Analysis of the Impact of a New Emission Source on Air Quality in the Corpus Christi Urban Airshed

by the

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Impact Assessment of a New Point Source in the Corpus Christi Urban Airshed

Las Brisas Case Study

Project Overview

The focus of this study is to find the impact of air pollutant emissions from a proposed power plant along the ship-channel of Corpus Christi, Texas. The proposed plant to be operated by Las Brisas Energy Center, LLC will use petroleum coke byproduct as a fuel source. The emissions from Las Brisas Energy Center, LLC was obtained from a permit application to the Texas Commission on Environmental Quality (TCEQ) and the impact of these emissions on urban and regional air quality was studied using air dispersion and photochemical modeling techniques. The following narrative describes the background, the modeling and analysis techniques, along with a detailed interpretation of the air pollution data.

Introduction

Corpus Christi area is a semi-arid coastal urban airshed located in south Texas and is approximately 250 km north of the U.S.-Mexico border. The Corpus Christi urban airshed (CCUA) is comprised of Nueces and San Patricio counties. The dominant sectors of economy in the urban area include – petroleum refining, chemical process industries defense bases, port and tourism. Major industrial point sources, on-road and non-road mobile sources comprise the largest emissions categories within this urban airshed. Despite being one of the largest industrialized urban areas in South Texas, Corpus Christi is currently in compliance with the U.S. Environmental Protection Agency's (EPA) National Ambient Air Quality Standards (NAAQS) for ozone and other criteria pollutants.

The air quality in the South Texas region is measured and characterized by continuous air monitoring performed by the Texas Commission on Environmental Quality (TCEQ). The state agency currently operates several continuous air monitoring stations (CAMS) within the Corpus Christi urban airshed that measures the levels of pollutants including ozone, sulfur dioxide, oxides of nitrogen, and other key criteria pollutants defined by the United States Environmental Protection Agency (EPA). Figure 1 highlights the monitoring locations within the Corpus Christi and surrounding areas in Nueces and San Patricio counties.

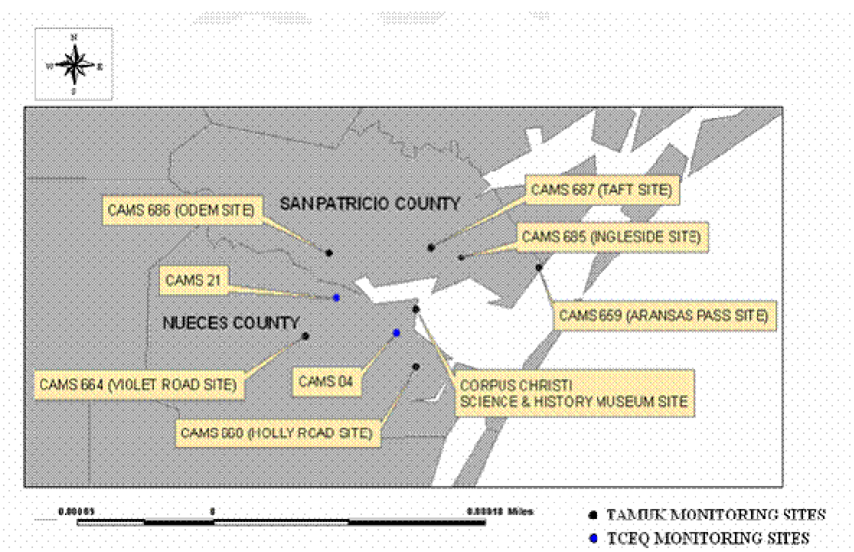


Figure 1 Air quality monitoring network in the Corpus Christi urban airshed

Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2) is produced both naturally and anthropogenically by various industrial processes and activities. The combustion of coal and petroleum generates significant amounts of sulfur dioxide in the atmosphere. SO_2 is key to the formation of sulfuric acid in the atmosphere and thus contributes to acidic precipitation events. The inhalation of sulfur dioxide results in labored breathing, coughing, and/or sore throat and it also causes permanent pulmonary damage. In addition, SO_2 results in redness and injury to human eyes.

As per the EPA prescribed ambient air quality standard for SO_2, the annual average SO_2 concentration measured at any site should not exceed 0.03 ppm or 30 ppb, while the daily average should not exceed 0.14 ppm or 140 ppb (EPA, 2008c). The annual average of SO_2 concentration in the Corpus Christi urban area measured at CAMS 04 is shown in Figure 2. It was noted that since 1998, the SO_2 concentration in the urban airshed never exceeded 2 ppb which makes the urban airshed currently in attainment of the National Ambient Air Quality Standards (NAAQS) for SO_2. Similarly the daily average of SO_2 concentrations at CAMS04 is also within the prescribed standards.

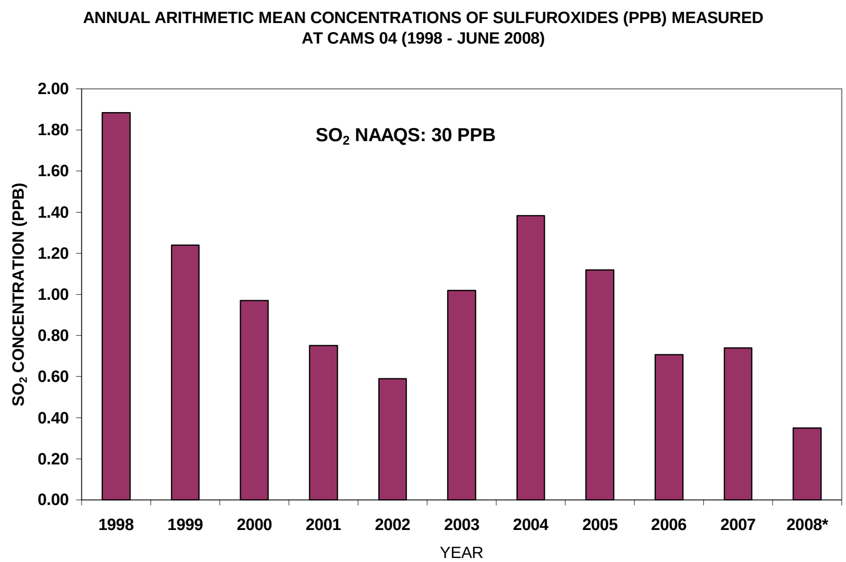


Figure 2 Design value trend of the annual averaged SO_2 concentrations at CAMS 04 in the Corpus Christi
**Data is available through June 2008*

Oxides of Nitrogen (NO_x)

NO_x is a generic term for the oxides of nitrogen including nitric oxide (NO) and nitrogen dioxide (NO_2). These oxides are produced during combustion, especially at high temperatures. In particular, the combustion of fossil fuels with air generates high temperatures that results in endothermic reactions between atmospheric nitrogen and oxygen to produce various oxides of nitrogen. The major source of NO_x production from nitrogen-bearing coals and oil is the conversion of fuel-bound nitrogen to NO_x during combustion. It is a key ozone precursor. Under favorable meteorological conditions and with the assistance of available volatile organic compounds (VOC), it helps in the formation of tropospheric ozone. The current NAAQS for NO_x is 0.053 ppm pr 53 ppb (annual arithmetic mean). Figure 3 shows the annual average NO_x concentrations observed at Holly Road site (CAMS 660) within the Corpus Christi urban airshed since 2006. The design value trend demonstrates that the Corpus Christi region is in attainment of the NO_x standard.

