

Houston 2011 PM_{2.5} Exceptional Event Demonstration

**For a PM_{2.5} Exceptional Event at the
Houston Clinton Monitoring Site**

8/30/2013

Table of Contents

Introduction..... 1

 Exceptional Event Definition and Criteria..... 3

 Summary of Approach..... 4

 Summary of Findings 4

Data and Analysis Methods 5

 Data and Imagery Used..... 5

 Analysis Methods 7

Houston PM_{2.5} Trends and Sources..... 9

 PM_{2.5} Air Quality Trends..... 9

 Local Source Contributions..... 11

Event Summary 12

Exceptional Events Demonstration 18

 Affects Air Quality 18

 Not Reasonably Controllable or Preventable 19

 Natural Event 19

 Clear Causal Relationship..... 23

 Event In Excess of Normal Historical Fluctuations..... 25

 No Exceedance But For the Event 26

Mitigation of Exceptional Events 37

 Prompt Public Notification 37

 Public Education 38

 Implement Measures to Protect Public Health 38

Conclusion..... 39

References..... 40

Appendix A: Proposed 2011 Houston PM_{2.5} Exceptional Event Flag.. A-1

Appendix B: Source Analyses..... B-1

 Back Trajectories..... B-1

 Satellite Imagery..... B-8

 Aerosol Analyses B-15

Appendix C: CMAQ Model Evaluation..... C-1

Appendix D: Web Page Examples C-1

List of Tables

Table 1. PM_{2.5} monitors with data used for analyses..... 6
Table 2. Summary of Houston area daily PM_{2.5} measurements for May 15 through May 26, 2011. 17
Table 3. Houston Clinton daily PM_{2.5} and speciation measurements and calculations for May 15 through May 26, 2011.....23
Table 4. Houston area daily average PM_{2.5} measurements by site from May 16 through May 26, 2011..... 27
Table 5. Summary of Houston area daily average PM_{2.5} measurements for May 16 through May 26, 2011, showing the Houston Clinton but for the smoke event. 32

Appendix A

Table A-1. Proposed 2011 Houston PM_{2.5} Exceptional Event Flag A-1

List of Figures

Figure 1. Map of Houston area PM_{2.5} monitoring sites in 2011, including the Houston Clinton FRM site, as well as other FRM, speciation, and continuous PM_{2.5} sites. 2

Figure 2. Map of regional PM_{2.5} transport sites in 2011. 2

Figure 3. Houston PM_{2.5} annual design value trends for long-term FRM monitoring sites including exceptional event days. 9

Figure 4. Texas annual average PM_{2.5} concentrations, 2008. a) Map showing the highest site annual averages by area, with the second highest shown for areas with more than one site. (b) Map showing the estimated annual average contribution from transport by area with the top average based on the second lowest area daily measurements for areas with more than one site. 10

Figure 5. Houston Clinton FRM annual PM_{2.5} averages, estimated Houston area incoming background level based on daily second lowest measurements, and estimated local contribution to PM_{2.5} levels from 2000 through 2012. 11

Figure 6. PM_{2.5} AQI levels by site on May 20, 2011. 12

Figure 7. Map of Houston area daily average PM_{2.5} (µg/m³) with Clinton wind measurement summary for May 20, 2011. 13

Figure 8. Regional map of daily average PM_{2.5} (µg/m³) measurements at selected Houston sites and area transport sites for May 20, 2011, showing a large-scale gradient with higher concentrations to the west and lower concentrations to the east across the area. 14

Figure 9. Houston-area wind rose plots for May 20, 2011. 15

Figure 10. Houston hourly PM_{2.5} concentrations by site for May 16 through May 26, 2011, with hourly wind direction at Houston Clinton. 16

Figure 11. Houston hourly PM_{2.5} concentrations by site for May 19 through May 21, 2011. 16

Figure 12. Houston Clinton FRM PM_{2.5} daily measurements from 2009 through 2011, with symbols showing analyzed events from African dust and from smoke from agricultural burning in Mexico and Central America. 18

Figure 13. Natural color image of smoke blowing across the western Gulf of Mexico from Mexico and Central America on May 20th. Satellite-indicated fires are shown as red dots. (Riebeek, 2011) 20

Figure 14. Houston Clinton speciated PM_{2.5} potassium ion measurements for 2006 through 2012 show the measurement from the proposed exceptional event day is among the highest in the period. 21

Figure 15. Houston Clinton IMPROVE calculated PM_{2.5} organic carbon concentrations for 2006 through 2012 show the measurement from the proposed exceptional event day is among the highest in the period.21

Figure 16. Houston area highest and second lowest daily average PM_{2.5} concentrations with Clinton PM_{2.5} and potassium ion concentrations for May 15 through 26, 2011.22

Figure 17. Plot of HYSPLIT model backward-in-time air parcel trajectory for the 2011 exceptional event day, for air arriving in Houston at noon Central Standard Time at 500 meters (green), 1,000 meters (red), and 1,500 meters (blue) above ground level. (NOAA ARL, 2013)24

Figure 18. NRL aerosol model output showing aerosol optical depth (left panel) and smoke surface concentration (right panel), for the smoke arriving in Houston on May 20, 2011.25

Figure 19. Houston area 2011 estimated incoming PM_{2.5} background level based on area second lowest daily measurement. ..26

Figure 20. Houston Clinton hourly PM_{2.5} concentrations for Houston Clinton and estimated incoming background, May 16 through May 26, 2011.28

Figure 21. Houston area highest and second lowest daily average PM_{2.5} with Clinton IMPROVE organic carbon, May 15 through May 26, 2011.29

Figure 22. Houston area daily average PM_{2.5} and Clinton IMPROVE organic carbon, May 15 through May 26, 2011, along with Isla Blanca and National Seashore.30

Figure 23. Houston Clinton daily estimated PM_{2.5} but for event concentrations May 16 through May 26, 2011.33

Figure 24. The CMAQ model output of daily PM_{2.5} average for May 17, 2011 (24-hour period ending 0600 UTC May 18, 2011). .34

Figure 25. The CMAQ model output of daily PM_{2.5} average for May 18, 2011 (24-hour period ending 0600 UTC May 19, 2011). .35

Figure 26. The CMAQ model output of daily PM_{2.5} average for May 19, 2011 (24-hour period ending 0600 UTC May 20, 2011). .35

Figure 27. The CMAQ model output of daily PM_{2.5} average for May 20, 2011 (24-hour period ending 0600 UTC May 21, 2011) ..36

Appendix B

Figure B-1. Backward-in-time air trajectory for May 20, 2011 B-2
Figure B-2. Backward-in-time air trajectory for May 21, 2011 B-3
Figure B-3. Backward-in-time air trajectory for May 22, 2011 B-4
Figure B-4. Backward-in-time air trajectory for May 23, 2011 B-5
Figure B-5. Backward-in-time air trajectory for May 24, 2011 B-6
Figure B-6. Backward-in-time air trajectory for May 25, 2011 B-7
Figure B-7. Visible satellite image for 1409 UTC on May 18, 2011... B-9
Figure B-8. Visible satellite image for 2209 UTC on May 18, 2011..B-10
Figure B-9. Visible satellite image for 1409 UTC on May 19, 2011
.....B-11
Figure B-10. Visible satellite image for 2209 UTC on May 19, 2011.....
.....B-12
Figure B-11. Visible satellite image for 1408 UTC on May 20, 2011.....
.....B-13
Figure B-12. Visible satellite image for 2208 UTC on May 20, 2011.....
.....B-14
Figure B-13. NRL aerosol analysis for 1800 UTC on May 18, 2011. B-15
Figure B-14. NRL aerosol analysis for 0000 UTC on May 19, 2011. B-16
Figure B-15. NRL aerosol analysis for 0600 UTC on May 19, 2011. B-17
Figure B-16. NRL aerosol analysis for 1200 UTC on May 19, 2011. B-18
Figure B-17. NRL aerosol analysis for 1800 UTC on May 19, 2011. B-19
Figure B-18. NRL aerosol analysis for 0000 UTC on May 20, 2011. B-20
Figure B-19. NRL aerosol analysis for 0600 UTC on May 20, 2011. B-21
Figure B-20. NRL aerosol analysis for 1200 UTC on May 20, 2011. B-22
Figure B-21. NRL aerosol analysis for 1800 UTC on May 20, 2011. B-23
Figure B-22. NRL aerosol analysis for 0000 UTC on May 21, 2011. B-24
Figure B-23. NRL aerosol analysis for 0600 UTC on May 21, 2011. B-25

Appendix C

Figure C-1. Comparison of CMAQ model-predicted PM_{2.5} concentrations
versus actual measured AQI levels on January 11, 2010..
..... C-2
Figure C-2. Comparison of CMAQ model-predicted PM_{2.5} concentrations
versus actual measured AQI levels on January 12, 2010..
..... C-3
Figure C-3. Comparison of CMAQ model-predicted PM_{2.5} concentrations
versus actual measured AQI levels on January 13, 2010..
..... C-4
Figure C-4. Comparison of CMAQ model-predicted PM_{2.5} concentrations
versus actual measured AQI levels on January 14, 2010.
..... C-5

Appendix D

Figure D-1. Sample of the TCEQ Today's Texas Air Quality Forecast. ... D-2
..... D-2

Figure D-2. Sample of the EPA AIRNOW web page..... D-3

Figure D-3. Sample of the TCEQ map of current PM_{2.5} levels. D-4

Figure D-4. Sample of a portion of the TCEQ Air Quality Index Report.
..... D-5

Figure D-5. Sample of a portion of the TCEQ particulate matter web
page. D-6

Figure D 6. Sample of a portion of the EPA Air Quality Index guide. D-7

Introduction

Exceptional events are unusual or naturally occurring events that affect air quality and are not reasonably controllable or preventable. An event may also be caused by human activity that is unlikely to recur at a particular location. Under Section 319 of the Federal Clean Air Act (FCAA), states are responsible for identifying air quality monitoring data affected by an exceptional event and requesting the United States Environmental Protection Agency (EPA) to exclude the data from consideration when determining whether an area is in attainment or nonattainment of a National Ambient Air Quality Standard (NAAQS). The EPA has promulgated an exceptional event rule, 40 Code of Federal Regulations (CFR) § 50.14, and guidance to implement the requirements of the FCAA regarding exceptional events. States are required to identify air quality monitoring data potentially affected by exceptional events by “flagging” the data submitted into the EPA air quality system (AQS) database. If the EPA concurs with this demonstration, the flagged data will not be eligible for consideration when making attainment or nonattainment determinations.

