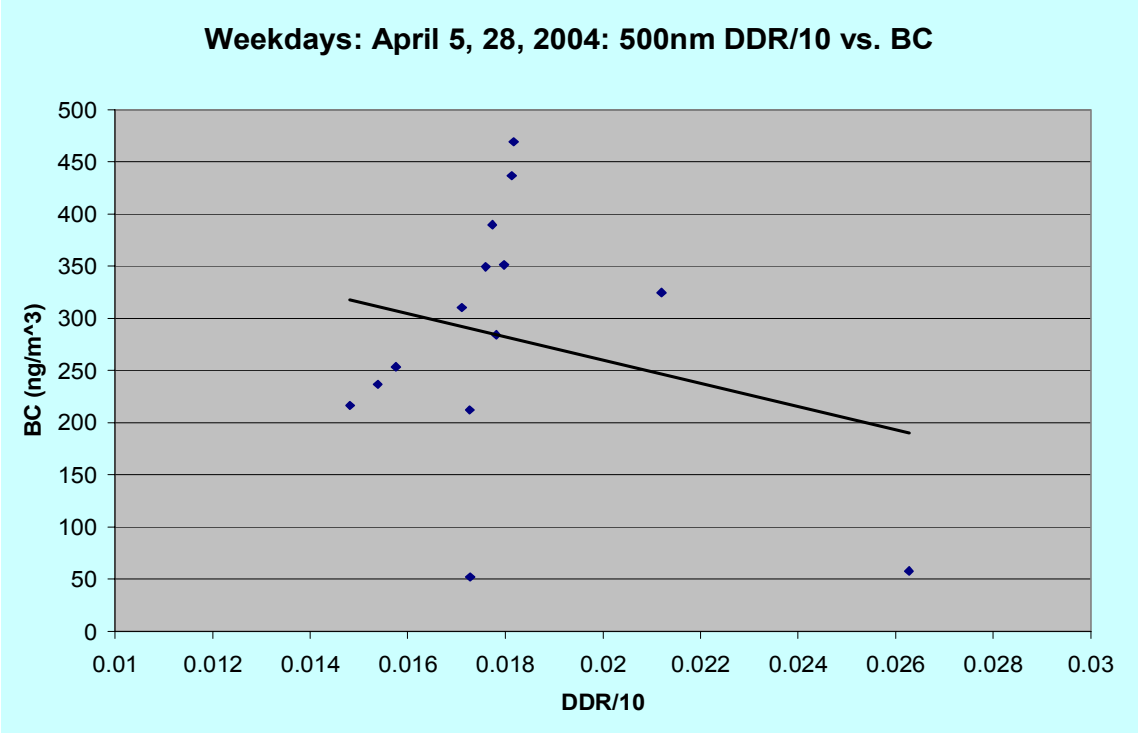

Figure 313. April 2004 Weekdays 500nm DDR/10 vs. BC Concentrations (ng/m^3)

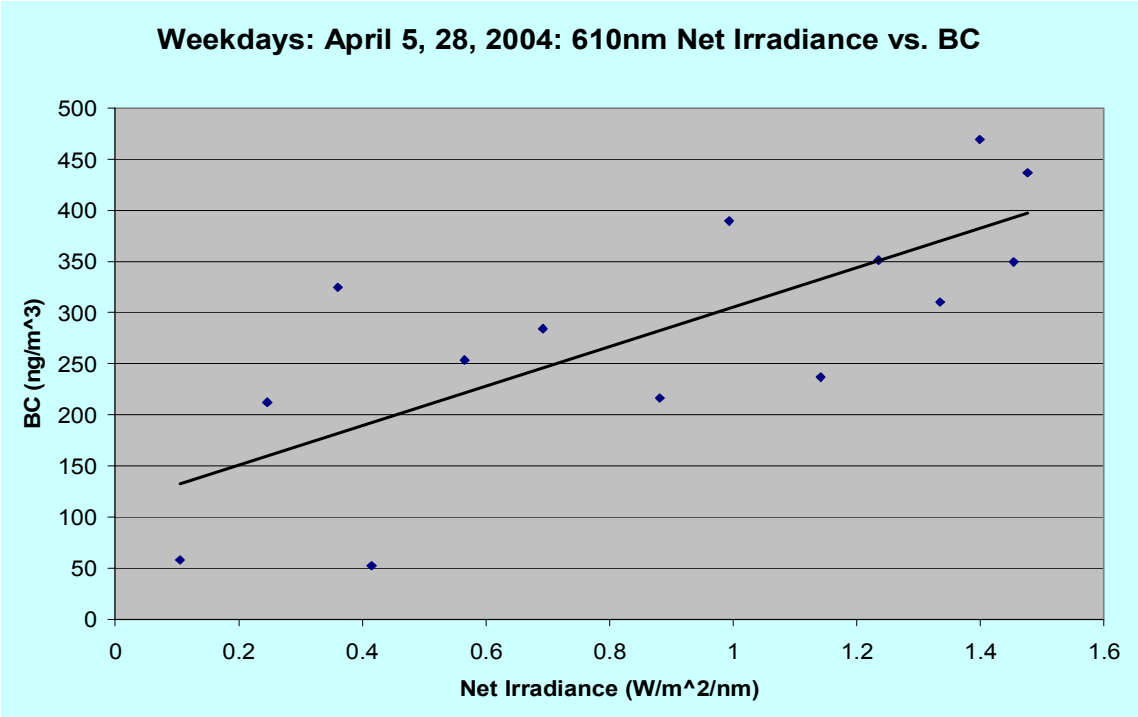

Figure 314. April 2004 Weekdays 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

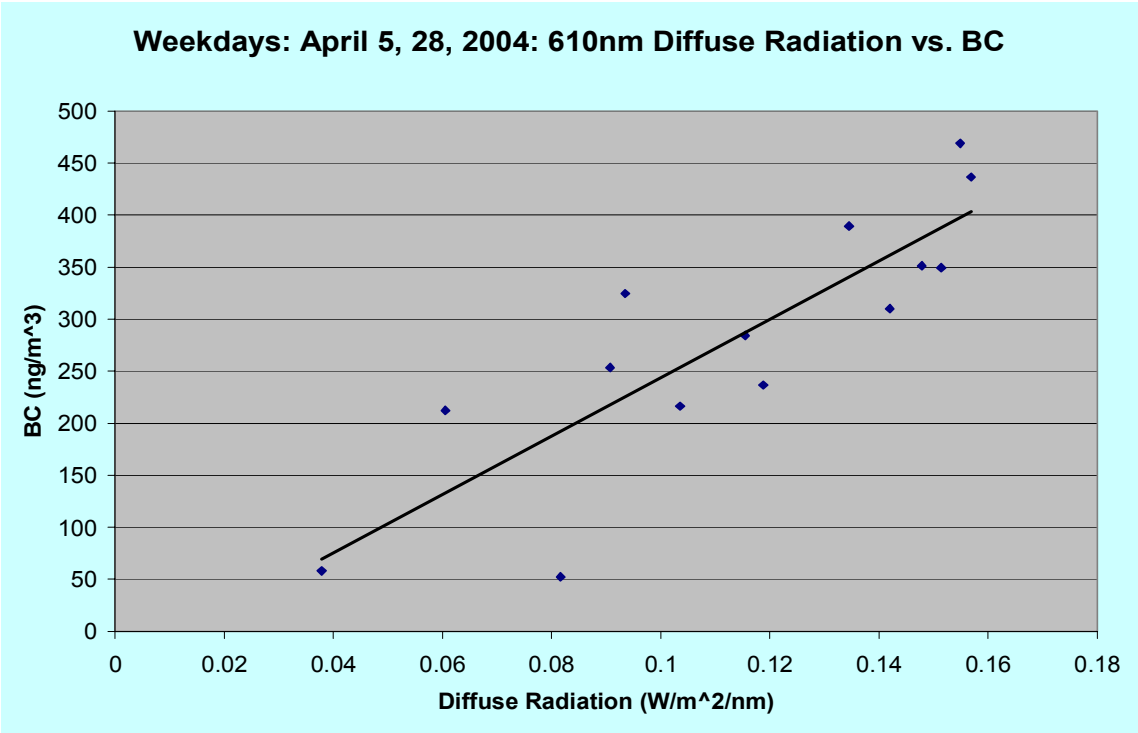

Figure 315. April 2004 Weekdays 610nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

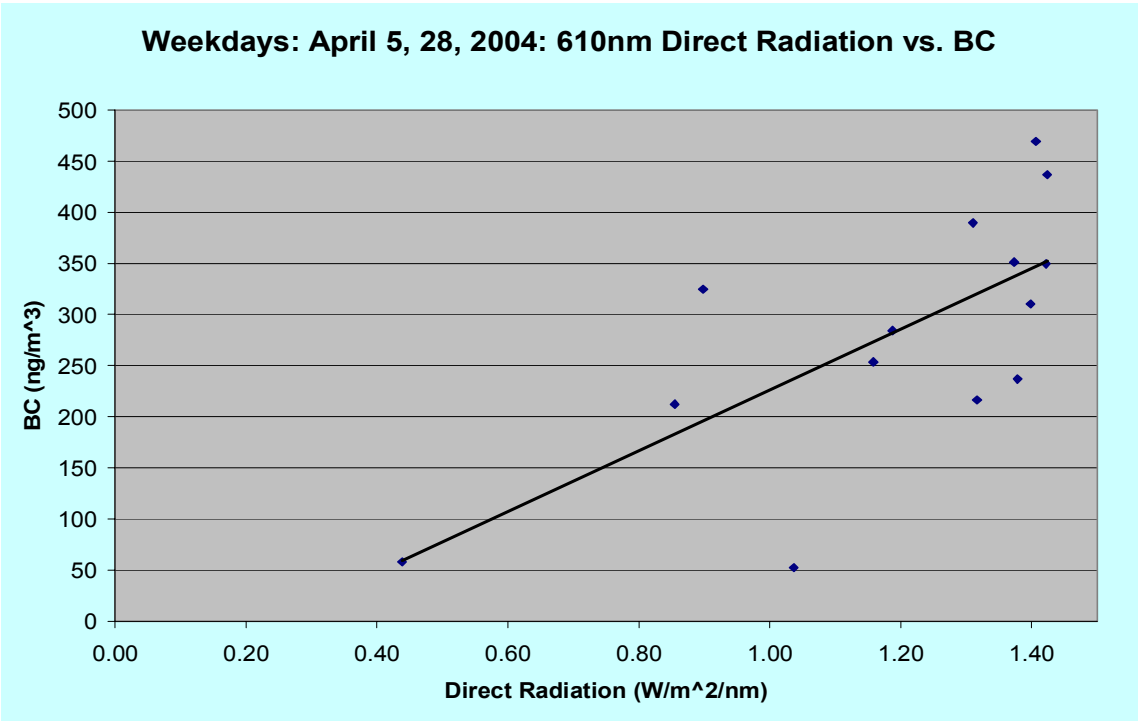

Figure 316. April 2004 Weekdays 610nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