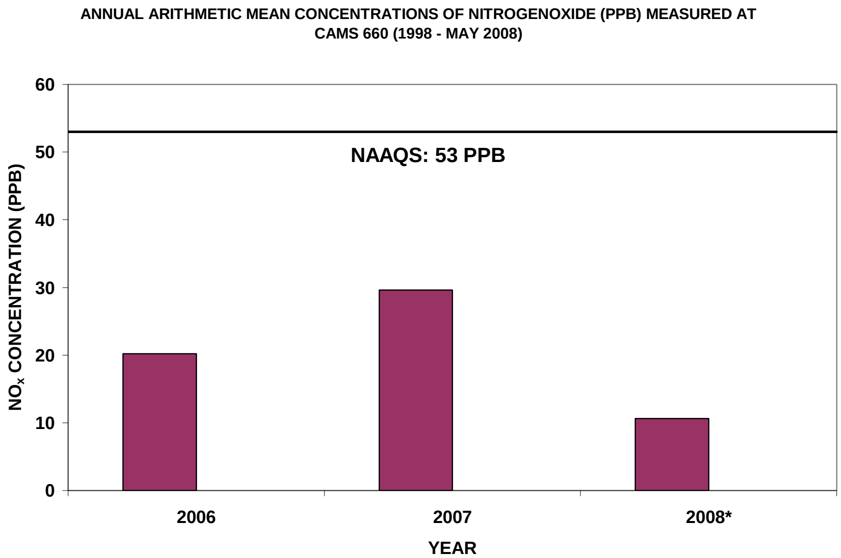


Figure 3 Design value trend of the annual averaged NO_x concentrations in the Corpus Christi region at Holly Road site (CAMS 660)

**Data is available through June 2008*

Ozone (O_3)

Tropospheric ozone (O_3) is one of the most widespread air pollution problems currently affecting major urban areas across the United States. Ozone is a secondary pollutant, and it is formed non-linearly by a series of complex photochemical reactions involving its precursors, namely oxides of nitrogen (NOx) and volatile organic compounds (VOCs) under favorable meteorological conditions. Since ozone can cause a variety of health problems and damage vegetation at very low concentrations, the US Environmental Protection Agency (EPA) recently revised the 8-hour ozone standards based on stricter health standards (EPA, 2008).

The newly revised NAAQS for ozone is a three-year average of the fourth highest 8-hour ozone concentration and it is set at 0.075 ppm (EPA, 2008a). Currently, the state of Texas has three urban areas that are in violation of the National Ambient Air Quality Standards (NAAQS) for ozone. These include Houston-Galveston, Dallas-Fort Worth and Beaumont-Port Arthur urban airsheds. Due to several recent regional-scale high ozone episodes in Texas, the Texas Commission on Environmental Quality (TCEQ) has designated additional five urban regions as being Near Non-attainment Areas (NNA) for ozone. The NNAs meet the federal standards but remain at risk of violating this standard. These NNAs include the cities of Austin, Corpus Christi, Longview-Tyler-Marshall, San Antonio and Victoria in Texas.

The urban areas in the South Texas region have experienced occasional exceedances of the 8-hour ozone standard over the past few years. This region is characterized by a unique climatology of semi arid coastal and inland areas and it consists of a number of urban areas classified by the Texas Commission on Environmental Quality (TCEQ) to be in near non-attainment status with regard to the 8-hour ozone standard. These near non-attainment areas (NNAs) have chosen to demonstrate an appropriate voluntary planning process to continue to remain in attainment of 8-hour ozone federal standards.

The 8-hour averaged ozone concentrations measured in the Corpus Christi area were calculated from hourly data collected at the TCEQ operated monitoring sites (viz., CAMS04 and CAMS21). Hourly maximum and 8-hour averaged ozone concentrations from 1990 through 2007 are used in the determination of the air quality status in light of the NAAQS for ozone. Figure 4 highlights the trend in the 4^{th} highest maxima of the 8-hour ozone and 3 year annual averaged 4^{th} highest 8-hour ozone levels at CAMS 04 and CAMS 21 in Corpus Christi urban area. Overall, this urban area is in attainment of the air quality standard for ozone. A decreasing trend was noted in the measured ozone levels at these regulatory sites since 1995, with a significant reduction observed since 2002.

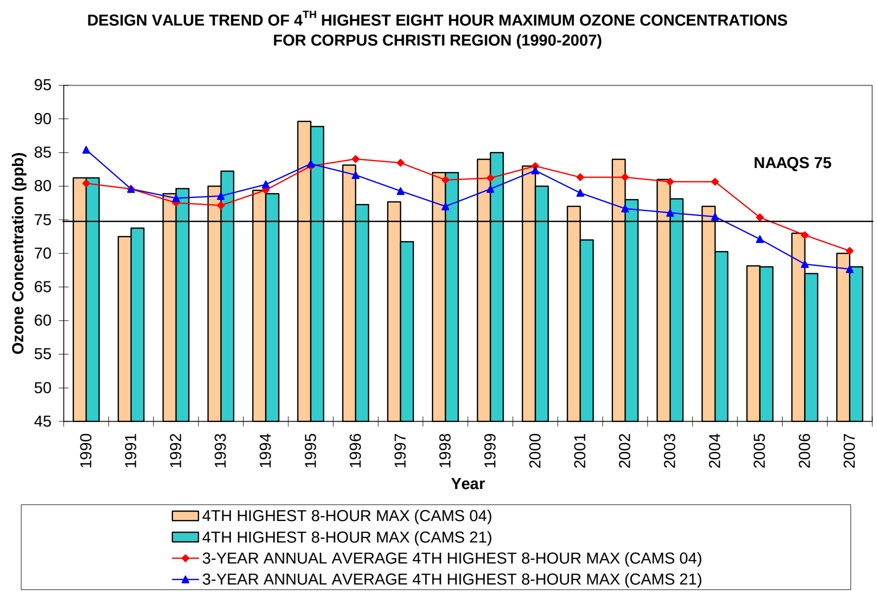


Figure 4 Design value trend of the 4th highest 8-hour maximum ozone levels for the Corpus Christi region

Petroleum Coke and Byproducts

The fuel for the proposed power plant along the Corpus Christi shipchannel will be petroleum coke. Petroleum refineries refine crude oil to produce useful products like gasoline, diesel, oil, and wax. The residue is further processed at high temperature and pressure to crack large molecules into smaller molecules. The coking process leaves behind a hard, coal like substance called petroleum coke. It consists mostly of carbon with a small amount of hydrocarbons and sulfur with trace amounts of metals. Petroleum coke is also known as green coke which is primarily used in industries. The calcining process removes nearly all residual oil leaving pure carbon with trace amounts of sulfur and metals and is also known as calcined coke.