This document discusses the Texas Commission on Environmental Quality’s (TCEQ) proposed exceptional event flag for particulate matter of 2.5 micrometers or less in aerodynamic diameter ($PM_{2.5}$) data collected at the Houston Clinton site on May 20, 2011, including technical analyses. This document will be posted on the main TCEQ web page beginning on August 30, 2013, for a 30-day public comment period. All comments received will be submitted to the EPA for consideration. With this demonstration, the TCEQ is providing detailed evidence to support concurrence by the EPA for the $PM_{2.5}$ exceptional event flag shown in Appendix A. This proposed exceptional event flag for 2011 is for the daily measurement from the Federal Reference Method (FRM) $PM_{2.5}$ monitor at the Houston Clinton site. A map identifying the Houston area $PM_{2.5}$ sites, including the Houston Clinton site, is shown in Figure 1 and a map of regional $PM_{2.5}$ transport sites used in the analyses is shown in Figure 2 along with the Houston Clinton site for reference.

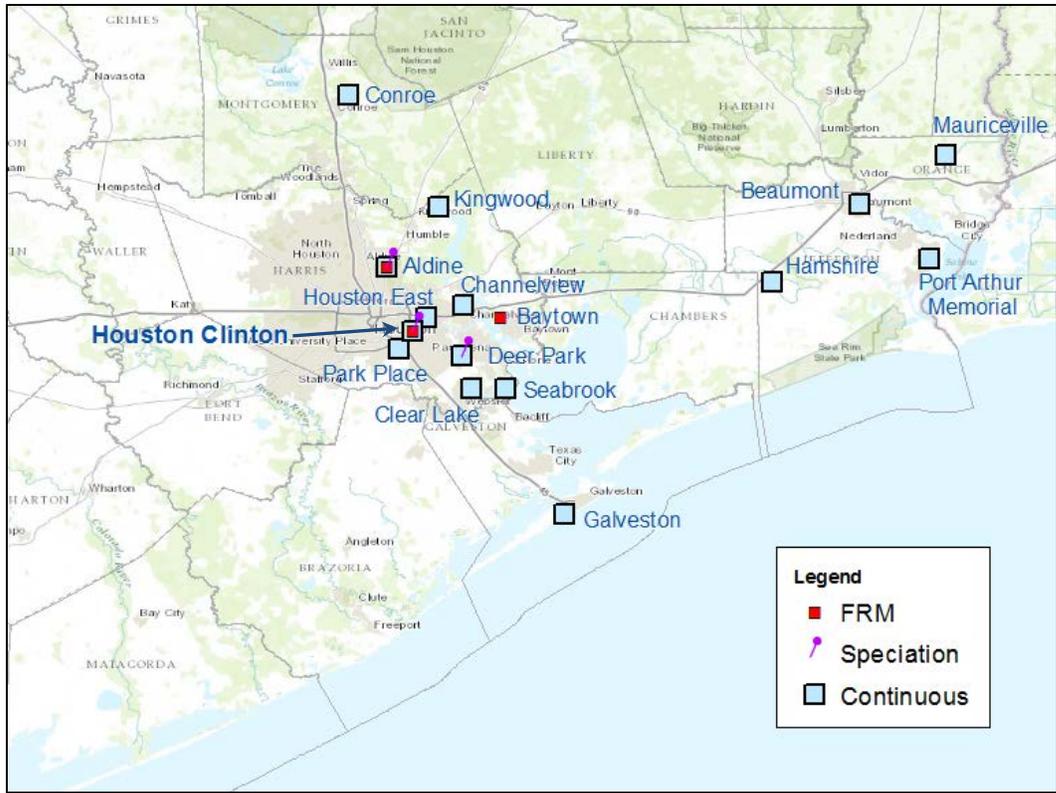


Figure 1. Map of Houston area PM_{2.5} monitoring sites in 2011, including the Houston Clinton FRM site, as well as other FRM, speciation, and continuous PM_{2.5} sites.

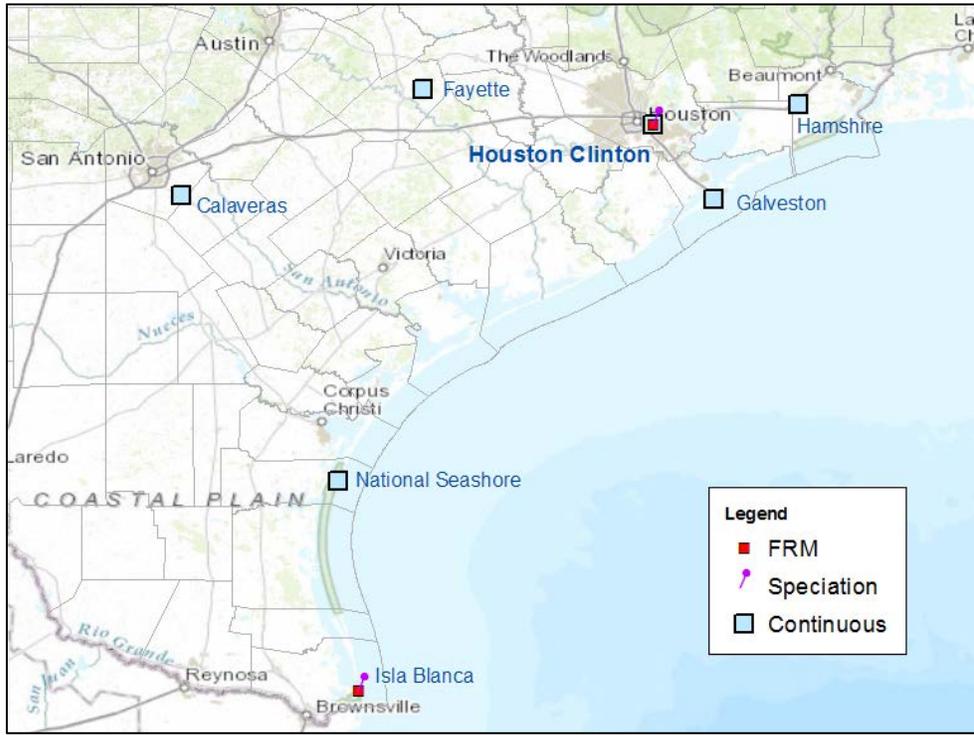


Figure 2. Map of regional PM_{2.5} transport sites in 2011.

Exceptional Event Definition and Criteria

An exceptional event is defined in 40 CFR Part 50.1(j) as “[1] an event that affects air quality, [2] is not reasonably controllable or preventable, [3] is an event caused by human activity that is unlikely to recur at a particular location or a natural event, and [4] is determined by the [EPA] Administrator in accordance with 40 CFR 50.14 to be an exceptional event”. Furthermore, 40 CFR 50.14(c)(3)(iv) states that the demonstration to justify data exclusion shall also provide evidence that “[5] there is a clear causal relationship between the measurement under consideration and the event that is claimed to have affected the air quality in the area; [6] the event is associated with a measured concentration in excess of normal historical fluctuations, including background; and [7] there would have been no exceedance or violation but for the event”. These seven requirements must all be satisfied for data to be excluded from regulatory decisions as an exceptional event. Requirements 1 through 3 and 5 through 7 will be addressed individually in this demonstration document.

Mitigation of exceptional events is also required by 40 CFR 51.930, which reads:

A State requesting to exclude air quality data due to exceptional events must take appropriate and reasonable actions to protect public health from exceedances or violations of the national ambient air quality standards. At a minimum, the State must:

(1) provide for prompt public notification whenever air quality concentrations exceed or are expected to exceed an applicable ambient air quality standard;

(2) provide for public education concerning actions that individuals may take to reduce exposures to unhealthy levels of air quality during and following an exceptional event; and

(3) provide for the implementation of appropriate measures to protect public health from exceedances or violations of ambient air quality standards caused by exceptional events.

These requirements will be addressed in the “Mitigation of Exceptional Events” section.