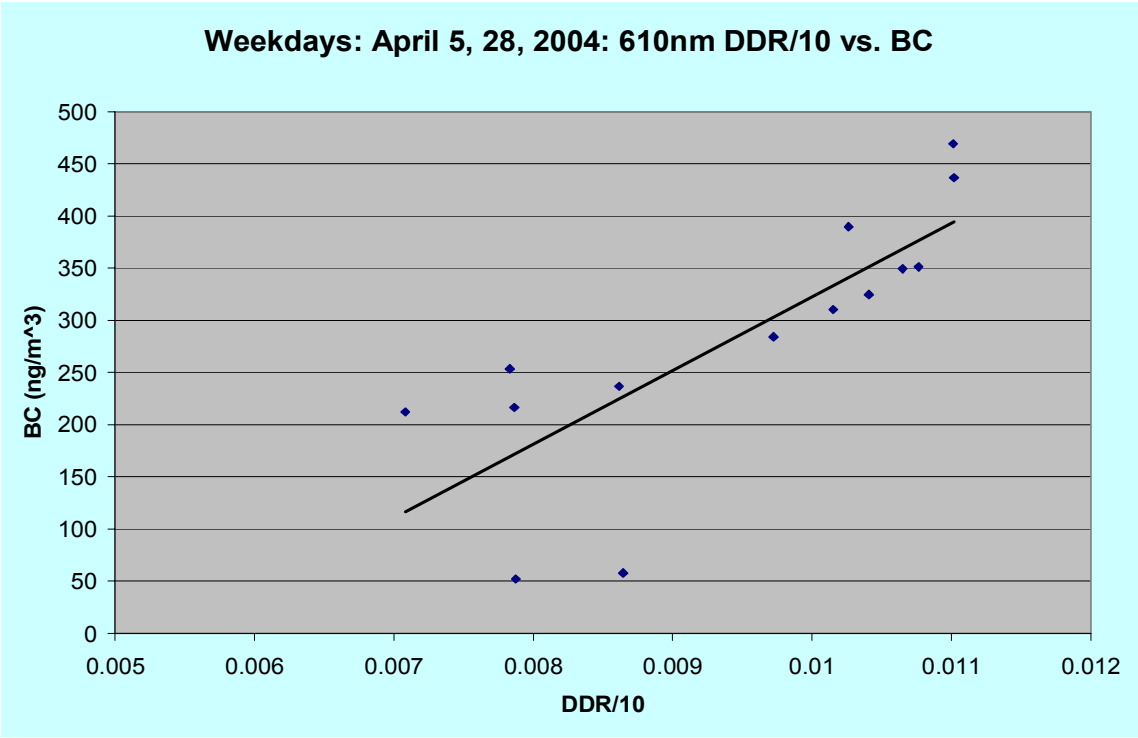

Figure 317. April 2004 Weekdays 610nm DDR/10 vs. BC Concentrations (ng/m^3)

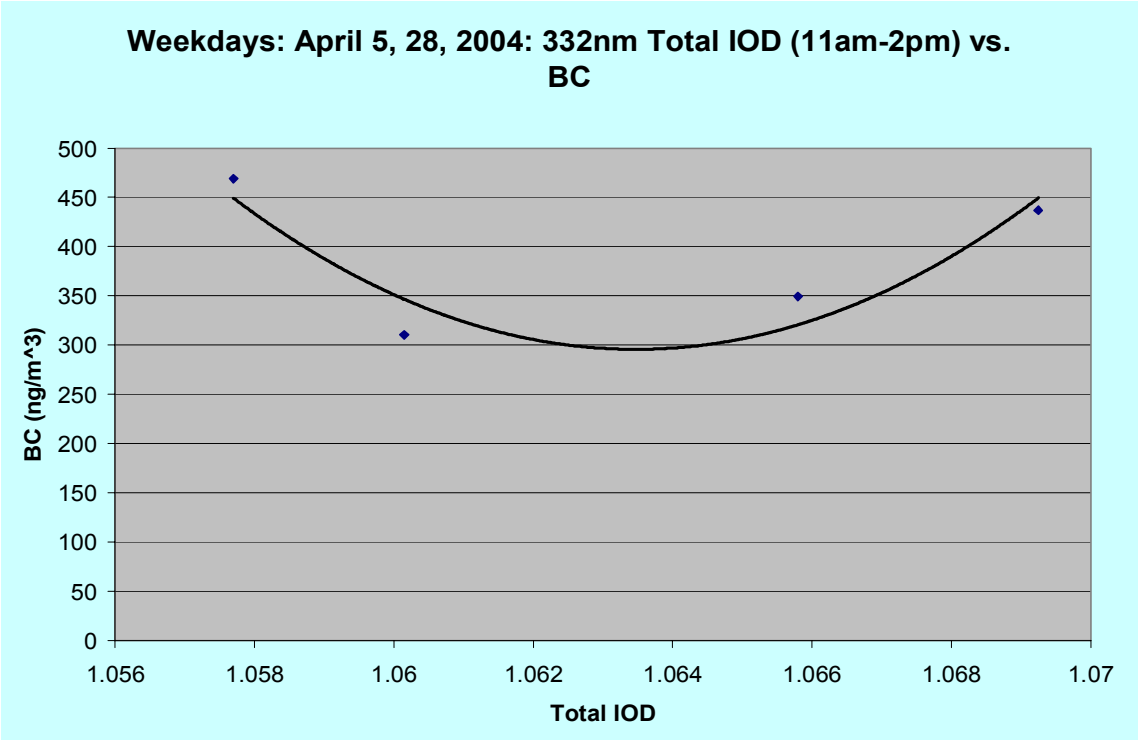

Figure 318. April 2004 Weekdays 332nm Total IOD vs. BC Concentrations (ng/m^3)

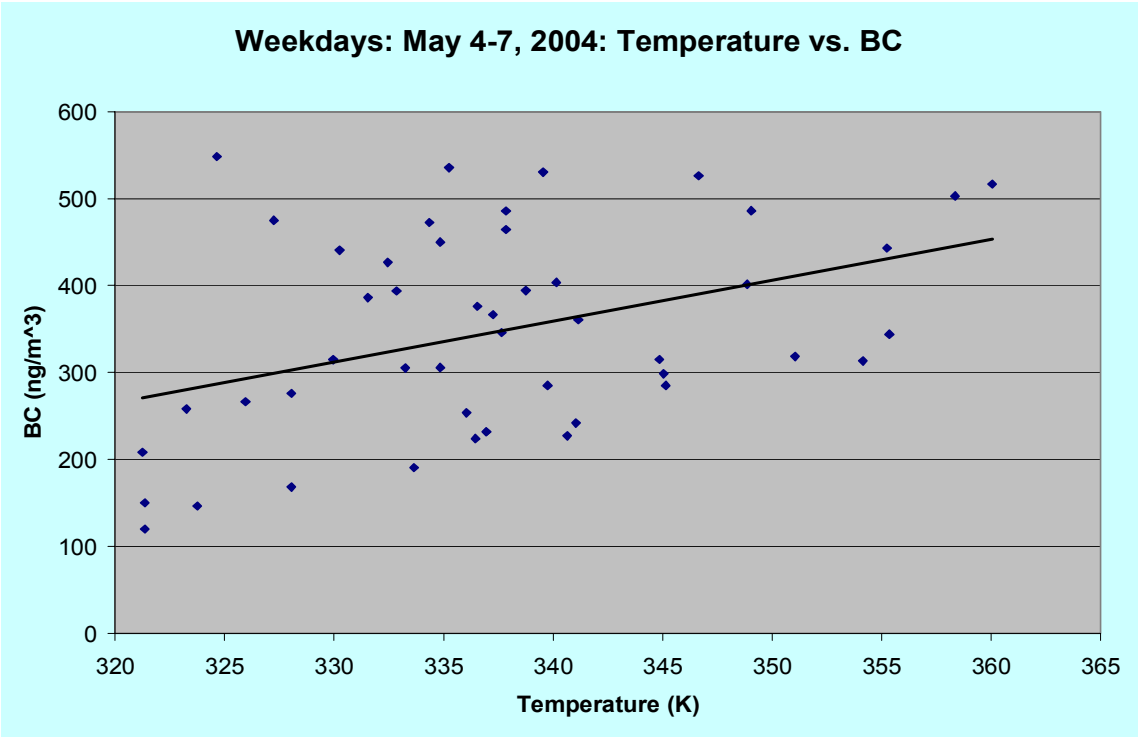

Figure 319. May 2004 Weekdays Temperature (K) vs. BC Concentrations (ng/m^3)

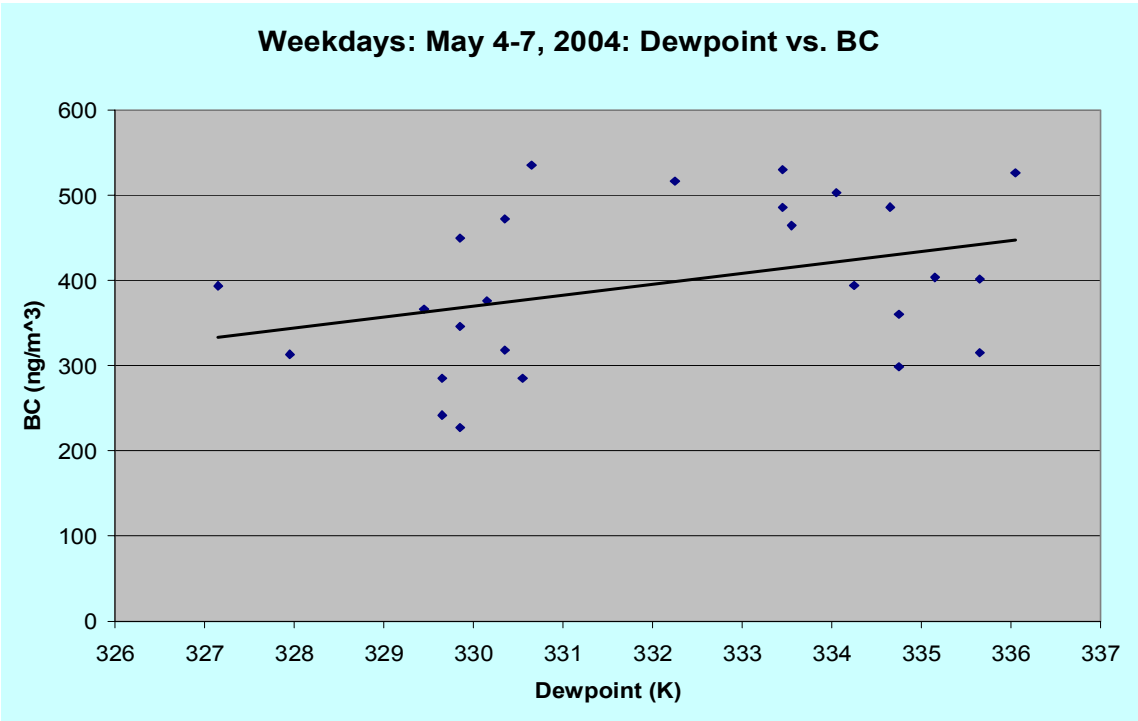

Figure 320. May 2004 Weekdays Dewpoint (K) vs. BC Concentrations (ng/m^3)