Air Quality Modeling

Air quality models are typically used to evaluate the impact of a new source within an urban airshed. There are two classes of air quality models that are used widely. One class of air quality models is the Lagrangian dispersion models used for permit applications by evaluating the dispersion characteristics of inert plumes and the corresponding maximum distance impact of emissions from industrial stack sources. The comprehensive Eulerian photochemical models are the other class of air quality models. These provide a robust mathematical description of complex emissions and meteorological characteristics and their interactions in the urban and regional-scale atmospheres. They are widely used in the study of urban and regional ozone, and for assessing the impact of aerosols in the atmosphere.

In this preliminary study, we have employed a dispersion model (AERMOD) to evaluate and assess the impact of primary pollutants (SOx and NOx) from a new emission source. In addition, a photochemical model (CAMx) was used to provide a preliminary assessment of the impact on ozone from a new emission source within the Corpus Christi urban airshed. The new emission source to be assessed on this study is titled the ***Las Brisas Energy Center*** and this will be located within the industrialized corridor of the Corpus Christi ship channel.

Dispersion modeling

Dispersion modeling uses mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by a source based on emissions and meteorological inputs. A dispersion model can be used to predict concentrations at selected downwind receptor locations (EPA, 2008b). The American Meteorological Society/Environmental Protection Agency (AMS/EPA) regulatory model (AERMOD) model provided in ISC-AERMOD View by Lakes Environmental Software ©. AERMOD is a steady state Gaussian dispersion model and it has three components: AERMOD (Dispersion Model), AERMET (Meteorological Preprocessor) and AERMAP (Terrain Preprocessor).

Photochemical Modelling

The Comprehensive Air quality Model with extensions (CAMx) version 3.1 (ENVIRON, 2002) has been applied to study ozone levels in South Texas and to assess the impact of new sources within the Corpus Christi region. The photochemical model (CAMx), simulating various atmospheric physical and chemical processes, was applied in a nested mode in this study. The base case and the new source simulations were performed for the high ozone episode of September 13-21, 1999 that occurred over major portions of Texas. The modeling domain and model setup for the CAMx model is described below:

Model Setup and Study Domain

The photochemical modeling system is in the Lambert conformal projection system centered at (-100, 40) with standard parallel latitudes at 30 and 60 degrees, respectively. The coarse outermost grid of the photochemical modeling domain grid resolution of 36 km covers the South, Southwest and Central portion of the continental United States. The inner grid of 12 km grid resolution envelops Houston-Galveston area, Beaumont-Port Arthur area, Dallas-Fort Worth area and the eastern Texas region. The innermost grid of 4 km grid resolution containing 90 x 108 cells is focused on South and Central Texas and covers all of the near non-attainment areas (NNAS) in this region (Austin, San Antonio, Victoria and Corpus Christi). The 14 vertical layers in CAMx extend from the surface all the way to 4 km above the surface level. Further details regarding the model set up have been presented in (Emery et al., 2002).

Emissions Processor

The Emission Processing System version 2 (EPS2) (EPA, 1992) was utilized to process emission inventory over the modeling domain and generate CAMx ready input gridded emission files. The report by ENVIRON highlights all of the details concerning the emissions inventory and emissions processing for the ozone episode of September 1999 (ENVIRON, 2004).

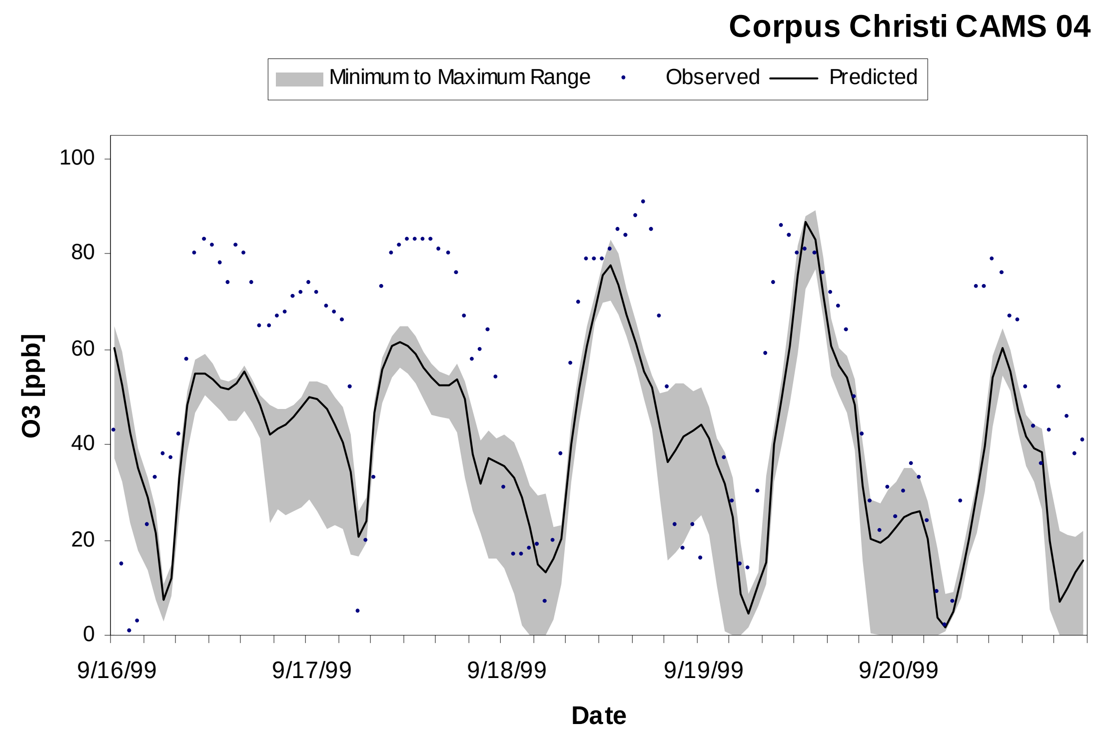
Meteorological Model

Hourly meteorological data from September 13- September 21, 1999 were simulated with the Fifth Generation Pennsylvania State University/National Center of Atmospheric Research (PSU/NCAR) Meteorological Model (MM5) version 4.3.(Grell et al., 1994) in a 3-way nested grid mode to produce gridded three-dimensional meteorological inputs for the CAMx photochemical model. The meteorological model used analysis grid-based nudging and the TCOON (Texas Coastal Ocean Observation Network) data for observational based nudging along the coast. The MM5 model consists of 28 half sigma levels in the vertical. Details regarding the meteorological model simulations have been presented in the report (ENVIRON, 2004).

Base Case Modeling (September 1999 Episode)

A comprehensive impact assessment of a new/future point source titled '***Las Brisas Energy Center***' located in the Corpus Christi industrialized ship channel was carried out by the Air Quality Research Group within the Department of Environmental Engineering at Texas A&M University – Kingsville. The evaluation was conducted using a grid-based photochemical model for the base year of 1999. The data for the 1999 base modeling episode was obtained from the Texas Commission on Environmental Quality (TCEQ). Emissions and meteorology from the existing 1999 base case episode were used while emissions for the Corpus Christi urban airshed were enhanced into the model (Emery at al. 2002). Emissions from Las Brisas Energy Center were added to the existing base case emissions developed to study the high ozone episode during September 1999.