Summary of Approach

The TCEQ used several methods for developing a demonstration that indicates that the high PM_{2.5} measurement in question qualifies as an exceptional event. PM_{2.5} concentrations from three Houston FRM monitors were evaluated for a period of over 10 years to adequately establish historical trends in the data. In addition, the TCEQ evaluated PM_{2.5} speciation data from these monitors to identify smoke impacts. Satellite imagery from the National Aeronautic and Space Administration (NASA) (NASA Earth Observatory, 2013) and National Oceanic and Atmospheric Administration (NOAA) (NOAA, 2013), along with aerosol modeling provided by the Naval Research Laboratory (NRL) was used to track smoke across the Gulf of Mexico. The TCEQ also analyzed Houston area PM_{2.5} data to estimate contribution from long-range transport (incoming background levels) and local sources during the event as well as to estimate the baseline incoming background levels without the transport event for use in the “but for” analysis. Finally, the TCEQ reviewed NOAA PM_{2.5} dispersion modeling output for the proposed exceptional event day as a basis to indicate that daily PM_{2.5} concentrations would not have exceeded the level of the annual NAAQS “but for” the event.

Summary of Findings

The information provided in this demonstration document supports the conclusion that the high PM_{2.5} measurement at Houston Clinton on May 20, 2011, qualifies as an exceptional event. The measured PM_{2.5} exceedance of the annual NAAQS on this day was not reasonably preventable, was clearly due to smoke from fires in Mexico and Central America, was in excess of normal historical fluctuations, and would not have occurred but for the smoke event. The TCEQ requests EPA’s concurrence on this exceptional event and to have this day removed from consideration when making attainment or nonattainment determinations for the annual PM_{2.5} NAAQS.

Data and Analysis Methods

Data and Imagery Used

For the analyses presented in this document, the TCEQ utilized an extensive set of monitoring data, satellite imagery, and air trajectory information. As detailed in Table 1, the monitoring data include FRM non-continuous PM_{2.5} daily measurements, non-continuous PM_{2.5} acceptable speciated daily measurements, and continuous PM_{2.5} acceptable hourly and daily measurements (used for daily reporting of the EPA Air Quality Index [AQI]), as well as hourly and daily wind measurements.

All of the TCEQ data used in this demonstration document are available in the EPA's AQS database (EPA1, 2013) and meet EPA quality assurance requirements and guidelines. The satellite imagery used in this document are from NASA and NOAA and the imagery shown in the appendices were received and processed by the TCEQ and routinely displayed on the TCEQ web site for 24 hours (TCEQ, 2013). The air parcel trajectories were produced using the NOAA Applied Research Laboratory (ARL) Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model available on the [ARL HYSPLIT web page](http://ready.arl.noaa.gov/HYSPLIT.php) (<http://ready.arl.noaa.gov/HYSPLIT.php>) (NOAA ARL, 2013).

Table 1. PM_{2.5} monitors with data used for analyses.

Site Name	AQS Site Identifier	AQS Parameter Identifier	AQS POC Identifier	PM _{2.5} Monitor Type
Calaveras	480290059	88502	3	Acceptable continuous
Isla Blanca	480612004	88101	1	FRM non-continuous
Isla Blanca	480612004	88101	5	Acceptable non-continuous speciated
Galveston	481671034	88101	1	FRM non-continuous
Galveston	481671034	88502	3	Acceptable continuous
Fayette	481490001	88502	3	Acceptable continuous
Aldine	482010024	88101	5	FRM non-continuous
Aldine	482010024	88502	5	Acceptable non-continuous speciated
Aldine	482010024	88502	3	Acceptable continuous
Channelview	482010026	88502	3	Acceptable continuous
Baytown	482010058	88101	1	FRM non-continuous
Park Place	482010416	88502	3	Acceptable continuous
Clear Lake	482010572	88502	3	Acceptable continuous
Houston East	482011034	88502	3	Acceptable continuous
Clinton	482011035	88101	1	FRM non-continuous primary
Clinton	482011035	88101	2	FRM non-continuous secondary
Clinton	482011035	88502	5	Acceptable non-continuous speciated
Clinton	482011035	88502	3	Acceptable continuous
Deer Park	482011039	88502	3	Acceptable continuous
Deer Park	482011039	88502	5	Acceptable non-continuous speciated
Kingwood	482011042	88502	3	Acceptable continuous
Seabrook	482011050	88502	3	Acceptable continuous
Port Arthur	482450021	88502	3	Acceptable continuous
Hamshire	482450022	88502	3	Acceptable continuous
Beaumont	482451050	88502	3	Acceptable continuous
National Seashore	482730314	88502	3	Acceptable continuous
Conroe	483390078	88502	3	Acceptable continuous
Mauriceville	483611100	88502	3	Acceptable continuous

Note: POC stands for parameter occurrence code.

AQS stands for EPA's air quality system database.

FRM stands for federal reference method.

Analysis Methods

Several methods were used to analyze the data to determine if the specific monitor value of concern qualifies as an exceptional event. These methods include time series plots to show trends and events, comparison to statistical percentiles to show relevance, examination of satellite imagery and aerosol model results for evidence of smoke, and review of backward-in-time air trajectories for independent confirmation of transport path of the affected air. Also, daily averages of hourly PM_{2.5} continuous data were compiled for comparison with non-continuous measurements.

The TCEQ also used Houston area PM_{2.5} monitoring data to estimate the transport contribution for the proposed exceptional event day in order to demonstrate what ambient conditions would have been but for the event. The transport contribution for historical and baseline days was derived using the second lowest area daily measurement. This approach has previously been presented as a method for estimating the impact of transport on annual PM_{2.5} averages (Lambeth, 2010). Choosing the second lowest area daily measurement rather than the lowest area daily measurement with a sufficient number of samples is more statistically robust, similar to using the 98th percentile rather than the maximum for the 24-hour PM_{2.5} NAAQS. Other researchers have also noted problems in using the lowest area measurement to represent incoming background levels in the Houston area (Nielson-Gammon et al., 2005). On days where the incoming background levels are more uniform, the lowest and second lowest measurements will be close. However, significant gradients in the incoming background levels can result in substantial differences between the lowest and second lowest measurements. In these instances, the lowest may not best represent the transport contribution at the site of interest. Given the size of the Houston metropolitan area, significant gradients in the incoming background levels are quite common and result from the passage of incoming smoke plumes, haze, and dust clouds. These gradients are typically seen as horizontal variations in incoming background levels, but vertical gradients in the incoming background levels can also be present and influence the horizontal background gradient because of horizontal gradients in vertical mixing of the air induced by coastal temperature effects. When incoming background concentrations are greater aloft coming into the coast, vertical mixing of the air inland to higher altitudes than near the coast will cause an increase in the incoming background levels inland as compared to what is measured at the coast. On May 20, 2011, spatial data plots show evidence of a large-scale west to east decreasing gradient with concentrations higher

on the west side of the Houston area and lower to the east, resulting in the need for a more detailed analysis to determine the transport contribution.

The TCEQ used the estimated transport contribution detailed above and monitoring data from the Houston Clinton site to estimate the local contribution to the PM_{2.5} measurement at Clinton. The local contribution was calculated by subtracting the transport contribution from the Houston Clinton measurement.

Houston PM_{2.5} Trends and Sources

PM_{2.5} Air Quality Trends

With the exception of the Houston Clinton site, PM_{2.5} levels in the Houston area have shown a gradual overall decline since monitoring began in 1999. As shown in Figure 3, the Houston Clinton site measured a pronounced increase in PM_{2.5} concentrations from 2002 to 2007 believed to be caused by localized sources in the immediate vicinity of the site. Localized contributions at the Houston Clinton site are discussed below. This increase has been followed by a sharp decline resulting from extensive voluntary source remediation efforts (Sullivan, Price, Sheedy, Lambeth, Savanich, & Tropp, 2013) that are described in the Local Source Contributions section below.