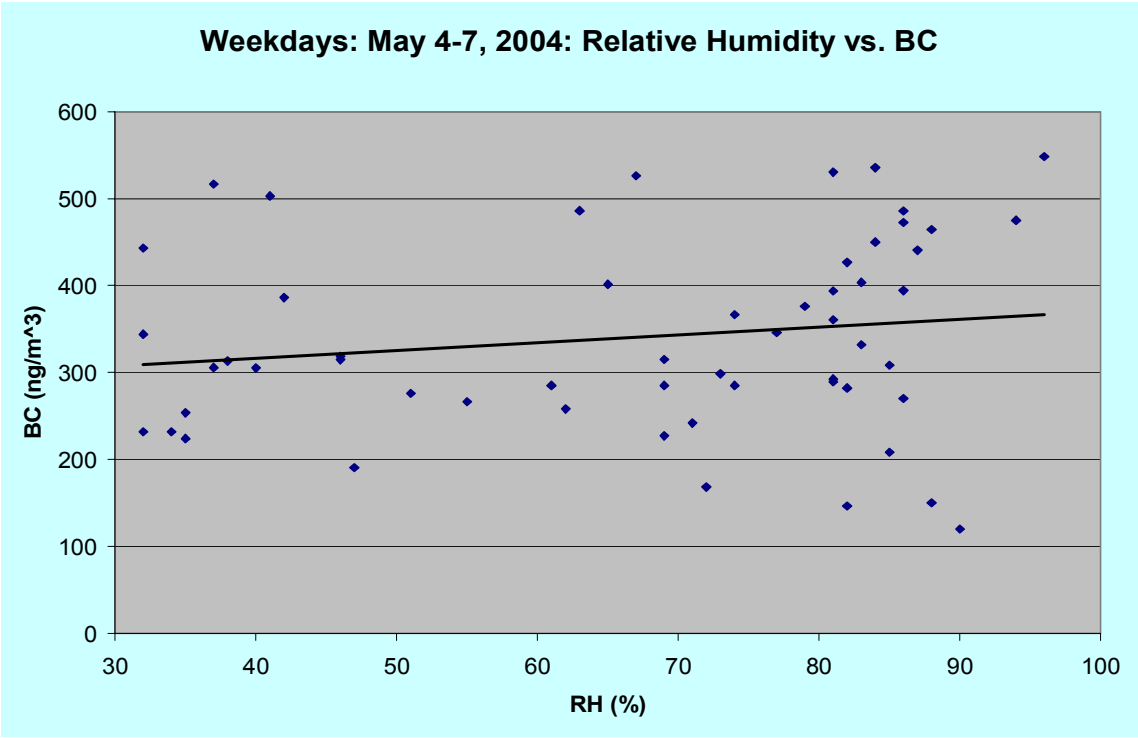

Figure 321. May 2004 Weekdays Relative Humidity (%) vs. BC Concentrations (ng/m^3)

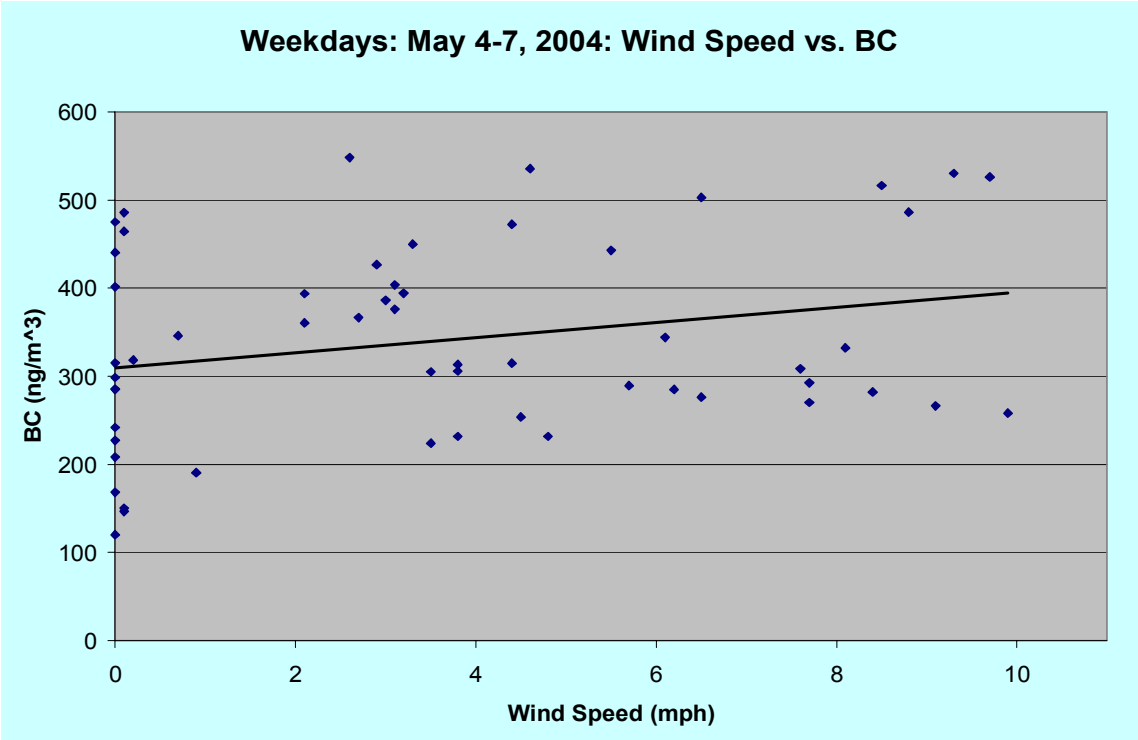

Figure 322. May 2004 Weekdays Wind Speed (mph) vs. BC Concentrations (ng/m^3)

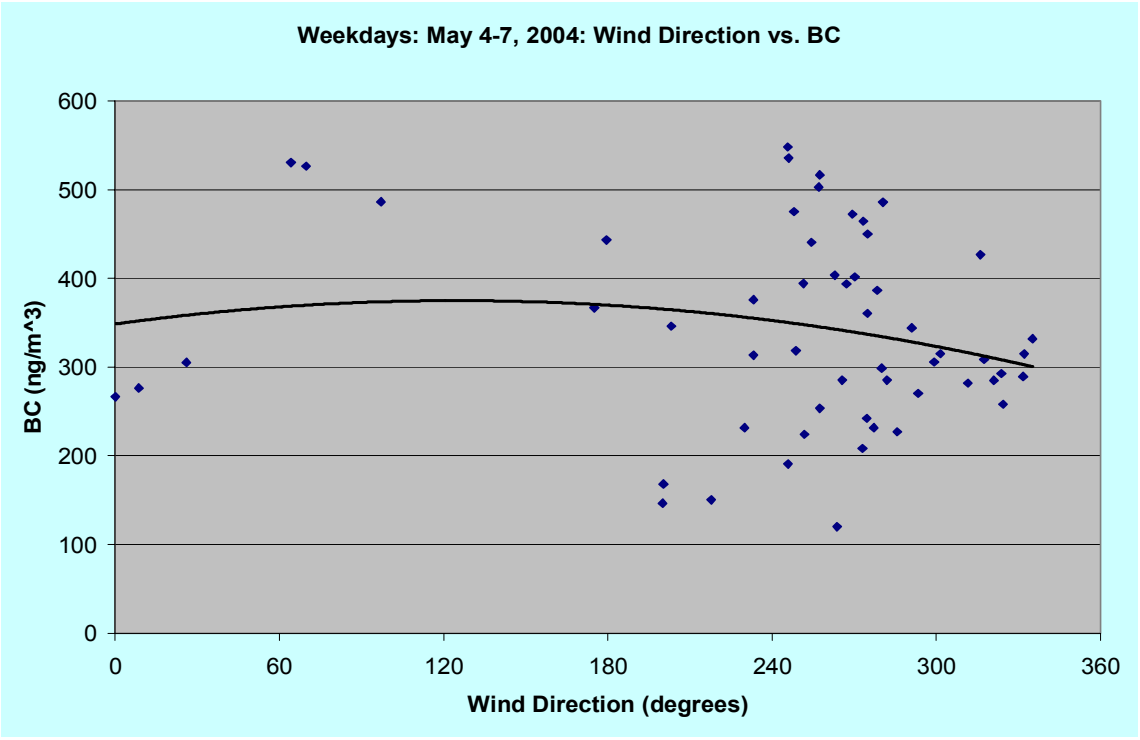

Figure 323. May 2004 Weekdays Wind Direction (degrees) vs. BC Concentrations (ng/m^3)

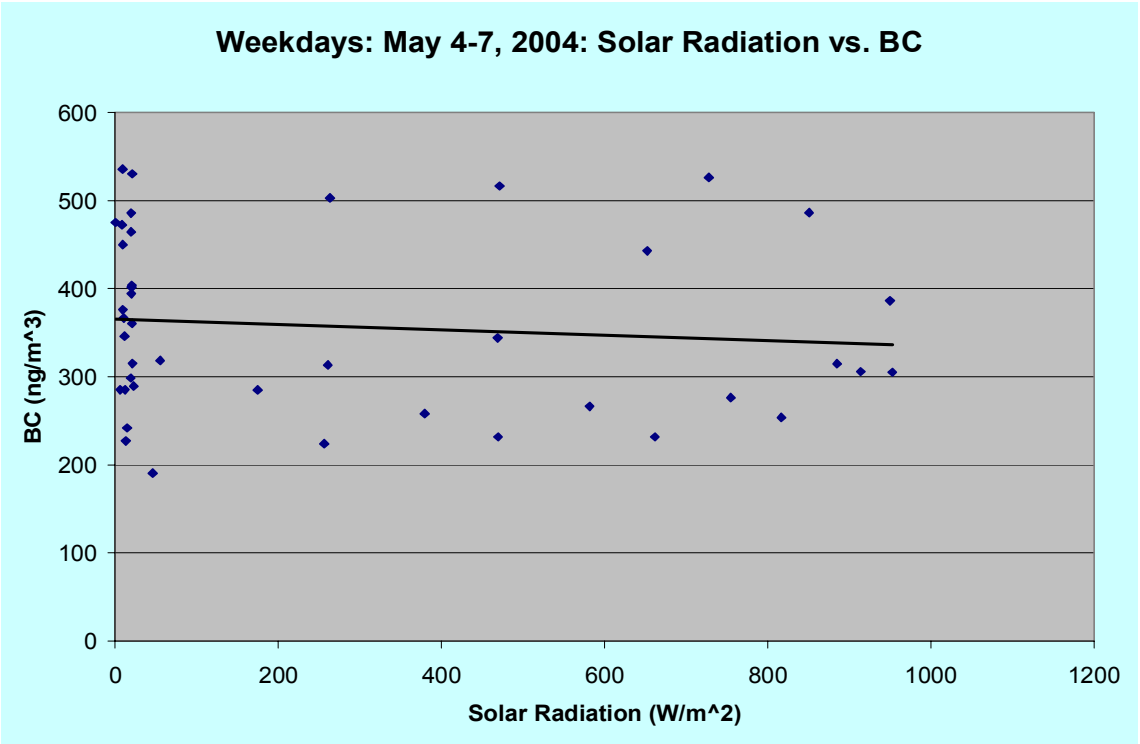

Figure 324. May 2004 Weekdays Solar Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