The model performance evaluation was conducted as per EPA recommended statistical methods for the Corpus Christi urban airshed and is shown in Table 1. The solid line represents 9-grid cell averaged value of 1-hour ozone value corresponding to the location of surface observation site (CAMS). The grey area represents minimum and maximum values among these 9-grid cells. The overall pattern of diurnal variability in ozone concentrations was quite similar between the observation and the base case. For the Corpus Christi area, the modeled 1-hour ozone level followed the observed diurnal profiles and for two of the modeled days the peak ozone levels were very close. However on two separate days the model under predicted the observed ozone levels as shown in Figure 5. The variability in the model performance could be attributed to the uncertainty in emissions and meteorology. Figure 6 highlights the peak 8-hour ozone concentration on a high ozone day from 7:00 a.m. to 5:00 p.m. and the hourly surface contour plots are shown in two hour intervals for the Corpus Christi urban airshed.



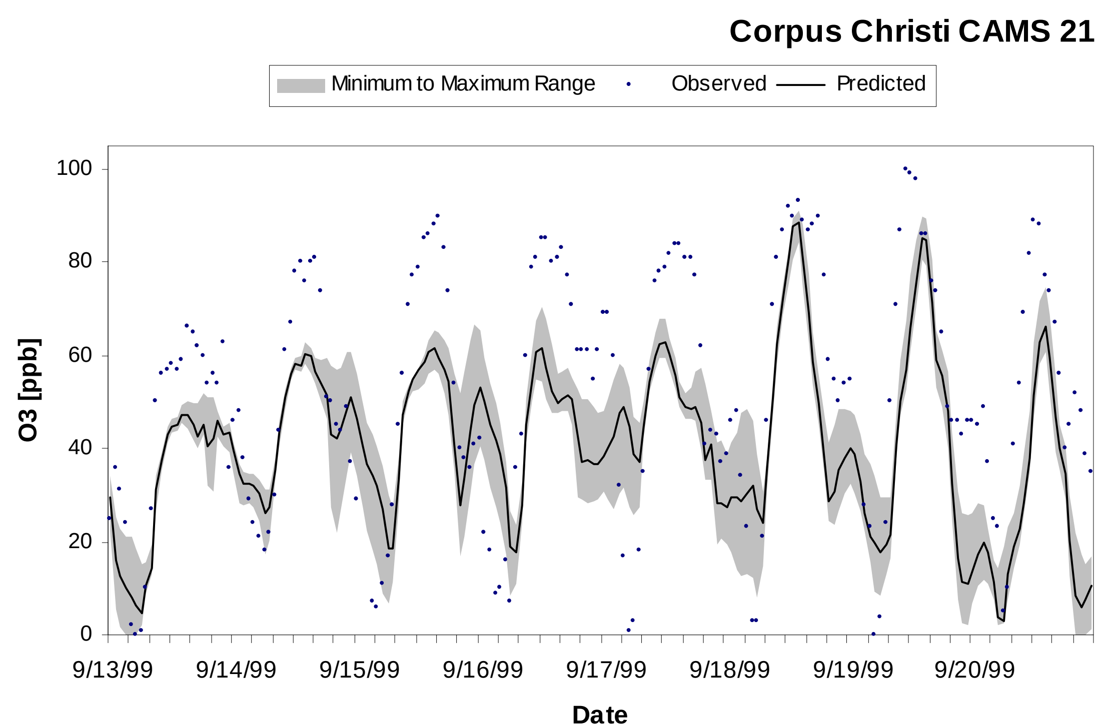


Figure 5 Time series plots of observed and predicted hourly ozone for two monitoring sites (CAMS 04 and 21) in Corpus Christi (September 13-20, 1999) for the base case simulation.

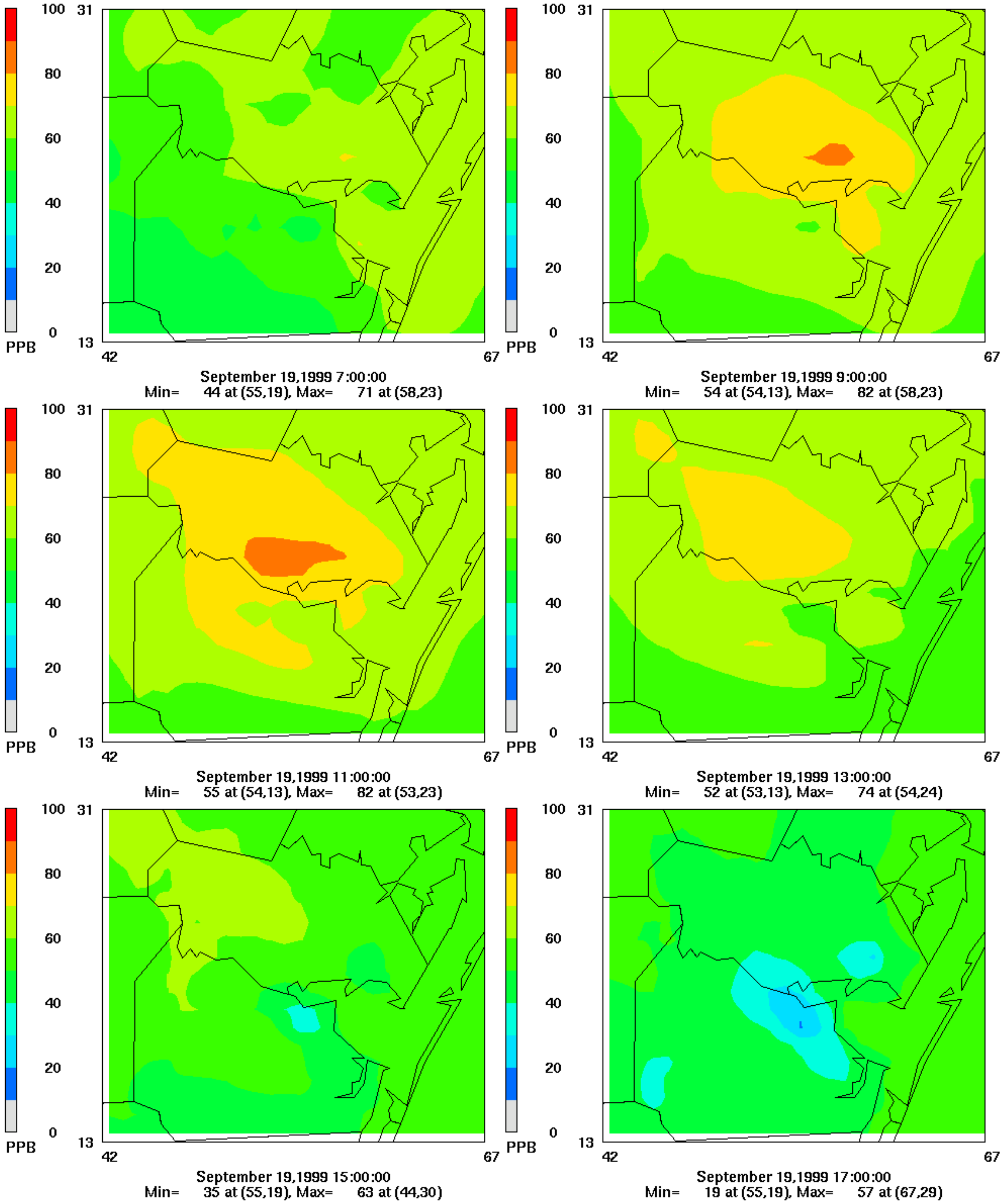


Figure 6 Peak 8-hour average ozone levels within the Corpus Christi urban airshed (base case emissions)