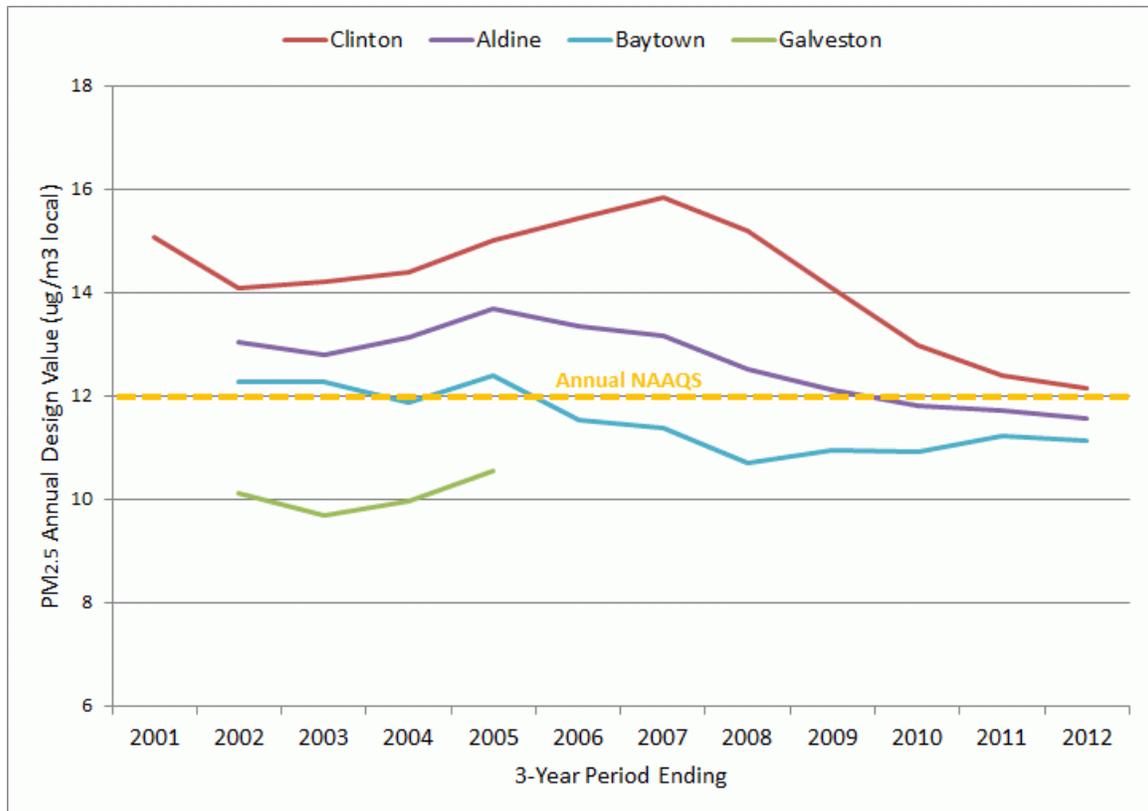


Figure 3. Houston PM_{2.5} annual design value trends for long-term FRM monitoring sites including exceptional event days.

Historically, PM_{2.5} levels in the Houston area have been greatly impacted by long-range transport from natural events outside of the area including wildfires; African dust; dust from large, intense regional dust storms in the West Texas-New Mexico-Northern Mexico area; and smoke from agricultural burning in Mexico and Central America. Long-range transport from other types of events also impact the Houston

area, including controlled burns and haze and smoke accumulated from man-made emissions in the U.S. and Canada (also known as continental haze).

Increased Houston-area $PM_{2.5}$ concentrations due to transport events have historically followed a seasonal pattern. Smoke from agricultural burning in Mexico and Central America affects the Houston area mainly from April to early June each year when winds bring in air from eastern Mexico and Central America. African dust impacts the Houston area every year, mainly in the summer, with typically three to six intense episodes that are characterized by high incoming background levels and lasting one to three days or more. Continental haze events are most common from May through October and often include high ozone background levels as well. All of these sources of $PM_{2.5}$ air pollution cannot be controlled locally and prior work indicates that these sources, along with the global background, account for about 75 to 90 percent of the annual $PM_{2.5}$ average at sites in the Houston area (Lambeth, 2010) as shown in Figure 4. A variety of urban and industrial local sources of $PM_{2.5}$ also contribute the remaining 10 to 25 percent of the annual means for 2010-2012.

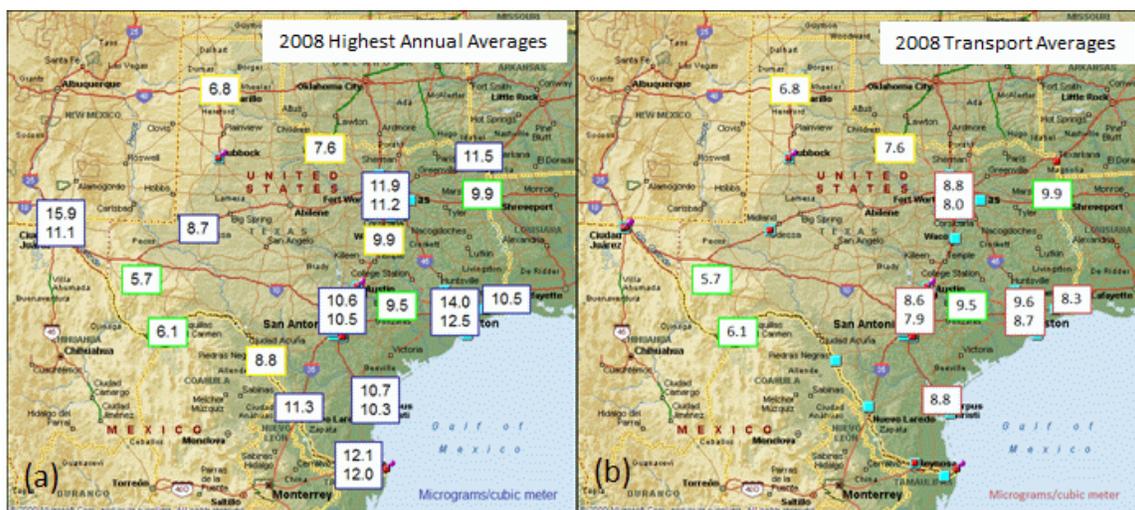


Figure 4. Texas annual average $PM_{2.5}$ concentrations, 2008. The green boxes indicate sites most representative of regional transport where local contributions should be minimal. The yellow boxes indicate sites where local contributions should be low. (a) Map showing the highest site annual averages by area, with the second highest shown for areas with more than one site. (b) Map showing the estimated annual average contribution from transport by area with the top average based on the second lowest area daily measurements for areas with more than one site. Areas where the number and placement of monitors were inadequate to determine local contribution were not included on this map. (Lambeth, 2010).

Local Source Contributions

The Houston Clinton monitoring site, located near the west end of the Houston Ship Channel, was originally sited to measure impacts from nearby industrial air pollution sources. When PM_{2.5} concentrations began rising to near the level of the annual NAAQS in 2005 and 2006, voluntary control measures from some of the nearby industrial air pollution sources were pursued by the TCEQ and the City of Houston, in addition to roadway improvements to address emissions from nearby roads. Implemented control strategies included constraining traffic flow through traffic barriers on the shoulder of Clinton Drive and traffic lights, adding vegetation along Clinton Drive, reducing locomotive emissions at the nearby port, replacing calcium sulfate from port roadways and work yards with fresh compacted soil topped by emulsified asphalt, paving of some parking areas, and implementing dust control measures at a nearby fluorspar unloading and storage facility. As a result of these activities, the estimated annual contribution from all Houston area PM_{2.5} sources at Houston Clinton declined approximately 50 percent from approximately 6 µg/m³ in 2006 to about 3 µg/m³ in 2011 as shown in Figure 5. The estimated incoming background level contribution to the annual average declined by about 1 µg/m³ from 2007 to 2012 as also shown in Figure 5. Analysis of the speciated PM_{2.5} data at Houston Clinton indicated a 2 µg/m³ decline in the soil component from 2006 to 2011 (Sullivan, Price, Sheedy, Lambeth, Savanich, & Tropp, 2013).

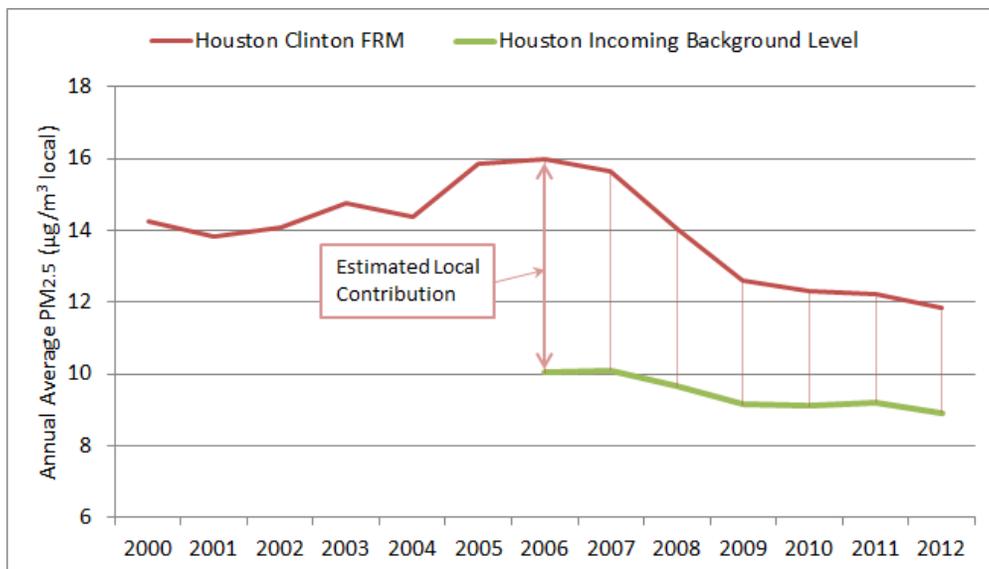


Figure 5. Houston Clinton FRM annual PM_{2.5} averages, estimated Houston area incoming background level (transport contribution) based on daily second lowest measurements, and estimated local contribution to PM_{2.5} levels from 2000 through 2012 (for all days including proposed exceptional events).

Event Summary

Intense smoke from agricultural fires in Mexico and Central America moved through the Houston area in mid- to late-May, causing the elevated $PM_{2.5}$ concentration on May 20, 2011. As a result of smoke covering the eastern half of Texas, daily $PM_{2.5}$ AQI ratings in parts of Central and South Texas reached "Unhealthy for Sensitive Groups," and "Moderate" levels were noted over much of the state, as illustrated in Figure 6. As further illustrated in Figure 6, widespread elevated $PM_{2.5}$ measurements along with moderate southerly winds across Southeast Texas on May 20th support the dominant influence of increased incoming background concentrations.