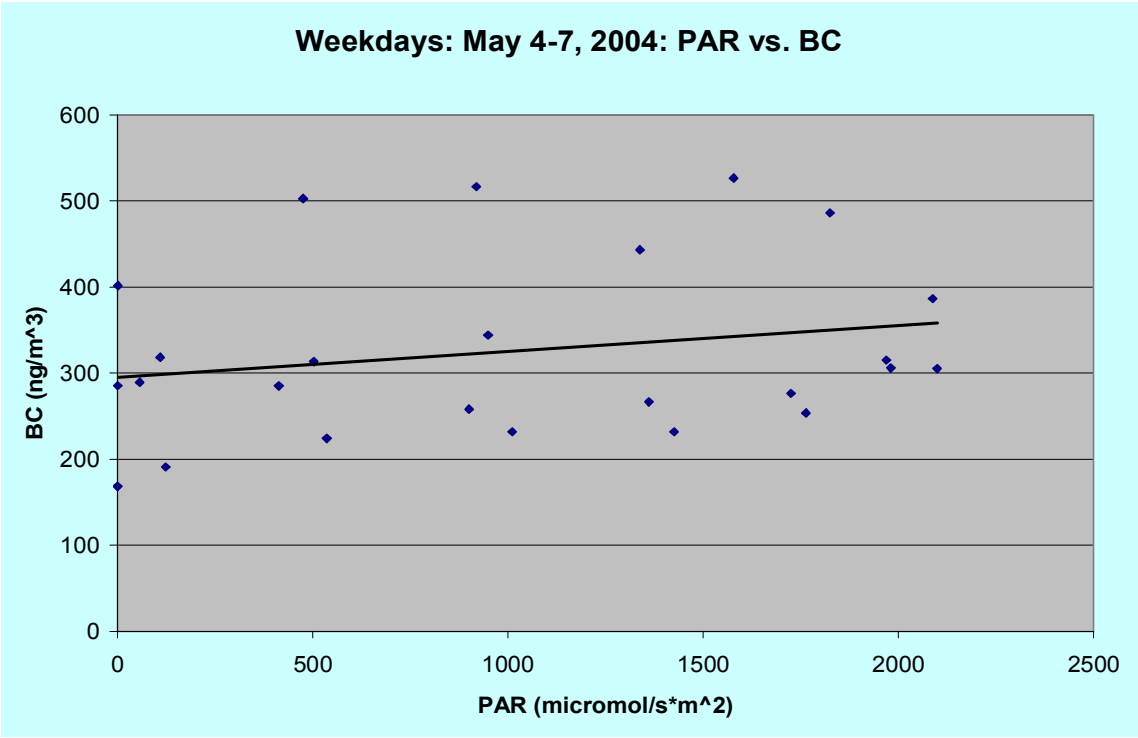

Figure 325. May 2004 Weekdays PAR (micromol/s*m^2) vs. BC Concentrations (ng/m^3)

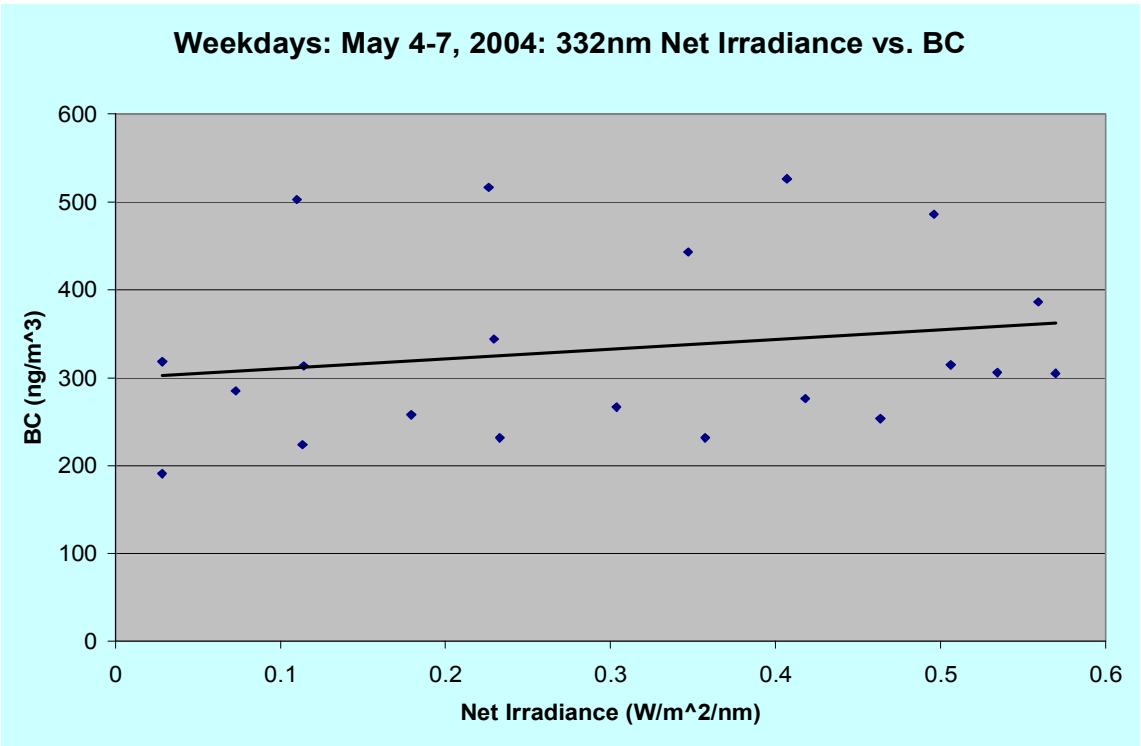

Figure 326. May 2004 Weekdays 332nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

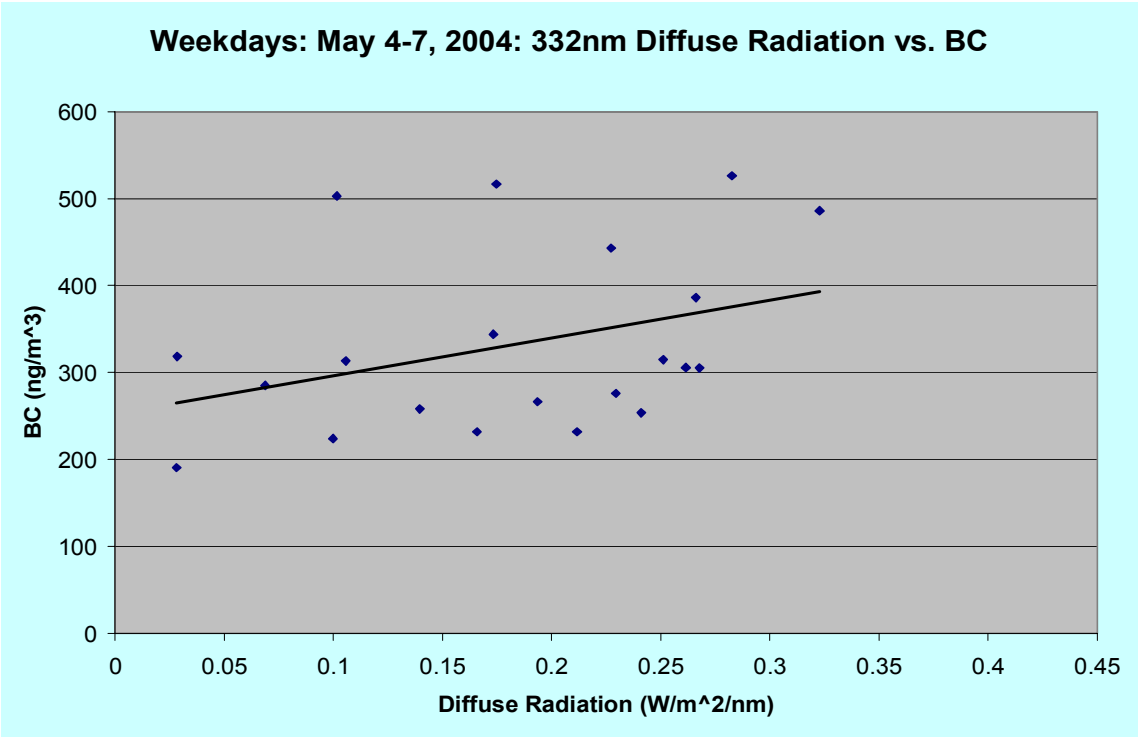

Figure 327. May 2004 Weekdays 332nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

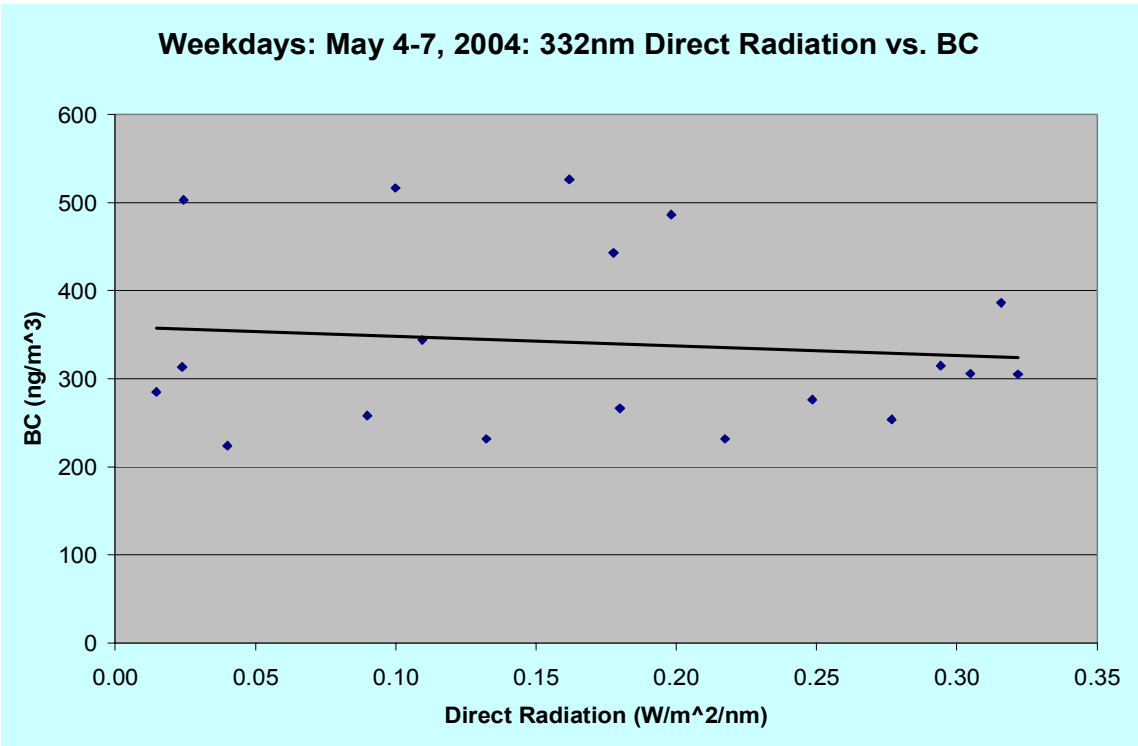

Figure 328. May 2004 Weekdays 332nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

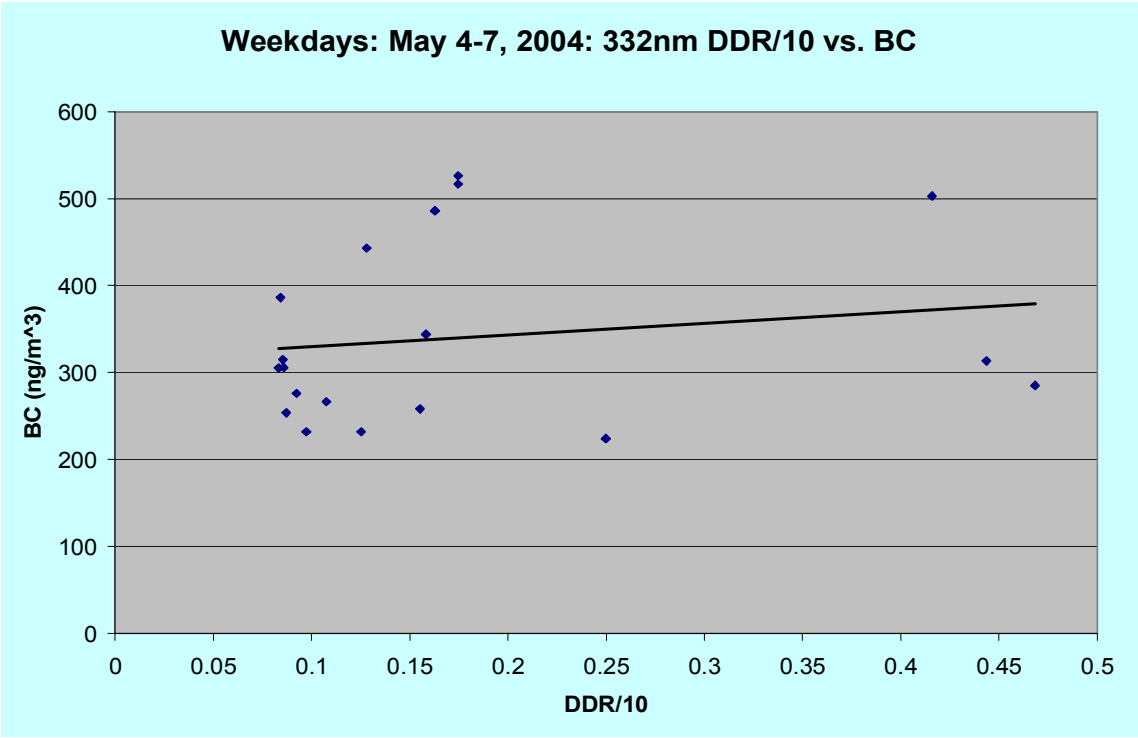

Figure 329. May 2004 Weekdays 332nm DDR/10 vs. BC Concentrations (ng/m^3)