Las Brisas Energy Center Emissions

The ***Las Brisas Energy Center*** power plant is a proposed new source of emissions in the Corpus Christi urban airshed. Its projected emissions were added to the grid-based photochemical modeling system. Net emissions were treated as elevated point source and estimated to be approximately 3823.8 tons/year of NO_x, 283 tons/year of VOC and 8154.2 tons/year of CO (Las Brisas, 2008). These new emissions were chemically speciated, temporally and spatially allocated using EPS2. Stack information and characteristics of the facility were used as provided in the Las Brisas air permit application (Las Brisas, 2008). New emissions were processed and subsequently added to the model ready input files employed in the new developed 1999 base case.

Emissions from Las Brisas Energy Center

NO_x	3,823.8 tons/year
VOC	283.0 tons/year
CO	8,154.2 tons/year
SO_2	10,480.3 tons/year

Impact Assessment of Las Brisas Energy Center

Dispersion modeling uses mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by a source based on emissions and meteorological inputs. A dispersion model can be used to predict concentrations at selected downwind receptor locations (EPA, 2008b). The American Meteorological Society/Environmental Protection Agency (AMS/EPA) regulatory model (AERMOD) model provided in ISC-AERMOD View by Lakes Environmental Software © was used to evaluate the dispersion of new point source form Las Brisas Energy Center. AERMOD is a steady state Gaussian dispersion model and it has three components: AERMOD (Dispersion Model), AERMET (Meteorological Preprocessor) and AERMAP (Terrain Preprocessor). NO_x and SO_2 concentration in parts per billion were modeled for the receptor grid using the AERMOD model. The atmospheric NO_x was assumed to be comprised of 90% NO_2 and 10% NO and the decay of fresh NO_x emissions corresponding to atmospheric transformation and sink processes was considered in the AERMOD model using a half life of 2 days. A half life of 4 hours was considered for the modeling of SO_2 plumes.

Impact of NO_x in the Corpus Christi urban airshed

The AERMOD model was applied to evaluate the impact of fresh NOx emissions from the Las Brisas Enercy Center plume. Dispersion modeling analysis provides a guidance on the maximum impact downwind from a source. NOx is highly reactive in the atmosphere and cannot be accurately simulated using a dispersion model alone. By employing a decay factor of 2 days half-life, we approximate the NOx removal processes within the atmosphere. The case study was conducted for 2007 using the most recently available meteorological data. The area was in attainment of the NOx standard in 2007 as shown in Figure 3. The model simulated maximum annual concentration of NO_x from the Las Brisas point source was found to be 21 ppb and this is shown in Figure 7. The additional NOx concentration arising from this potential new source is significant and can move the area closer to nonattainment of the NOx standard. However, this analysis is rudimentary in determining the worst case scenario based just on plume dispersion of emissions.

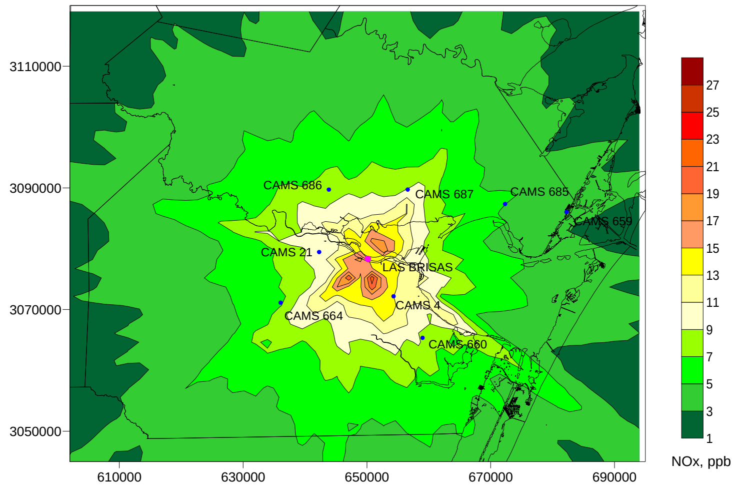


Figure 7 AERMOD simulated maximum hourly dispersion of NO_x in ppb over Corpus Christi urban airshed for the year 2007

The AERMOD model was then applied to selected high ozone days in 2007. Table 2 highlights selected days when one or more the air quality monitoring sites in the Corpus Christi area recorded an exceedance of 75 ppb.

Table 2 1-hour high ozone (ppb) days during 2007 within Corpus Christi urban airshed

Date	CAMS 4	CAMS 21	CAMS 659	CAMS 660	CAMS 664
5/13/2007	82	80	82	75	90
9/21/2007	73	78	76	72	78
9/22/2007	89	90	94	92	91
10/11/2007	72	75	81	73	82

The simulated dispersion plots of NO_x from the proposed Las Brisas Energy Center facility on selected high ozone days of May 13, September 21-22, and October 11 are shown in Figure 8. The NO_x plume from the proposed facility would have shown a south- southwest orientation on May 13, 2007 with the predicted maximum NOx concentration of 12 ppb as shown in Figure 8(a). During the high ozone days of September 21 and 22, 2007, over 90 ppb of ozone was observed at several sites in the Corpus Christi area as shown in Table 2. During these days, the potential increase in the NO_x concentration due to the proposed new facility would have been significantly higher and the plume dispersed to the south and southwest direction with a predicted maximum concentration of 21 ppb of NOx that would add to the NOx loading of the urban atmosphere. This case study is illustrated in Figure 8(b). The simulated NO_x concentrations for October 11, 2007 would have been comparatively lower than the other modeled days and the plume would have revealed a southwesterly orientation as shown in Figure 8(c).