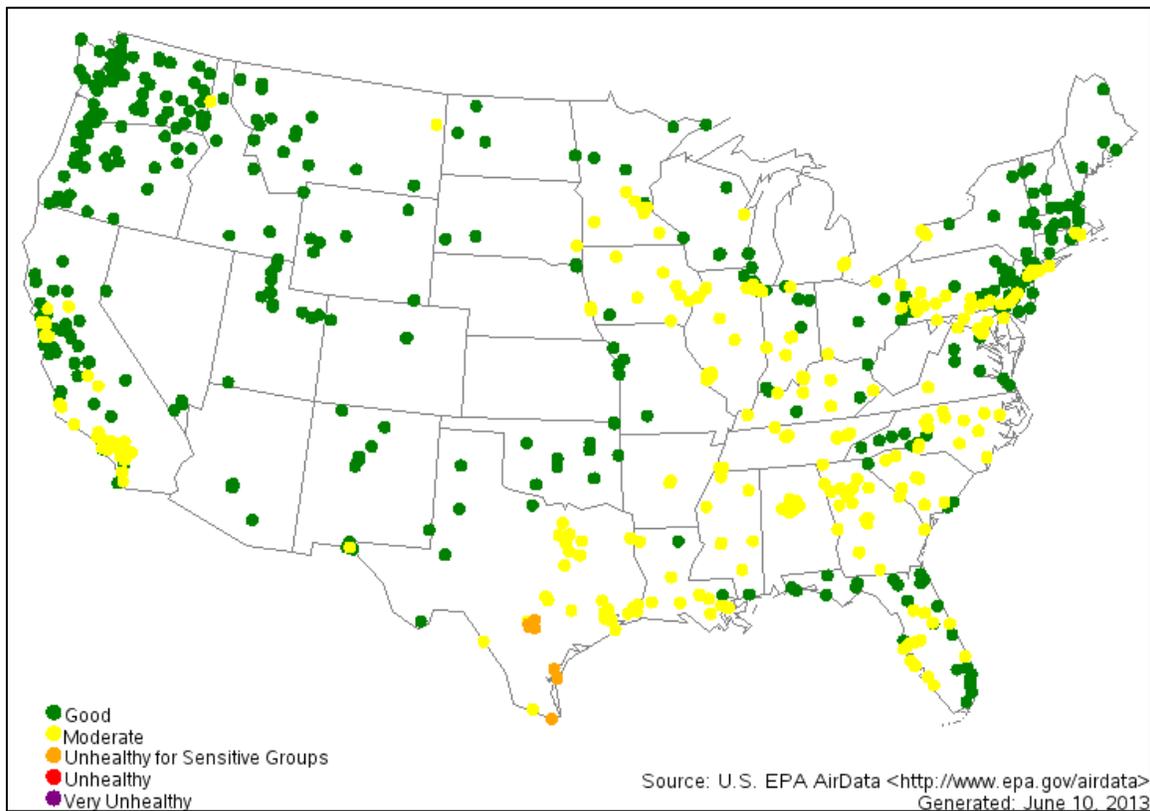


Figure 6. $PM_{2.5}$ AQI levels by site on May 20, 2011.

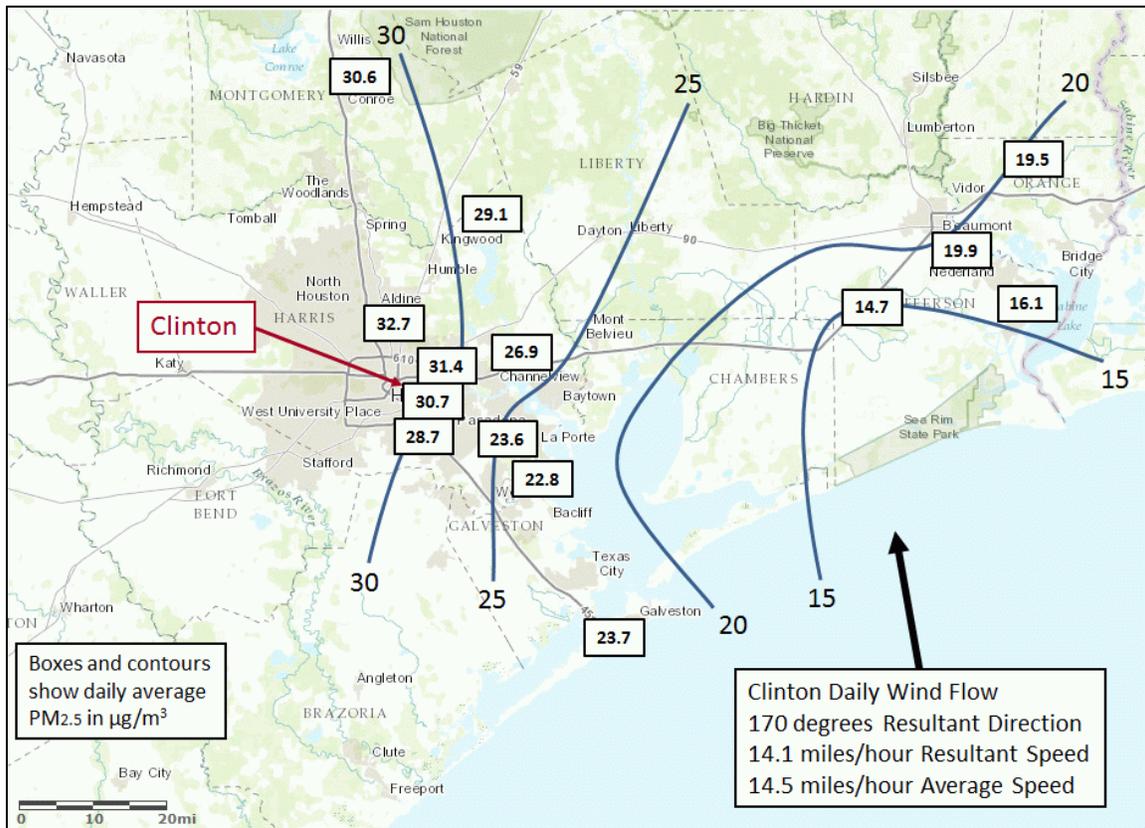


Figure 7. Map of Houston area daily average PM_{2.5} ($\mu\text{g}/\text{m}^3$) with Clinton wind measurement summary for May 20, 2011.

In addition to elevated PM_{2.5} levels, Figures 7 and 8 indicate evidence of a large-scale regional gradient in PM_{2.5} levels with higher PM_{2.5} concentrations to the west and lower concentrations to the east. This regional gradient accounts for lower PM_{2.5} measurements on the east side of the Houston area and therefore measurements on the east side of the area do not accurately represent the incoming background levels affecting central and western portions of the area. The contour analyses in Figures 7 and 8 indicate that the difference in PM_{2.5} concentration between Park Place and the area second lowest measurement at Deer Park is consistent with the decreasing regional gradient in PM_{2.5} concentrations on the east side of the Houston area. Thus, because of the southerly wind flow, the PM_{2.5} measurement at Park Place should be more representative of the incoming background level at Clinton than sites farther to the east such as Deer Park and Seabrook where lower concentrations were observed because of the gradient.



Figure 8. Regional map of daily average PM_{2.5} (µg/m³) measurements at selected Houston sites and area transport sites for May 20, 2011, showing a large-scale gradient with higher concentrations to the west and lower concentrations to the east across the area.

Wind directions and speeds for May 20th are depicted in Figure 9 using wind roses for selected monitoring locations in the region. The length of the bars on each wind rose indicates the frequency of winds occurring in the direction of the bar. The wind flow is along the bar toward the site. The wind roses show that winds were persistently from the south to southeast at all sites that day.