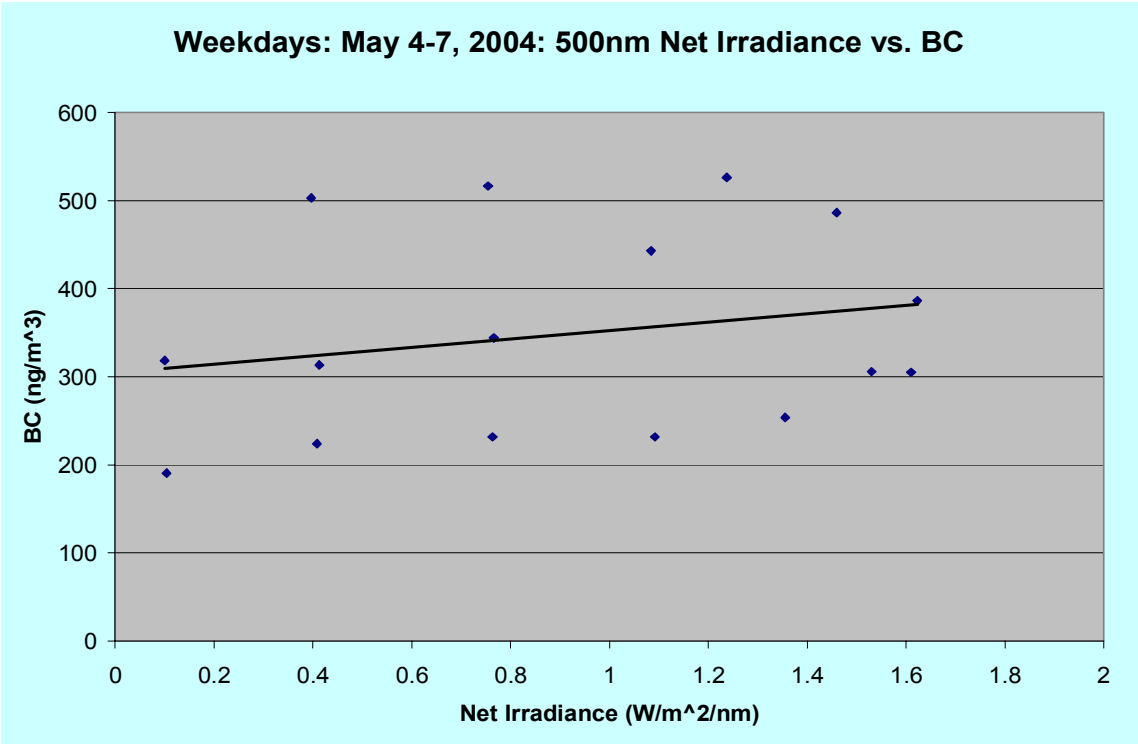

Figure 330. May 2004 Weekdays 500nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

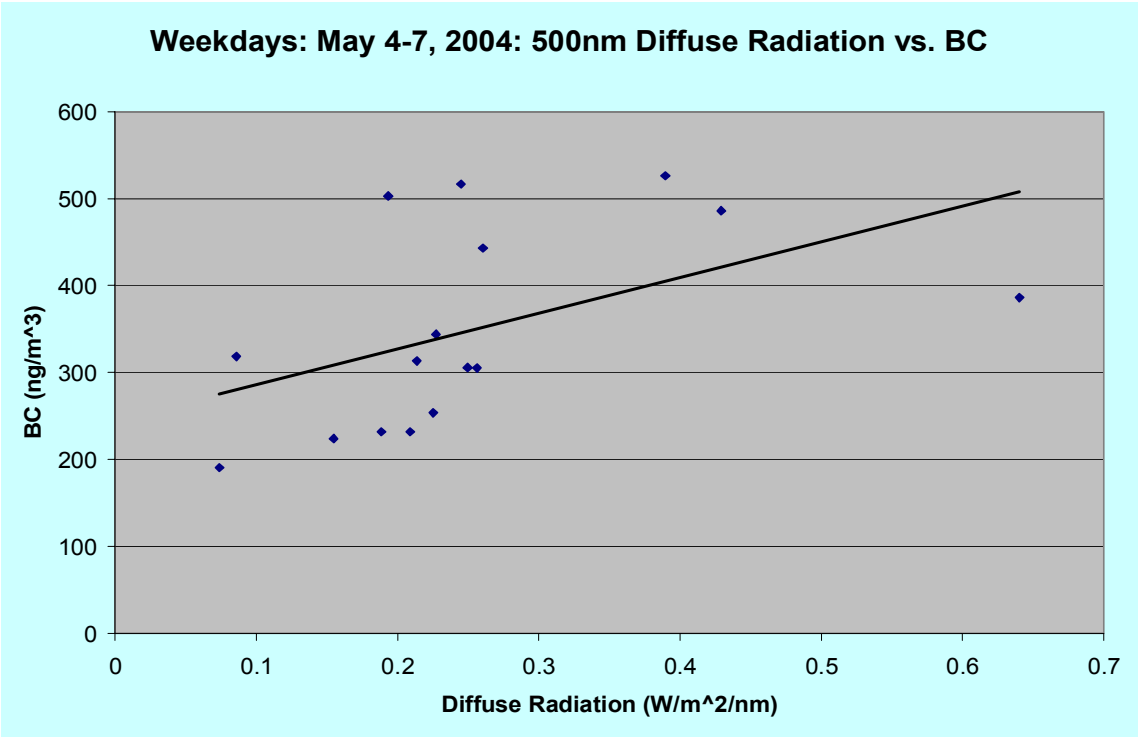

Figure 331. May 2004 Weekdays 500nm Diffuse Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

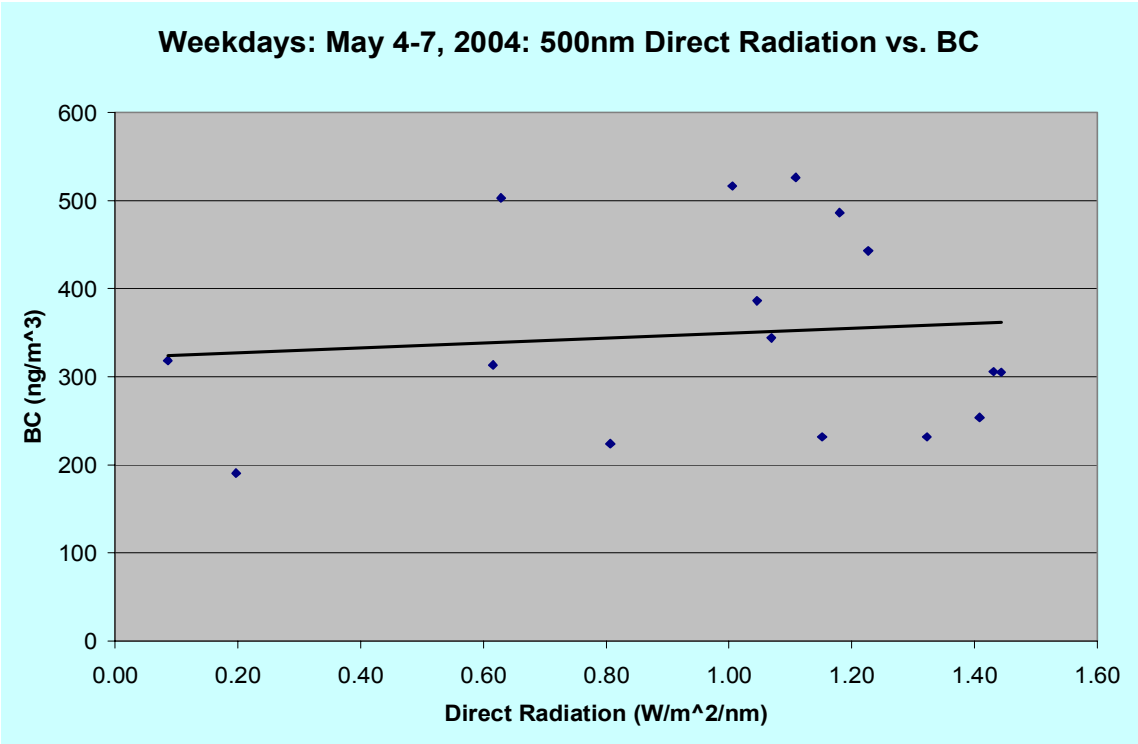

Figure 332. May 2004 Weekdays 500nm Direct Radiation (W/m^2/nm) vs. BC Concentrations (ng/m^3)

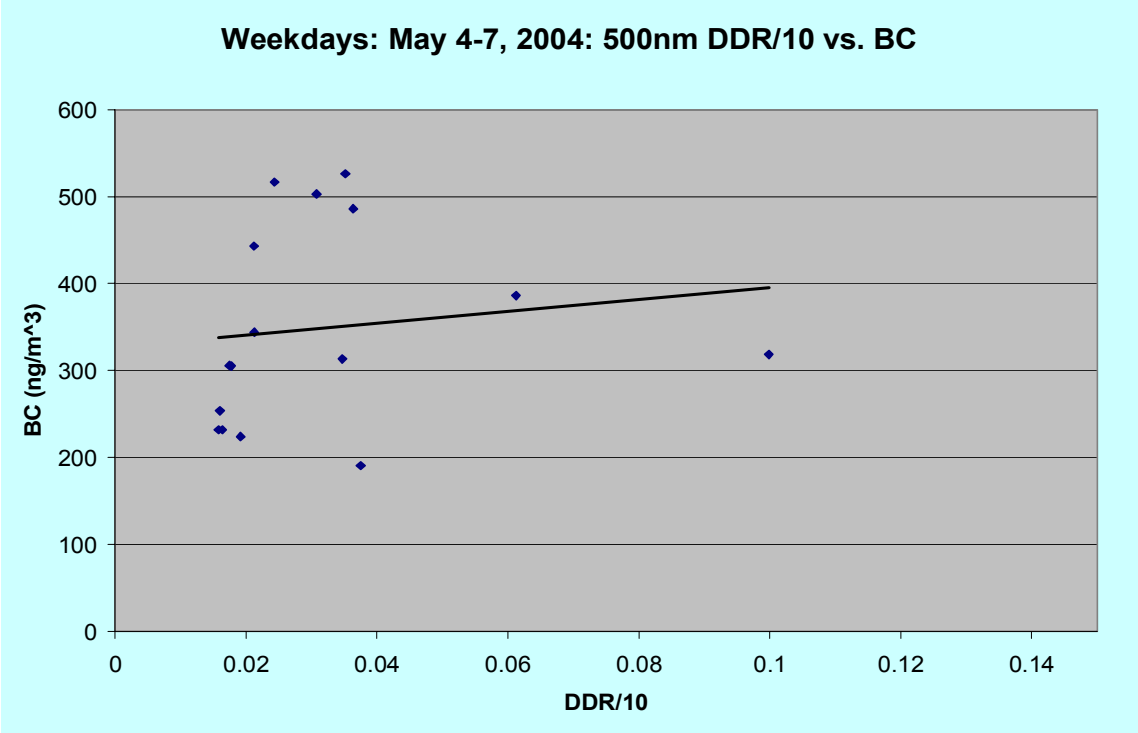

Figure 333. May 2004 Weekdays 500nm DDR/10 vs. BC Concentrations (ng/m^3)