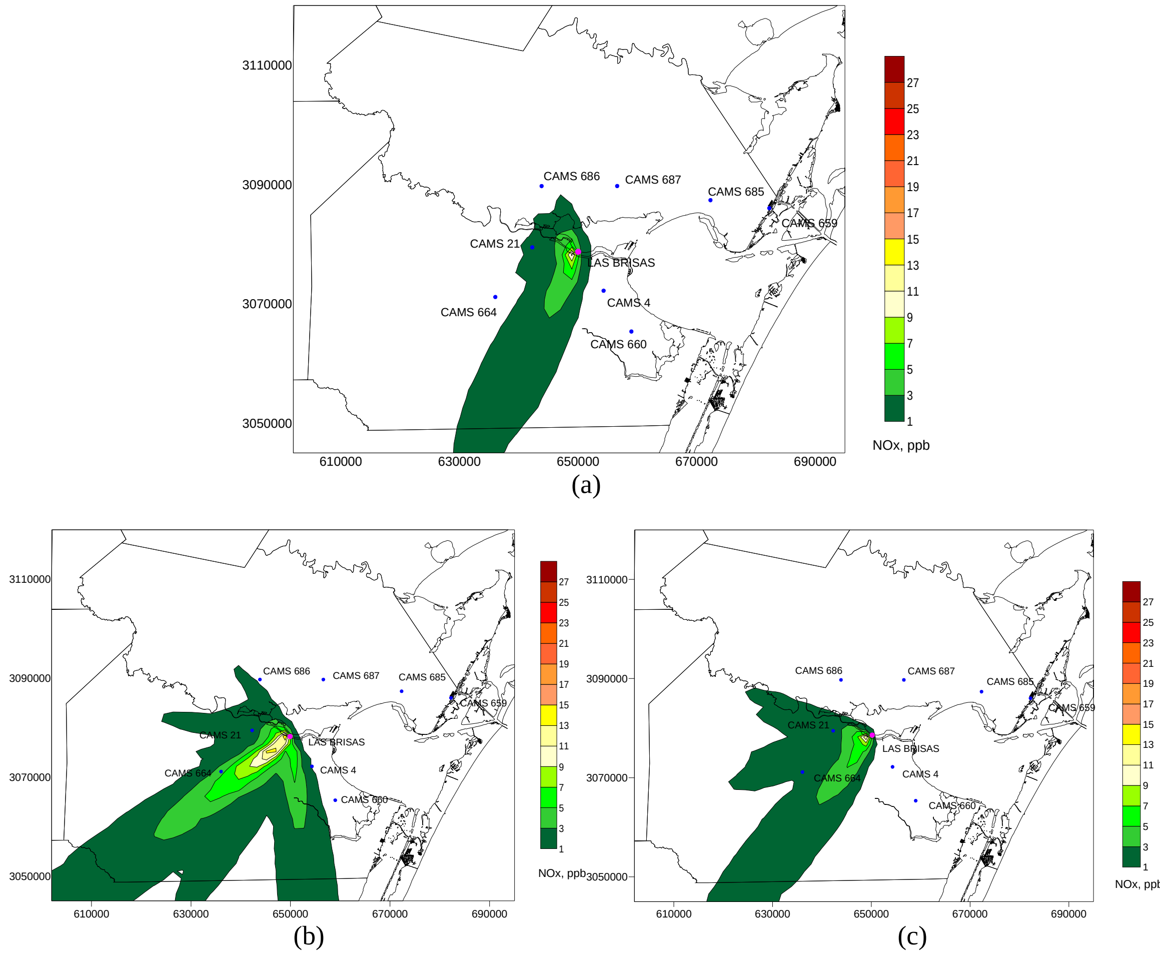


Figure 8 AERMOD simulated maximum hourly dispersion of NO_x in ppb over the Corpus Christi urban airshed for the high ozone days of (a) May 13, 2007, (b) September 21-22, 2007, and (c) October, 11, 2007

Impact of SO_2 in the Corpus Christi urban airshed

The AERMOD model was applied to evaluate the impact of fresh SO_2 emissions from the Las Brisas Enercy Center plume. Dispersion modeling analysis provides a guidance on the maximum impact downwind from a source. The maximum annual loading of SO_2 from the Las Brisas point source was found to be up to 45 ppb and is shown in Figure 9. By employing a decay factor of 4 days half-life, we approximate the SO_2 removal processes within the atmosphere. The case study was conducted for 2007 using the most recently available meteorological data. Since the area is in attainment of the SO_2 standard, this additional loading can affect the attainment designation based on the NAAQS for SO_2 for this urban airshed. The additional SO_2 concentration arising from this potential new source is significant and can move the area closer to nonattainment of the SO_2 standard. However, this analysis is rudimentary in determining the worst case scenario based just on plume dispersion of emissions.

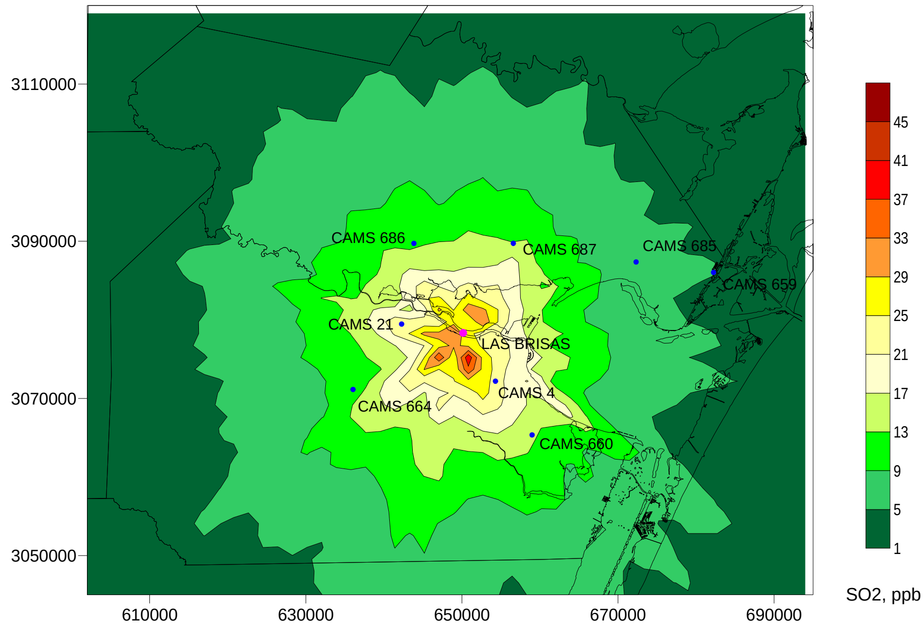


Figure 9 AERMOD simulated maximum hourly dispersion of SO_2 in ppb over Corpus Christi urban airshed for the year 2007

Impact on Ozone in the Corpus Christi Urban Airshed

A comprehensive impact assessment of a new/future point source titled '***Las Brisas Energy Center***' located in the Corpus Christi industrialized ship channel was carried out by the Air Quality Research Group within the Department of Environmental Engineering at Texas A&M University – Kingsville. The evaluation was conducted using a grid-based photochemical model for the base year of 1999. The data for the 1999 base modeling episode was obtained from the Texas Commission on Environmental Quality (TCEQ). Emissions and meteorology from the existing 1999 base case episode were used while emissions for the Corpus Christi urban airshed were enhanced into the model (Emery at al. 2002). Emissions from Las Brisas Energy Center were added to the existing base case emissions developed to study the high ozone episode during September 1999.

The CAMx photochemical model was employed to quantify the impact assessment of new emissions on the urban 8-hour ozone levels. ***Las Brisas Energy Center*** emissions were added to the new developed 1999 base case. Figure 10 shows the peak 8-hour ozone concentration predicted within the urban airshed from 7:00AM to 5:00 PM in two hour intervals with the addition of ***Las Brisas Energy Center*** emissions to the 1999 base case emissions. The maximum 8-hour ozone to the urban airshed was up to 82 ppb. The hourly difference plots of 8-hour ozone at two hour interval between control case and base case are shown in Figure 11.