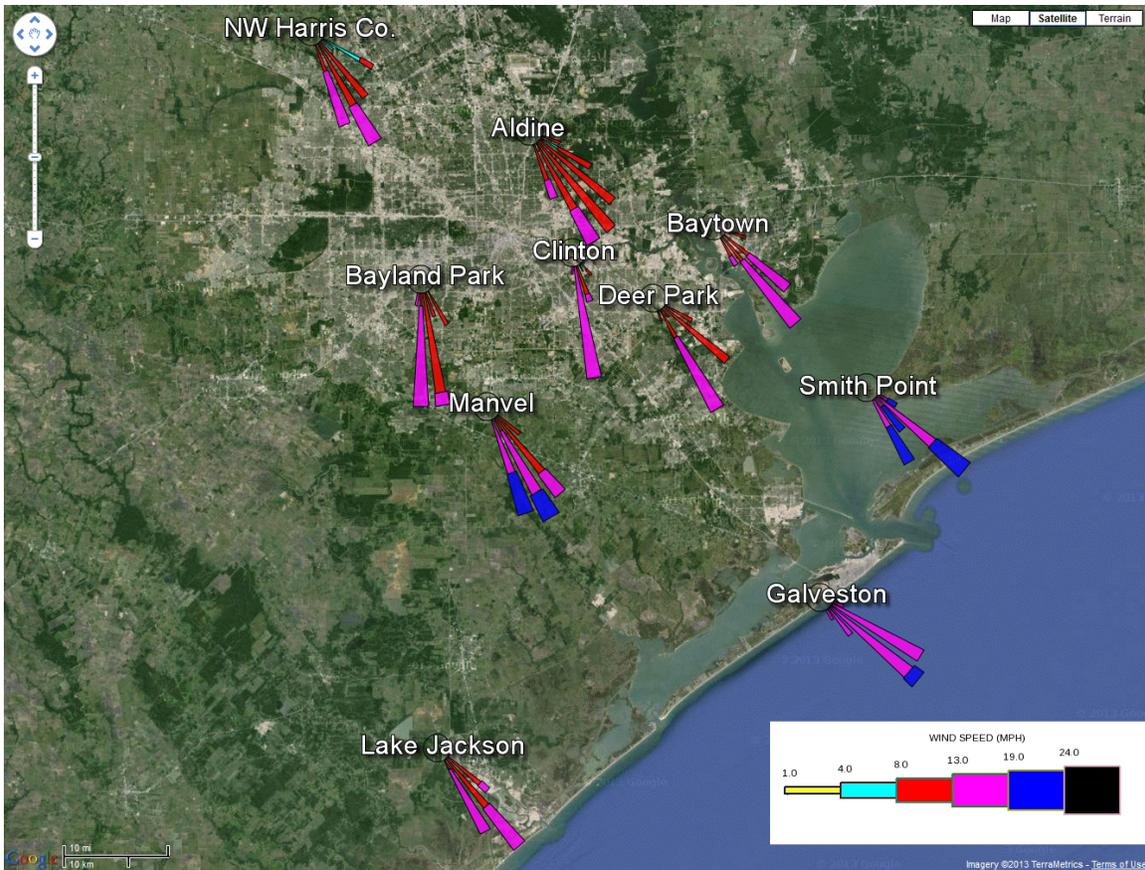


Figure 9. Houston-area wind rose plots for May 20, 2011.

PM_{2.5} measurements at sites across the Houston area showed a rapid increase in concentrations from incoming transport of particulate matter beginning on May 19th, as illustrated in Figures 10 and 11. These PM_{2.5} measurements along with a predominant south to southeast wind flow indicate that PM_{2.5} levels coming onshore into Texas from the Gulf of Mexico were in the range from about 24 to 38 µg/m³ as indicated by coastal measurements at Galveston and National Seashore. Continuous hourly PM_{2.5} measurements from all Houston sites during the time period of the event show a tight clustering of measurements as concentrations increase and decrease, providing strong evidence of a regional transport event affecting all sites, as illustrated in Figures 10 and 11. In these figures, measurements from the Houston Clinton site are plotted with a thicker line. Variations among the sites can be caused by gradients in the incoming background levels, impacts from local sources, and/or measurement uncertainties, all of which vary over time.

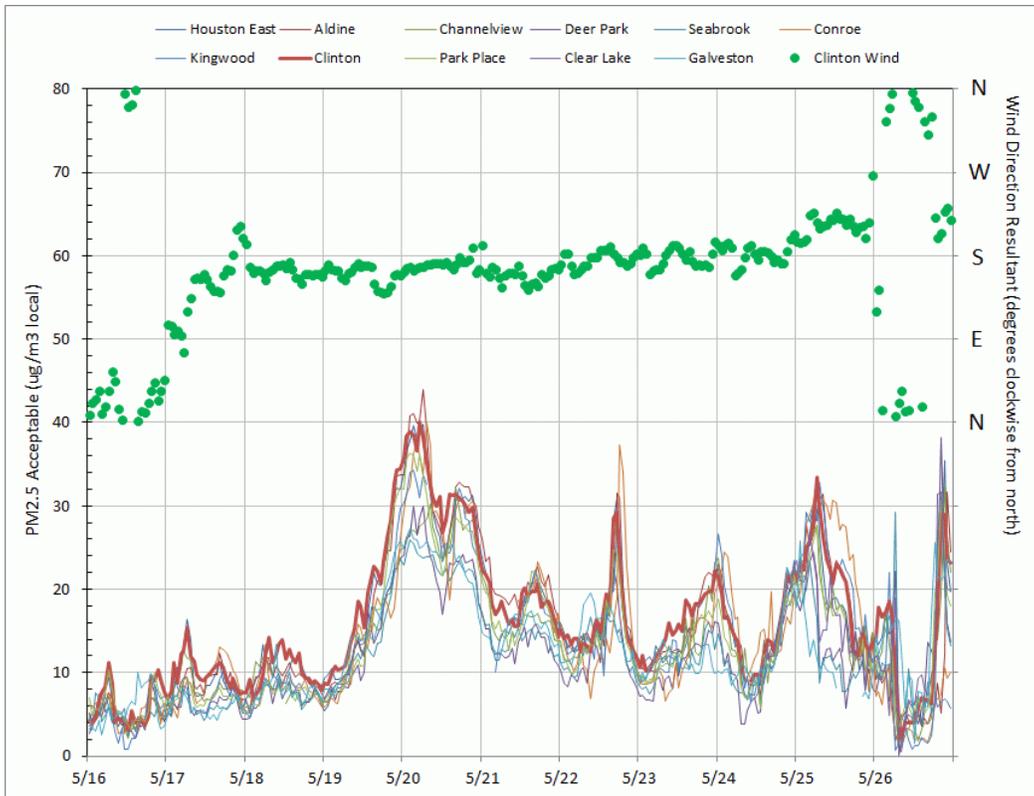


Figure 10. Houston hourly PM_{2.5} concentrations by site for May 16 through May 26, 2011, with hourly wind direction at Houston Clinton.

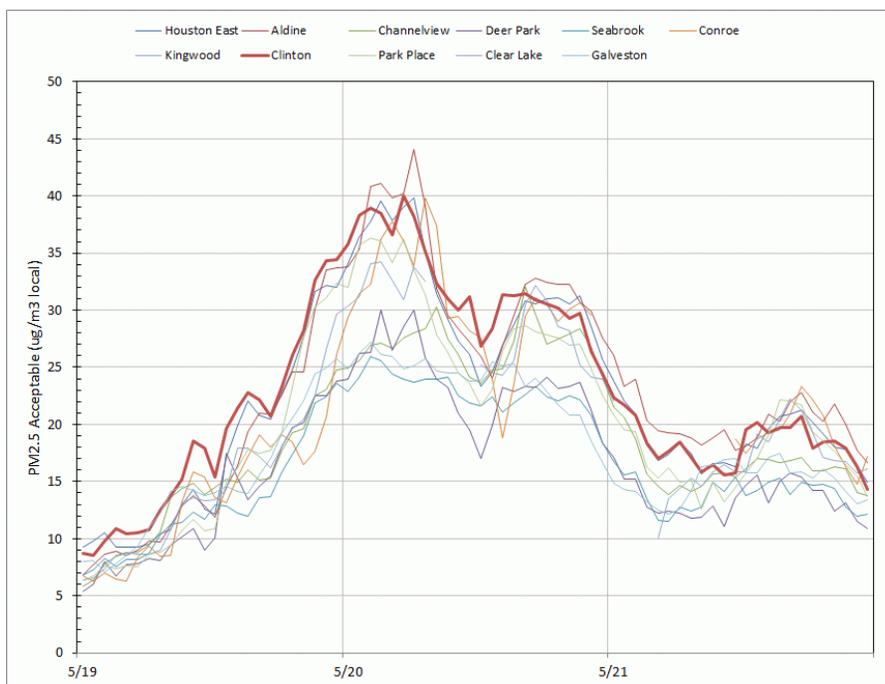


Figure 11. Houston hourly PM_{2.5} concentrations by site for May 19 through May 21, 2011.

Daily area summary statistics for the event are shown in Table 2, including the area maximum, area second lowest, and lowest PM_{2.5} concentrations. These measurements show the large increase in area concentrations from the baseline days before the event and the corresponding decrease following the event.

Table 2. Summary of Houston area daily PM_{2.5} measurements (µg/m³) for May 15 through May 26, 2011.

Houston Area Daily PM _{2.5} Summary (µg/m ³)	05/15/11	05/16/11	05/17/11	05/18/11	05/19/11	05/20/11	05/21/11	05/22/11	05/23/11	05/24/11	05/25/11	05/26/11
Maximum	5.4	6.1	9.9	10.2	18.6	32.7	20.1	16.8	15.6	15.7	24.2	14.1
Second Lowest	4.0	4.6	6.2	7.2	12.8	23.6	13.9	12.9	11.1	11.3	13.6	5.6
Lowest	3.7	4.5	5.8	7.1	12.8	22.8	13.4	12.3	10.6	11.0	12.9	5.2

Note: *Italics* indicate that a measurement is above the level of the annual PM_{2.5} NAAQS.

Exceptional Events Demonstration Affects Air Quality

The proposed exceptional event flag for May 20, 2011, is for a measurement of $30.7 \mu\text{g}/\text{m}^3$, which is well above the annual $\text{PM}_{2.5}$ standard of $12.0 \mu\text{g}/\text{m}^3$. This measurement is also well above the 95th percentile of all Houston Clinton FRM $\text{PM}_{2.5}$ measurements ($21.5 \mu\text{g}/\text{m}^3$) during the period from 2009 through 2011. Thus, this measurement was among the highest five percent of measurements over the three-year period ending with 2011 at the Houston Clinton FRM $\text{PM}_{2.5}$ monitor. The preamble to the Exceptional Event rule (72 *Federal Register* 13569) states:

For extremely high concentrations relative to historical values (e.g., concentrations greater than the 95th percentile), a lesser amount of documentation or evidence may be required to demonstrate that the event affected air quality.