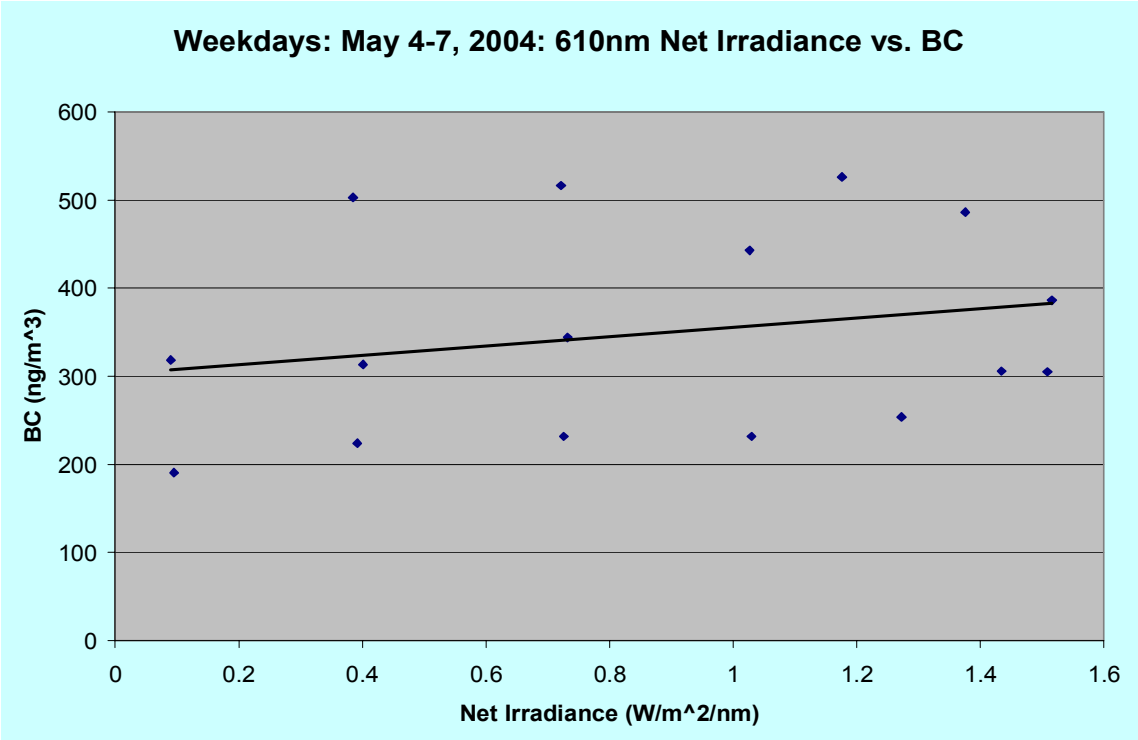

Figure 334. May 2004 Weekdays 610nm Net Irradiance (W/m^2/nm) vs. BC Concentrations (ng/m^3)

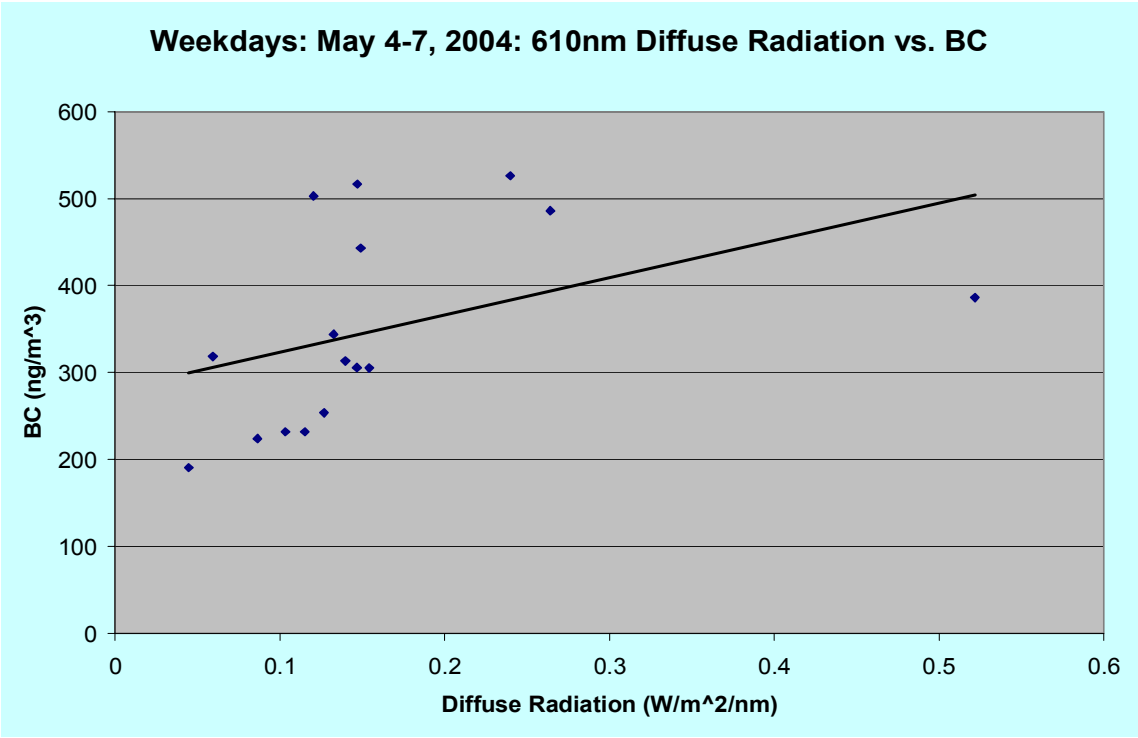

Figure 335. May 2004 Weekdays 500nm Diffuse Radiation(W/m^2/nm) vs. BC Concentrations (ng/m^3)

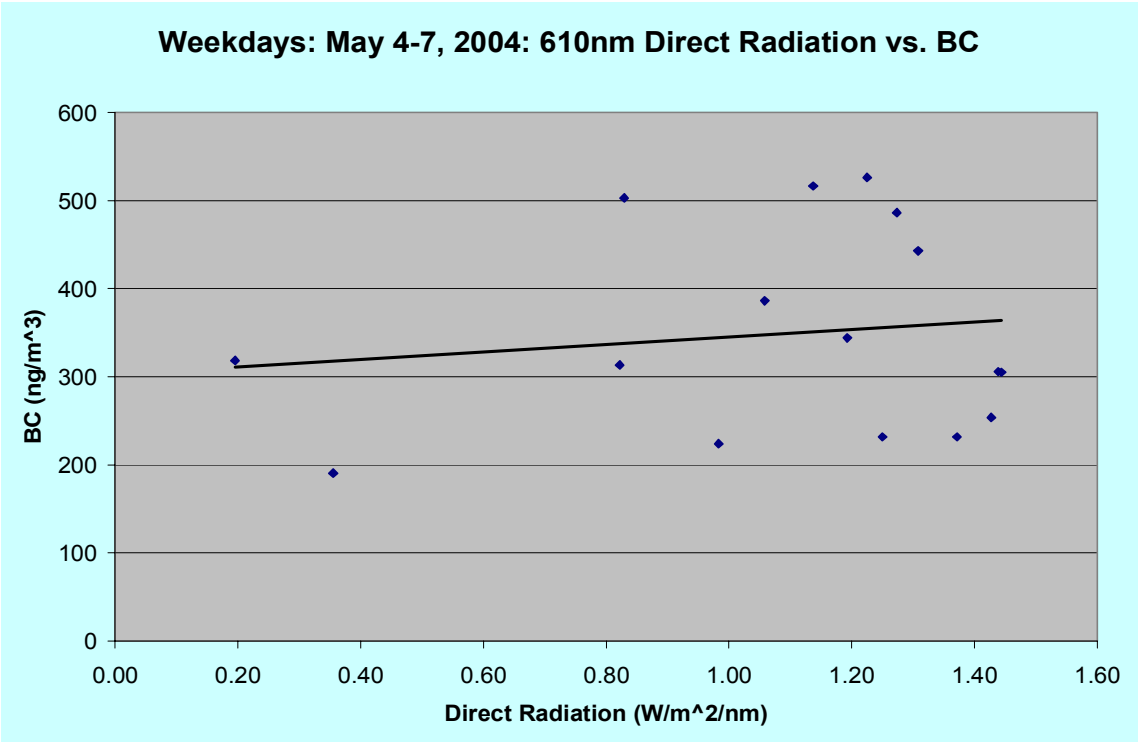

Figure 336. May 2004 Weekdays 610nm Direct Radiation(W/m^2/nm) vs. BC Concentrations (ng/m^3)

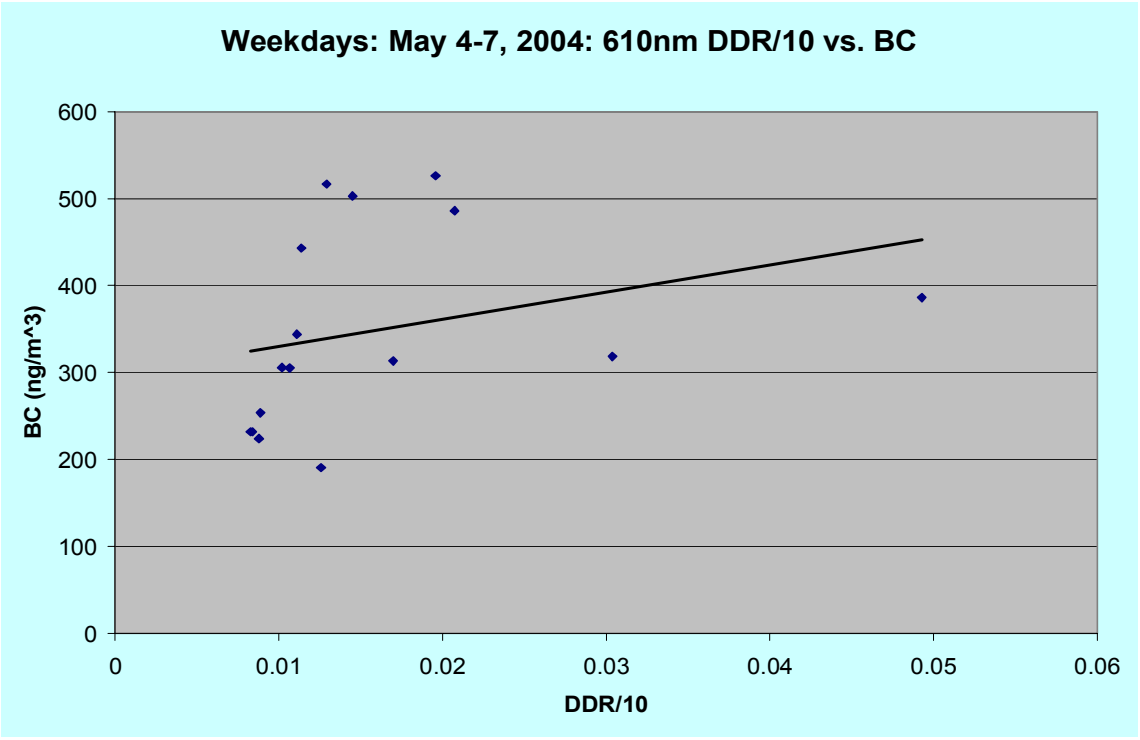

Figure 337. May 2004 Weekdays 610nm DDR/10 vs. BC Concentrations (ng/m^3)