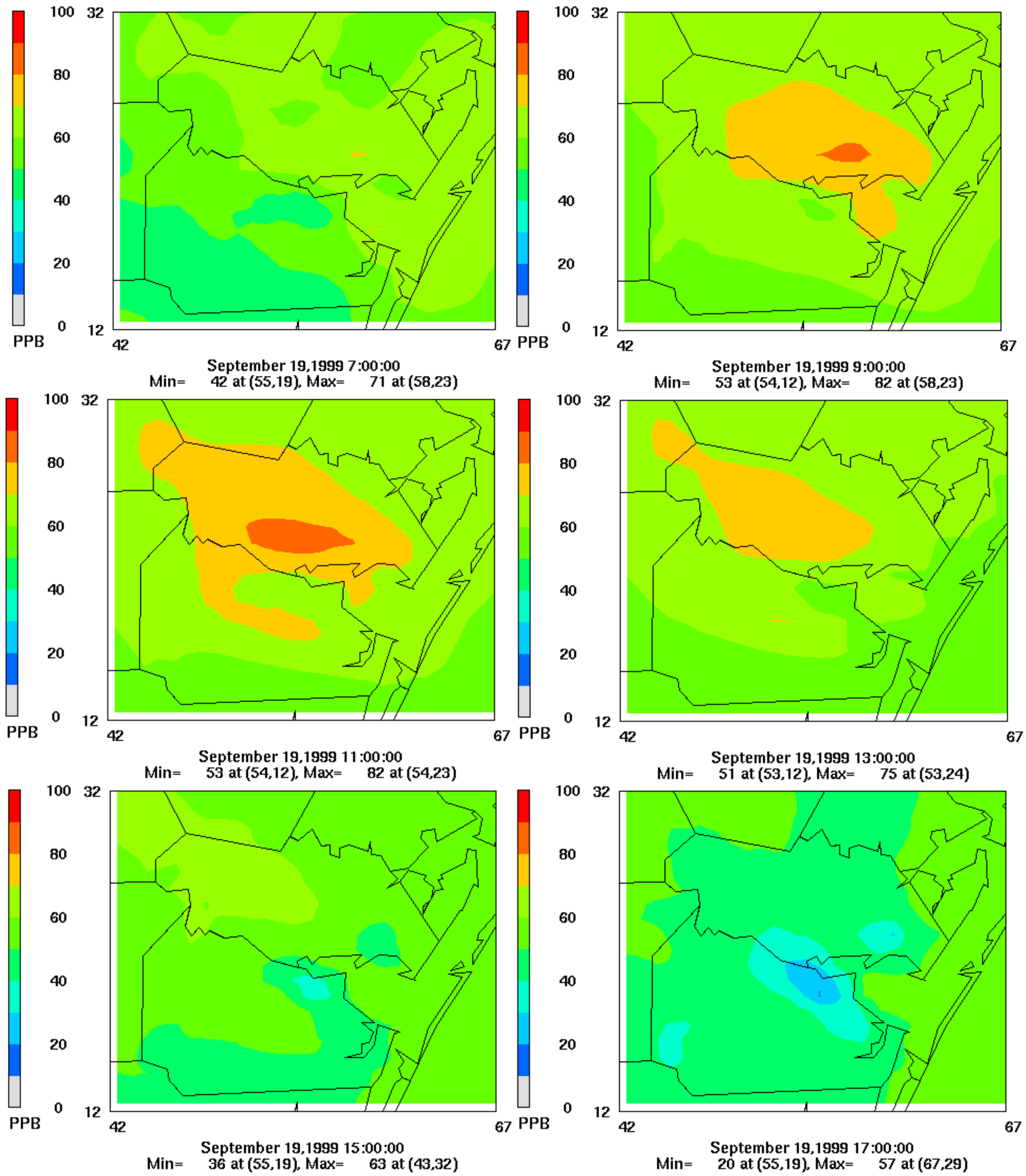


Figure 10 Peak 8-hour average ozone within Corpus Christi urban airshed (base case + Las Brisas emissions)