Figure 12 shows the 1,044 Houston Clinton FRM $\text{PM}_{2.5}$ valid daily measurements for the period from 2009 through 2011 and indicates the proposed 2011 exceptional event day.

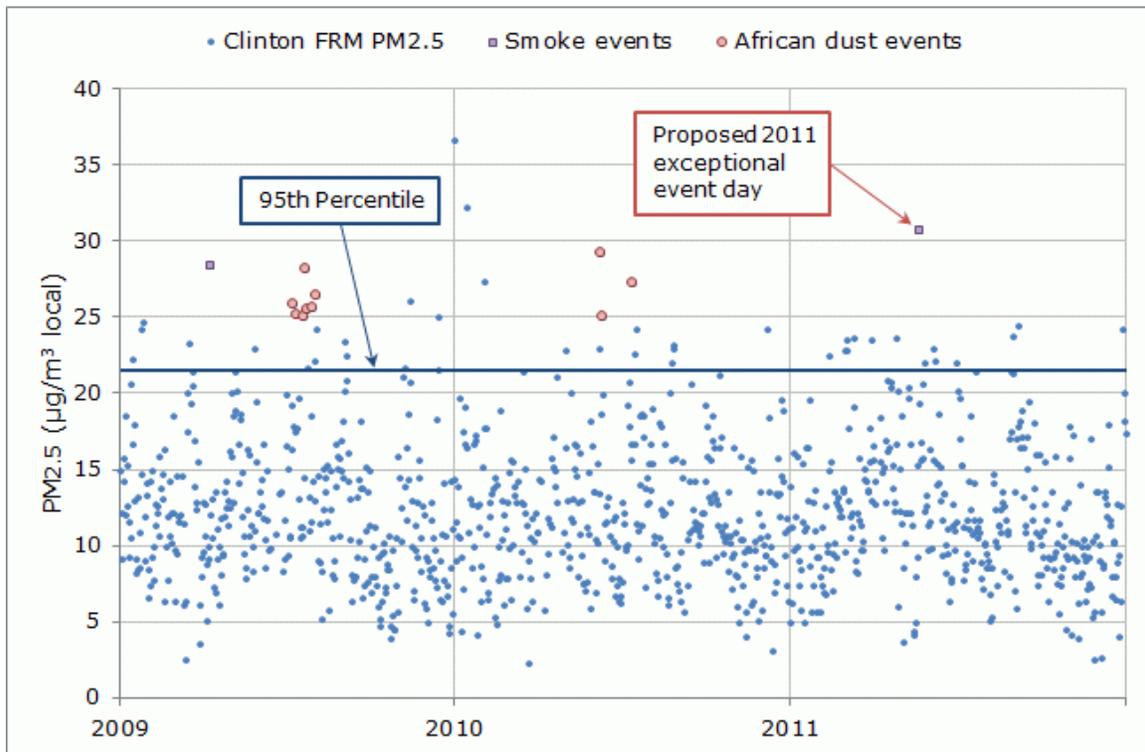


Figure 12. Houston Clinton FRM $\text{PM}_{2.5}$ daily measurements from 2009 through 2011, with symbols showing analyzed events from African dust and from smoke from agricultural burning in Mexico and Central America.

Not Reasonably Controllable or Preventable

The proposed exceptional event had an incoming regional background level greatly exceeding the annual standard as indicated by the second lowest area daily measurement (see Figures 20 and 21 below). Local source controls could not reduce these high incoming levels. Also, satellite imagery and back trajectories show the transport of large amounts of fine particulate from sources outside of the United States and Texas associated with fires in Mexico and Central America as shown in Appendix B and discussed further below. These fire sources are not subject to control by Texas or the United States.

Natural Event

The proposed exceptional event flag for 2011 is for smoke from Mexico and Central America, which is a natural, transported pollution event of international origin (72 *Federal Register* 13564). Smoke from this area impacts the Houston area every year, mainly in April and May. Several episodes per year are typically intense and characterized by high incoming background levels that last one to three days or more. Satellite imagery provides good visual evidence of smoke moving across the Gulf of Mexico. Figure 13 is a satellite image showing smoke across the western Gulf of Mexico on May 20th blowing northwestward toward Texas and coming from numerous fires in Mexico and Central America. NASA's description of this image states:

The widespread fires shown here are evidence of the extreme fire season 2011 turned out to be in Mexico. By May 19, more than 530,000 hectares (1,300,000 acres or 2,000 square miles) of land had burned in the country since the beginning of the year, said the Mexican government. In terms of area burned, 2011 surpassed every year since (and including) 1998, making it one of the most challenging fire seasons in 30 years. (Riebeek, 2011)

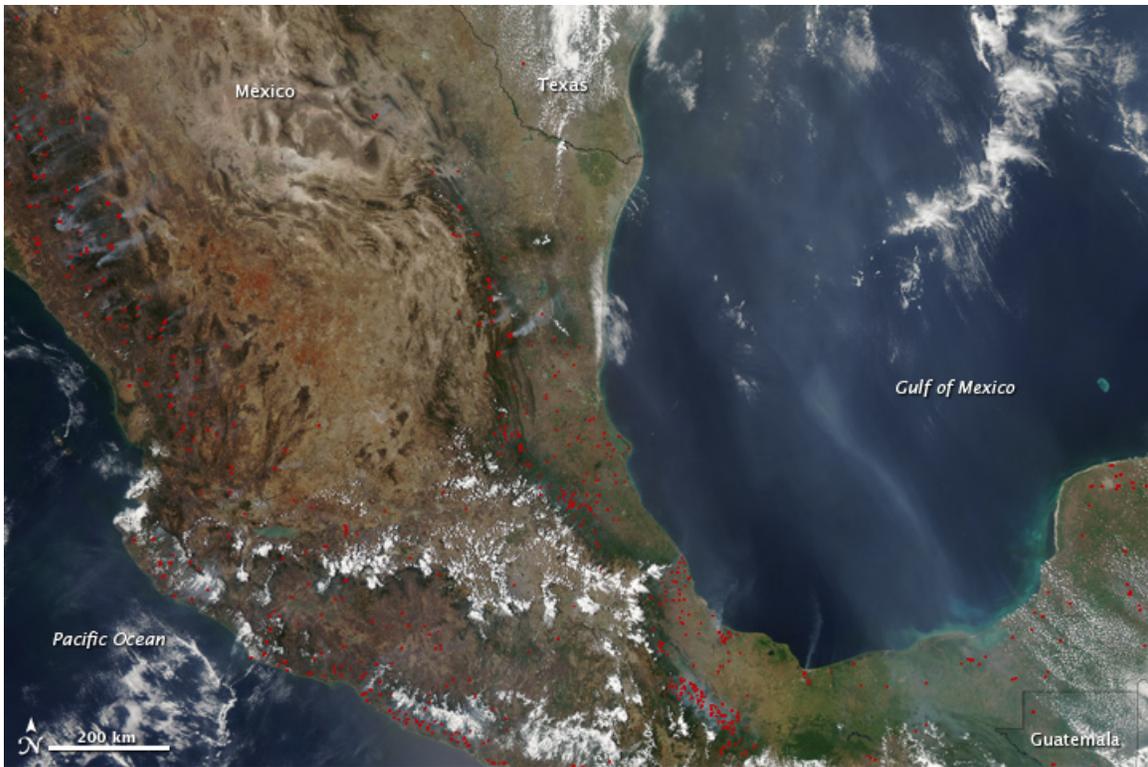


Figure 13. Natural color image of smoke blowing across the western Gulf of Mexico from Mexico and Central America on May 20th. Satellite-indicated fires are shown as red dots. (Riebeek, 2011)

Monitoring data also provide evidence that the high PM_{2.5} concentration during this event was from biomass burning. Organic carbon and potassium ion are associated with biomass burning (Ma et al., 2003) and levels of both were greatly increased during this event. Figure 14 shows that the potassium ion level for May 20, 2011, was among the highest Houston Clinton measurements for the entire period from 2006 through 2012. This measurement was also above the 99th percentile for routine measurements from 2005 through 2012. Likewise, Figure 15 shows that the Interagency Monitoring of Protected Visual Environments (IMPROVE) (IMPROVE, 2013) formula calculated organic carbon concentration on May 20th was much higher than most of the 2006 through 2012 Houston Clinton measurements. This organic carbon measurement was above the 98th percentile of routine measurements for 2005 through 2012. This speciation data indicates both the dominance of smoke on the proposed exceptional event day and that smoke levels remained high through May 25th, as shown in Figure 16 and Table 3. All of the IMPROVE calculated PM_{2.5} components are also included in Table 3 for comparison.