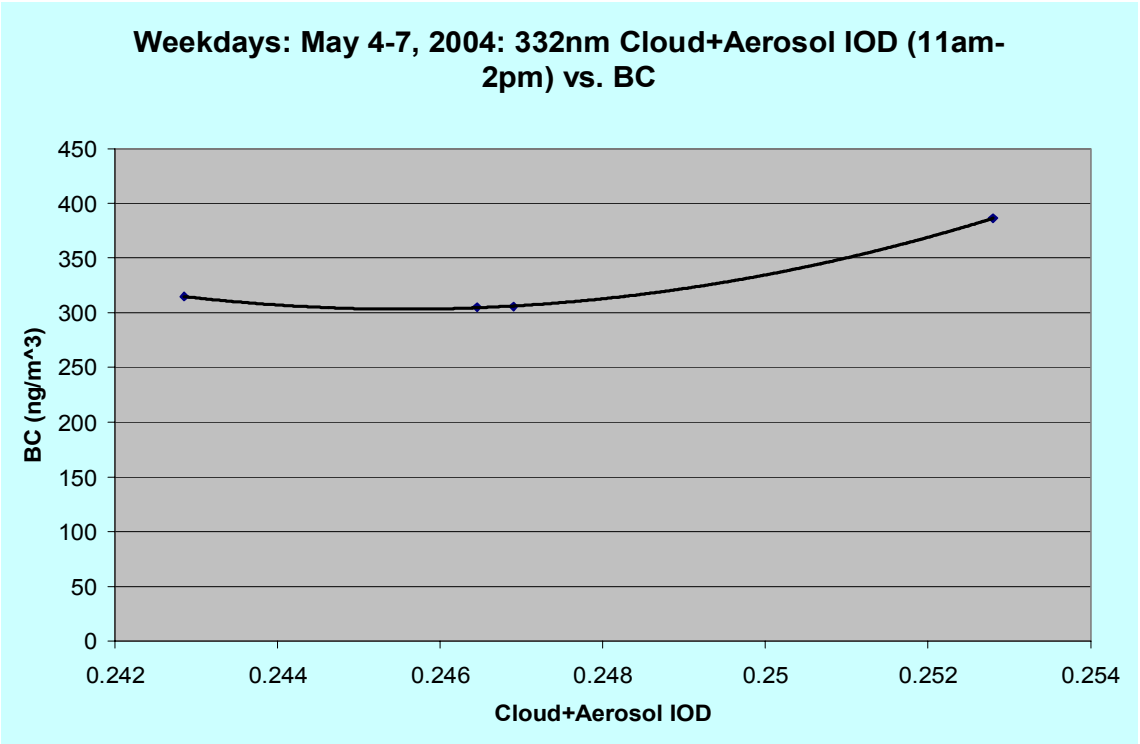

Figure 338. May 2004 Weekdays 332nm Cloud+Aerosol IOD vs. BC Concentrations (ng/m^3)

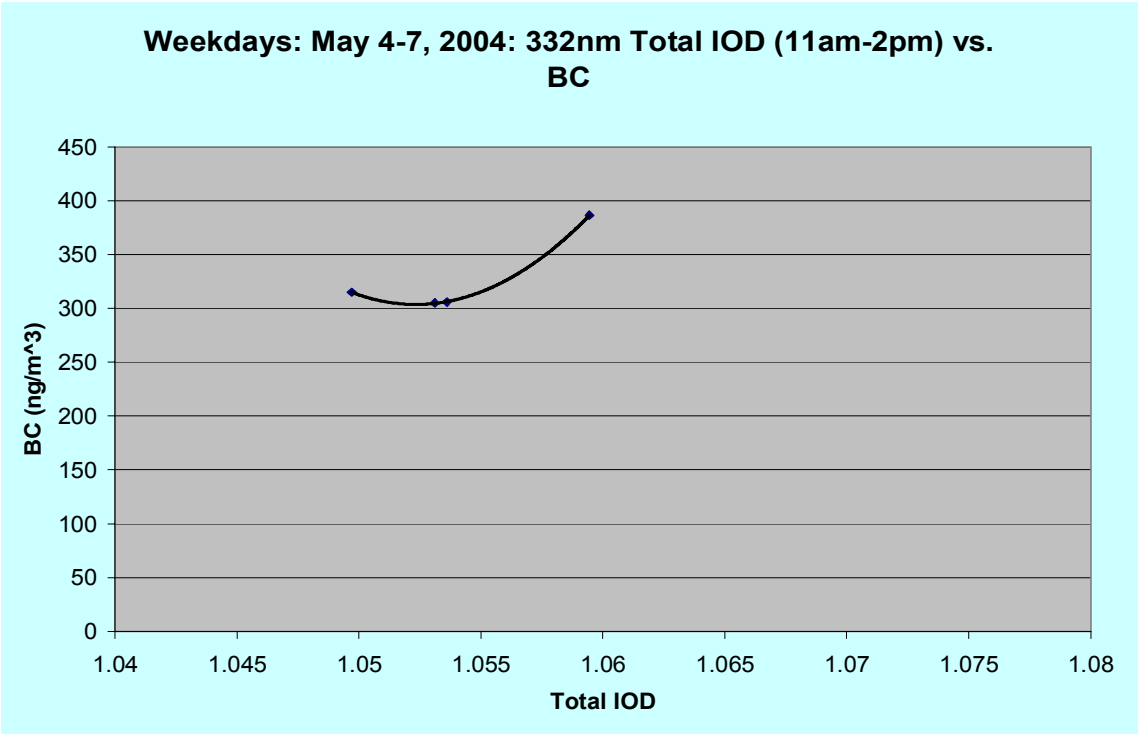

Figure 339. May 2004 Weekdays 332nm Total IOD vs. BC Concentrations (ng/m^3)

6. TABLES

Table 1. June 2003 and September 2003 Weekdays R^2 Values

Weekdays Only		***Weekdays Only***	
Jun-03	**R^2**	**Sep-03**	**R^2**
Temp	0.025	Temp	-0.163
Dewpoint	-0.684	Dewpoint	-0.541
RH	-0.118	RH	0.066
Wind Speed	0.369	Wind Speed	0.206
Wind Direction	0.129	Wind Direction	-0.391
Solar Radiation	0.735	Solar Radiation	0.646
PAR	0.436	PAR	0.667
332 Net	0.645	332 Net	0.839
332 Diffuse	0.639	332 Diffuse	0.776
332 Direct	0.529	332 Direct	0.891
500 Net	0.634	500 Net	0.808
500 Diffuse	0.631	500 Diffuse	0.714
500 Direct	0.580	500 Direct	0.650
610 Net	0.628	610 Net	0.802
610 Diffuse	0.622	610 Diffuse	0.724
610 Direct	0.548	610 Direct	0.588
332 C+A	N/A	332 C+A	N/A
332 Total	N/A	332 Total	N/A
500 C+A	N/A	500 C+A	N/A
500 Total	N/A	500 Total	N/A
610 C+A	N/A	610 C+A	N/A
610 Total	N/A	610 Total	N/A

Table 2. October 2003 Weekend and Weekdays R^2 Values

Weekend Only		***Weekdays Only***	
Oct-03	**R^2**	**Oct-03**	**R^2**
Temp	-0.424	Temp	0.212
Dewpoint	-0.862	Dewpoint	0.357
RH	0.135	RH	0.074
Wind Speed	0.334	Wind Speed	-0.004
Wind Direction	-0.156	Wind Direction	0.036
Solar Radiation	0.404	Solar Radiation	0.192
PAR	0.439	PAR	0.209
332 Net	0.467	332 Net	0.208
332 Diffuse	0.406	332 Diffuse	0.216
332 Direct	0.539	332 Direct	0.166
500 Net	0.444	500 Net	0.210
500 Diffuse	0.291	500 Diffuse	0.112
500 Direct	0.356	500 Direct	0.121
610 Net	0.444	610 Net	0.209
610 Diffuse	0.265	610 Diffuse	0.358
610 Direct	0.346	610 Direct	0.093
332 C+A	0.609	332 C+A	0.805
332 Total	0.560	332 Total	0.798
500 C+A	-0.428	500 C+A	0.568
500 Total	-0.418	500 Total	0.563
610 C+A	-0.553	610 C+A	0.384
610 Total	-0.554	610 Total	0.339

Table 3. November 2003 Weekend and Weekdays R^2 Values

Weekdays Only		***Weekend Only***	
Nov-03	**R^2**	**Nov-03**	**R^2**
Temp	-0.030	Temp	0.004
Dewpoint	0.018	Dewpoint	0.267
RH	0.164	RH	0.120
Wind Speed	-0.223	Wind Speed	0.026
Wind Direction	-0.218	Wind Direction	-0.389
Solar Radiation	0.449	Solar Radiation	0.309
PAR	0.436	PAR	0.301
332 Net	0.433	332 Net	0.218
332 Diffuse	0.419	332 Diffuse	0.272
332 Direct	0.396	332 Direct	0.106
500 Net	0.436	500 Net	0.217
500 Diffuse	0.396	500 Diffuse	0.476
500 Direct	-0.413	500 Direct	-0.049
610 Net	0.432	610 Net	0.221
610 Diffuse	0.399	610 Diffuse	0.558
610 Direct	0.391	610 Direct	0.129
332 C+A	-0.248	332 C+A	0.953
332 Total	-0.312	332 Total	0.953
500 C+A	-0.683	500 C+A	0.973
500 Total	-0.721	500 Total	0.973
610 C+A	N/A	610 C+A	0.900
610 Total	-0.662	610 Total	0.978

Table 4. December 2003 Weekend and Weekdays R^2 Values

Weekend Only		***Weekdays Only***	
Dec-03	**R^2**	**Dec-03**	**R^2**
Temp	-0.014	Temp	-0.111
Dewpoint	0.032	Dewpoint	0.448
RH	0.054	RH	0.377
Wind Speed	0.499	Wind Speed	0.342
Wind Direction	0.077	Wind Direction	-0.006
Solar Radiation	0.666	Solar Radiation	0.328
PAR	0.673	PAR	0.338
332 Net	0.847	332 Net	0.447
332 Diffuse	0.803	332 Diffuse	0.420
332 Direct	0.872	332 Direct	0.195
500 Net	0.830	500 Net	0.448
500 Diffuse	0.732	500 Diffuse	0.321
500 Direct	0.726	500 Direct	0.400
610 Net	0.827	610 Net	0.449
610 Diffuse	0.732	610 Diffuse	0.168
610 Direct	0.726	610 Direct	0.374
332 C+A	-0.911	332 C+A	-0.359
332 Total	-0.912	332 Total	-0.373
500 C+A	-0.648	500 C+A	-0.114
500 Total	-0.688	500 Total	-0.114
610 C+A	-0.994	610 C+A	-0.102
610 Total	-0.994	610 Total	-0.128