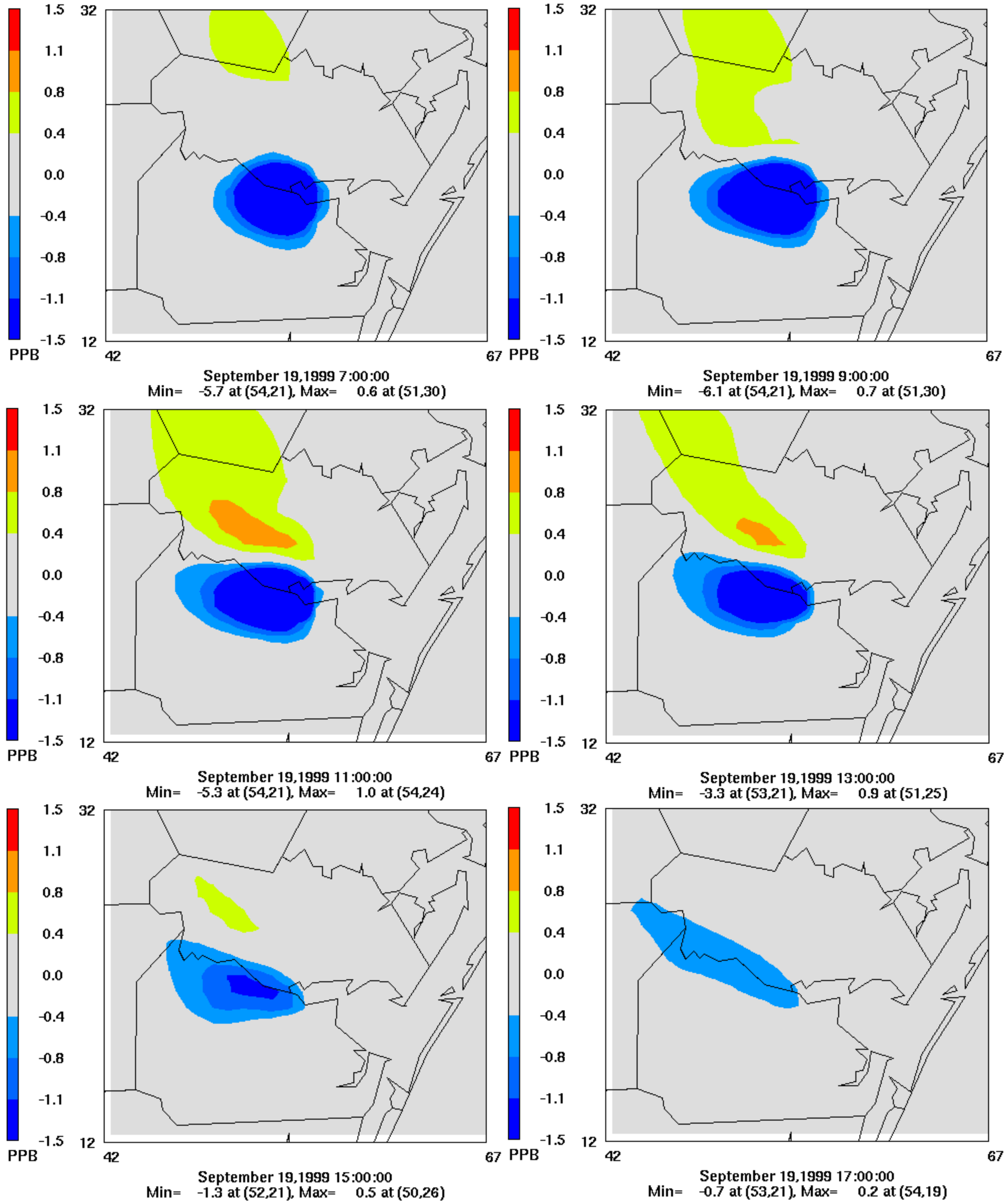


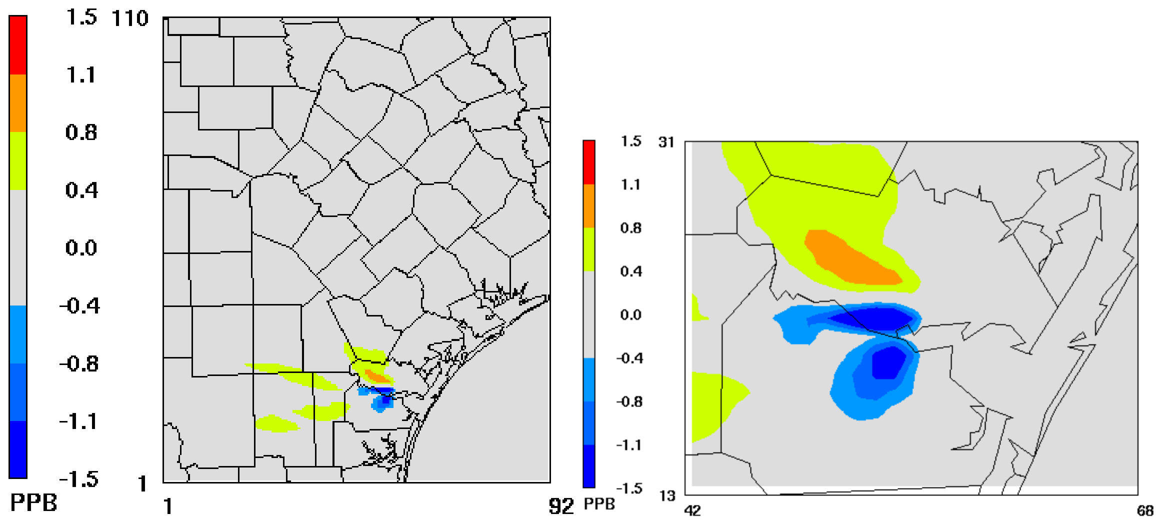
Figure 11 Impact of ***Las Brisas Energy Center*** on 1-hr average ozone within Corpus Christi urban airshed (control case – base case)

Maximum impact on the 8-hour ozone levels

The impact on ozone was quantified by subtracting the new base case runs from control case which is with added ***Las Brisas Energy Center*** emissions as described above. The EPA recommended method of peak ozone analysis difference between maximum peak of the control case and maximum peak of base case was employed. The maximum impact to the 8-hour ozone concentration was estimated with the following equation.

$$\textit{Impact of emissions} = MAX(O_{3,8-hour,control}) - MAX(O_{3,8-hour,base})$$

It was found that the emissions from the new point source had a rather disproportionate impact on the urban airshed. Overall, the net impact of ***Las Brisas Energy Center*** power plant emissions was measurably up to 1.1 ppb on 8-hour average ozone. A split impact was observed because of the ***Las Brisas Energy Center*** emissions within the urban airshed and surrounding areas. Near the vicinity of the projected power plant a small titration effect was observed extending south and west from the plant, and over the metropolitan area of Corpus Christi. The subsequent increase in ozone concentration occurs further downwind of the source and is predicted to be 1.1 ppb. The predicted increase in ozone levels does not become evident until the plume has migrated north and west into western San Patricio County and Jim Wells County. The plume of increased O_3 then dissipates quickly as it moves further downwind. The delta impact on the surface ozone concentrations are shown in Figure 12(a) in the 4 km domain. Figure 12(b) provides a zoomed in view of the same data that is displayed the two-county urban airshed region. The positive difference shows a dis-benefit or an increase in the predicted ozone levels, while negative values show a decrease in the predicted surface ozone levels. The figure reveals that the overall impact of the new source on the attainment status of the study region is small and the net increase in 8-hour surface ozone levels was computed to be below 1.1 parts per billion.



(a) (b)

Figure 12 Impact of ***Las Brisas Energy Center*** on 8-hour average ozone within Corpus Christi Urban Airshed (a) entire 4 km domain (b) Corpus Christi urban airshed (max. control case – max. base case)

Figure 13 shows hourly difference of 8-hour ozone concentration from 7:00 AM to 5:00 PM at two hours interval in the Corpus Christi urban area. The solid black and red lines represent base case and control case 8-hour average ozone values at CAMS 21. The model predicts that at CAMS 21 site due to Las Brisas NO_x emissions, 8-hour ozone concentration drops up to 3.96 ppb due to ***Las Brisas*** emissions. The titration of ozone is due to the fresh NO_x emissions which react with ozone resulting in a drop of its concentration. The figure reveals that the overall impact of the new source on the attainment status of the study region would be marginal. The increase in the 8-hour surface ozone levels would be less than 1.1 parts per billion downwind of the source.

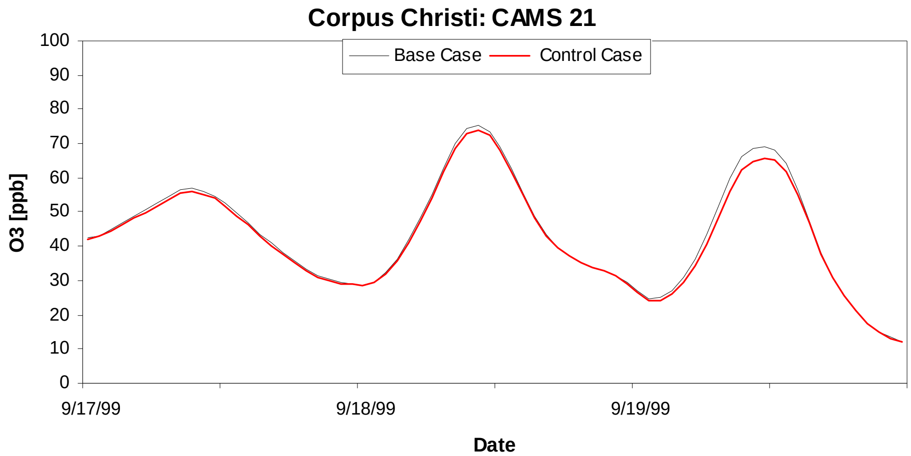


Figure 13 Impact of ***Las Brisas Energy Center*** on 8-hour average ozone at TCEQ operated compliance site CAMS 21 within Corpus Christi Urban Airshed

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[12] Environmental Protection Agency, National Ambient Air Quality Standards http://www.epa.gov/air/criteria.html (last assessed July, 2008c)