Table 5. January 2004 Weekend and Weekdays R^2 Values

Weekend Only		***Weekdays Only***	
Jan-04	**R^2**	**Jan-04**	**R^2**
Temp	0.532	Temp	0.471
Dewpoint	0.081	Dewpoint	0.129
RH	0.300	RH	-0.161
Wind Speed	0.288	Wind Speed	0.493
Wind Direction	0.046	Wind Direction	0.404
Solar Radiation	0.033	Solar Radiation	0.558
PAR	0.049	PAR	0.542
332 Net	-0.262	332 Net	-0.213
332 Diffuse	-0.286	332 Diffuse	-0.204
332 Direct	-0.364	332 Direct	-0.248
500 Net	-0.284	500 Net	-0.210
500 Diffuse	0.007	500 Diffuse	-0.169
500 Direct	-0.457	500 Direct	-0.195
610 Net	-0.288	610 Net	-0.207
610 Diffuse	0.387	610 Diffuse	-0.169
610 Direct	-0.509	610 Direct	-0.166
332 C+A	0.958	332 C+A	0.439
332 Total	0.956	332 Total	1.000
500 C+A	0.914	500 C+A	0.383
500 Total	0.912	500 Total	0.351
610 C+A	0.886	610 C+A	-0.140
610 Total	0.885	610 Total	-0.115

Table 6. February 2004 Weekend and March 2004 Weekdays R^2 Values

Weekend Only		***Weekdays Only***	
Feb-04	**R^2**	**Mar-04**	**R^2**
Temp	-0.334	Temp	0.263
Dewpoint	-0.106	Dewpoint	0.235
RH	0.238	RH	0.071
Wind Speed	0.622	Wind Speed	0.414
Wind Direction	0.024	Wind Direction	0.473
Solar Radiation	-0.085	Solar Radiation	0.279
PAR	-0.067	PAR	0.274
332 Net	-0.215	332 Net	0.253
332 Diffuse	-0.251	332 Diffuse	0.226
332 Direct	-0.196	332 Direct	0.268
500 Net	-0.225	500 Net	0.248
500 Diffuse	-0.435	500 Diffuse	0.052
500 Direct	-0.267	500 Direct	0.250
610 Net	-0.209	610 Net	0.252
610 Diffuse	-0.484	610 Diffuse	-0.054
610 Direct	-0.239	610 Direct	0.272
332 C+A	0.522	332 C+A	-0.442
332 Total	0.453	332 Total	-0.467
500 C+A	0.869	500 C+A	-0.574
500 Total	0.862	500 Total	-0.589
610 C+A	0.854	610 C+A	-0.661
610 Total	0.687	610 Total	-0.608

Table 7. April 2004 and May 2004 Weekdays R^2 Values

Weekdays Only		***Weekdays Only***	
Apr-04	**R^2**	**May-04**	**R^2**
Temp	0.842	Temp	0.398
Dewpoint	0.071	Dewpoint	0.359
RH	-0.715	RH	0.163
Wind Speed	-0.350	Wind Speed	0.249
Wind Direction	0.141	Wind Direction	-0.125
Solar Radiation	0.742	Solar Radiation	-0.103
PAR	0.731	PAR	0.221
332 Net	0.744	332 Net	0.193
332 Diffuse	0.752	332 Diffuse	0.357
332 Direct	0.729	332 Direct	0.022
500 Net	0.750	500 Net	0.222
500 Diffuse	0.815	500 Diffuse	0.492
500 Direct	0.709	500 Direct	0.100
610 Net	0.751	610 Net	0.229
610 Diffuse	0.848	610 Diffuse	0.419
610 Direct	0.697	610 Direct	0.138
332 C+A	-0.012	332 C+A	0.910
332 Total	-0.012	332 Total	0.910
500 C+A	N/A	500 C+A	0.361
500 Total	N/A	500 Total	0.361
610 C+A	N/A	610 C+A	0.404
610 Total	N/A	610 Total	0.405

7. REFERENCES

Ackerman, A.S., Toon, O.B., Stevens, D.E., Heymsfield, A.J., Ramanathan, V., Welton, E.J., 2000. Reduction of tropical cloudiness by soot. Science 288, 1042-1047.

Allen, G.A., Lawrence, J., Koutrakis, P., 1999. Field validation of a semi-continuous method for aerosol black carbon (aethalometer) and temporal patterns of summertime hourly black carbon measurements in southwestern PA. Atmospheric Environment 33, 817-823.

Barrie, L.A., Bottenheim, J.W., 1991. Sulpher and nitrogen pollution in the Arctic atmosphere. In: Pollution of the Arctic Atmosphere, Sturges, W. (Ed.), Elsevier, England.

Barrie, L.A., 1986. Arctic air pollution: an overview of current knowledge. Atmospheric Environment 20, 643-663.

Baltensperger, U., Gaggler, H.W., Jost, D.T., Emmenegger, M., Nageli, W., 1991. Continuous background aerosol monitoring with the epiphaniometer. Atmospheric Environment 25A (3/4), 629-634.

Bhugwant, C., Cachier, H., Bessafi, M., Leveau, J., 2000. Impact of traffic on black carbon aerosol concentration at la Reunion Island (Southern Indian Ocean). Atmospheric Environment 34, 3463-3473.

Bizjak, M., Tursic, J., Lesnjak, M., Cegnar, T., 1999. Aerosol black carbon and Ozone measurements at Mt. Krvavec EMEP/GAW station, Slovenia. Atmospheric Environment 33, 2783-2787.

Bond, T.C., 2000. Light absorption by primary particles from fossil-fuel

combustion: implications of radiative forcing. Ph.D. Dissertation, University of Washington, 383pp.

Cachier, H., 1998. Combustion carbonaceous particles. In: Harrison, R.M., Van Grieken, R.E. (Eds.), IUPAC book on Atmospheric Particles, IUPAC Environmental Series, Vol. 5. Wiley, New York, pp. 295-348.

Chameides, W.L., Yu, H., Liu, S.C., Bergin, M., Zhou, X., Mearns, L., Wang, G., Kiang, S.C., Saylor, R.D., Luo, C., Huang, Y., Steiner, A., Giorgi, F., 1999. Chase study of the effects of atmospheric aerosols and regional haze on Agriculture: an opportunity to enhance crop yields in China through emission controls? Proceedings of the National Academy of Sciences 96, 13626-13633.

Cooke, W.F., Liousse, C., Cachier, H., Fechter, F., 1999. Construction of a 1x1 fossil fuel emission data set for carbonaceous aerosol and implementation and radiative impact in the ECHAM-4 model. Journal of Geophysical Research 104, 22137-22162.

Cooke, W.F., Wilson, J.J.N., 1996. A global black carbon aerosol model. Journal of Geophysical Research 101, 19395-19409.

Crutzen, P.J., Andreae, M.O., 1990. Biomass burning in the tropics - impact on a atmospheric chemistry and biogeochemical cycles. Science 250, 1669-1678.

Delmas, R.A., Loudjani, P., Podaire, A., 1991. Biomass burning in Africa. In: Levine, J. (Ed.), Global Biomass Burning. MIT Press, Cambridge, MA. USA, pp. 126-132.

Derwent, R.G., Ryall, D.B., Jennings, S.G., Spain, T.G., Simmonds, P.G., 2001.

Black carbon aerosol and carbon monoxide in European regionally polluted air masses at Mace Head, Ireland during 1995-1998. Atmospheric Environment 35, 6371-6378.

Gatari, M.J., Boman, J., 2003. Black carbon and total carbon measurements at Urban and rural sites in Kenya, East Africa. Atmospheric Environment 37, 1149-1154.

Girgzdiene, R., Sopauskiene, D., Gyrgzdys, A., Juozaitis, A., Trakumas, S., 1996. Concentration levels and episodes of surface ozone and submicron aerosol. Proceedings of EUROTRAC Symposium '96 Transport and Transformation of Pollutants in the Troposhere, vol. 1, pp. 261-265.

Hamilton, R.S., Mansfield, T.A., 1991. Airborne particulate elemental carbon: its sources, transport and contribution to dark smoke and soiling. Atmospheric Environment 25, 715-723.

Hansen, J., Nazarenko, L., 2003. Soot climate forcing via snow and ice albedos. Proceedings of National Academy of Science 101, 423-428.

Hopper, J.F., Worthy, D.E.J., Barrie, L.A., Trivett, N.B.A., 1994. Atmospheric observations of aerosol black carbon, carbon dioxide, and methane in the high arctic. Atmospheric Environment 28, 3047-3054.

INSEE, 1998, Tableau Economique de La Reunion (in French), pp. 220-223.

Intergovernmental Panel on Climate Change, 1996. In: Houghton, J.T., Meira Filho, L.G., Challander, B.A., Harris, N., Kattenberg, A., Maskell, K. (Eds.), Climate Change 1995: The Science of Climate Change. Cambridge University Press, Cambridge, UK.

Jacobson, M.Z., 2000. A physically-based treatment of elemental carbon optics: Implications for global direct forcing of aerosols. Geophysical Research Letters 27, 217-220.

Liousse, C., Penner, J.E., Chuang, C., Walton, J.J., Eddleman, H., Cachier, H., 1996. A global three-dimensional model study of carbonaceous aerosols. Journal of Geophysical Research 101, 19411-19432.

Mark, D., 1998. Atmospheric Particles. Harrison, R.M., van Grieken, R.E. (Eds.), Wiley, Chichester, pp. 29-94.

Menon, S., Hansen, J., Nazarenko, L., Luo, Y., 2002. Climate effects of black carbon aerosols in India and China. Science 297, 2250-2253.

Mohler, O., Naumann, K-H., Saathoff, H., Schurath, U., 1997. The influence of soot surface reactions on the ozone and NOx chemistry. Journal of Aerosol Science 28, S309-S310.

Moloi, K., Chimidza, S., Lindgren, E.S., Viksna, A., Standzenieks, P., 2002. Black carbon, mass and elemental measurements of airborne particles in the village of Serowe, Botswana. Atmospheric Environment 36, 2447-2457.

Novakov, T., Hansen, J.E., 2004. Black carbon emissions in the United Kingdom during the past four decades: an empirical analysis. Atmospheric Environment 38, 4155-4163.

Penner, J.E., Ghan, S.J., Walton, J.J., 1991. The role of biomass burning in the budget and cycle of carbonaceous soot aerosols and their climate impact. In: Levine, J.S. (Ed.), Global Biomass Burning; Atmospheric, Climatic, and Biospheric Implications. MIT Press, Cambridge, MA, pp. 387-393.

Parungo, F., Nagamoto, C., Zhou, M-Y., Hansen, A.D.A., Harris, J., 1994. Aeolian transport of aerosol black carbon from China to the ocean. Atmospheric Environment 28, 3251-3260.

Qui, J., Yang, L., 2000. Variation characteristics of atmospheric aerosol optical depths and visibility in North China during 1980-1994. Atmospheric Environment 34, 603-609.

Sillanpaa, M., Frey, A., Hillamo, R., Pennanen, A.S., Salonen, R.O., 2005. Comparison of the levels of organic, elemental and inorganic carbon in particulate matter in six urban environments in Europe. Atmospheric Chemistry and Physics Discussions 5, 2719-2747.

Streets, D.G., Gupta, S., Waldhoff, S.T., Wang, M.Q., Bond, T.C., Yiyun, B., 2001. Black carbon emissions in China. Atmospheric Environment 35, 4281-4296.

Streets, D.G., Waldhoff, S.T., 2000. Present and future emissions of air pollutants in China: SO2, NOx, and CO. Atmospheric Environment 34, 363-374.

USDA UVB Monitoring and Research Program. [web page] 1993; http://uvb.nrel.colostate.edu/. [Accessed 20 Jan 2006].

WHO (World Health Organization): Health aspects of air pollution with particulate matter, ozone and nitrogen dioxide, Report on a WHO Working Group; Bonn, Germany 13-15 January 2003, http://www.euro.who.int/document/e79097.pdf, 2003.

Wolff, G.T., 1981. Particulate elemental carbon in the atmosphere. Journal of the

Air Pollution Control Association 31, 935-939.