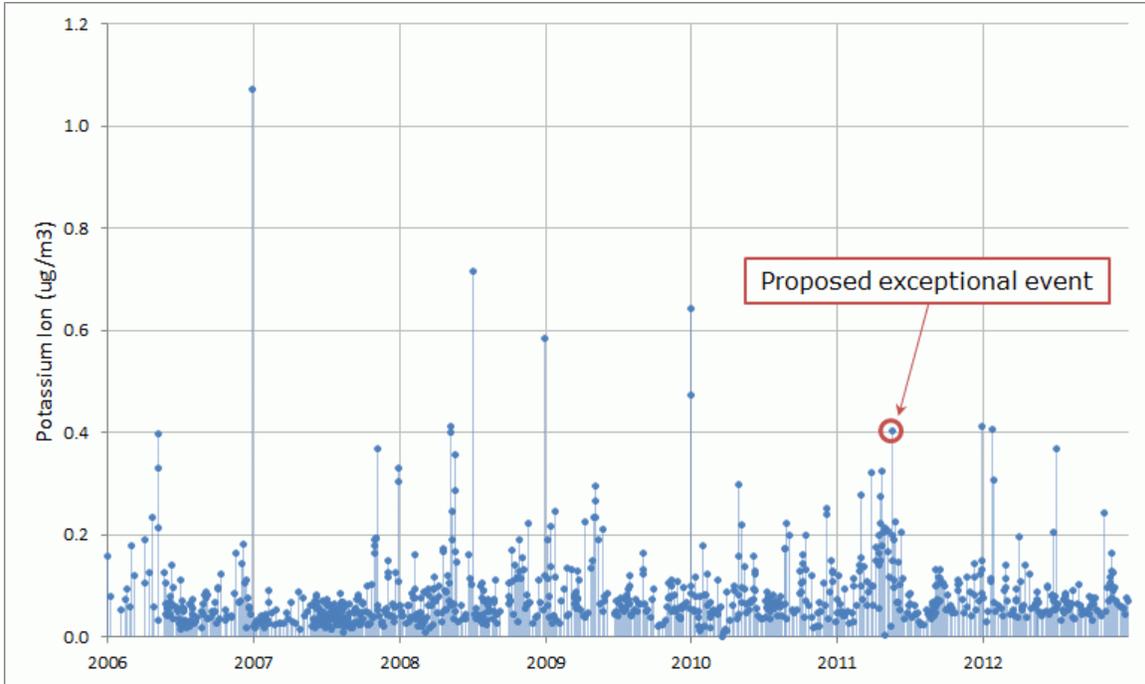


Figure 14. Houston Clinton speciated PM_{2.5} potassium ion measurements for 2006 through 2012 show the measurement from the proposed exceptional event day is among the highest in the period.

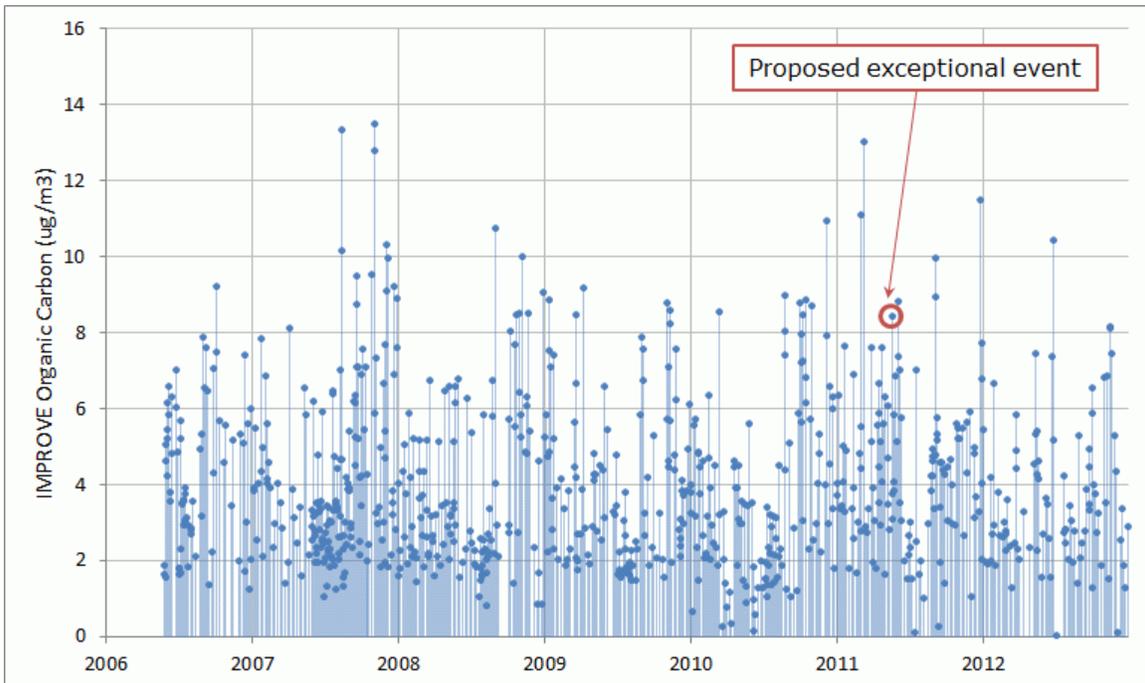


Figure 15. Houston Clinton IMPROVE calculated PM_{2.5} organic carbon concentrations for 2006 through 2012 show the measurement from the proposed exceptional event day is among the highest in the period.

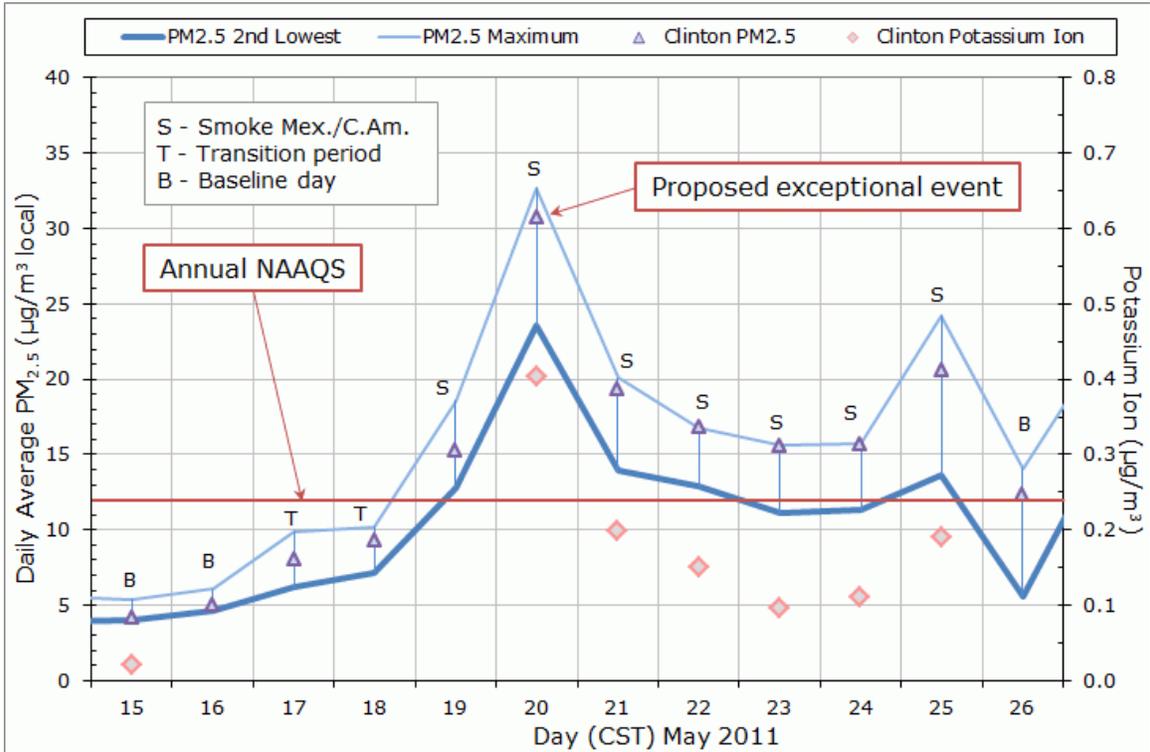


Figure 16. Houston area highest and second lowest daily average PM_{2.5} concentrations with Clinton PM_{2.5} and potassium ion concentrations for May 15 through 26, 2011.

Table 3. Houston Clinton daily PM_{2.5} and speciation measurements and calculations for May 15 through May 26, 2011.

Speciation Measurements (µg/m ³)	2010-2012*	05/15/11	05/16/11	05/17/11	05/18/11	05/19/11	05/20/11	05/21/11	05/22/11	05/23/11	05/24/11	05/25/11	05/26/11
PM _{2.5}	12.4	4.2	5.0	8.0	9.3	15.3	30.7	19.3	16.8	15.6	15.7	20.6	12.3
OC	3.2	2.8					8.4	3.8	3.1	3.8	4.1	5.8	
KI	0.07	0.02					0.40	0.20	0.15	0.10	0.11	0.19	
LAC	0.9	0.4					1.0	0.6	0.5	0.8	0.7	0.8	
AS	4.7	1.5					10.6	7.9	6.8	5.2	4.8	5.5	
AN	0.5	0.0					0.9	1.2	1.0	0.7	0.8	1.0	
Soil	1.8	0.4					1.8	0.9	0.9	1.5	1.3	1.5	

Note: *Italics* indicate that a measurement is above the level of the annual PM_{2.5} NAAQS and blank entries indicate no sample was scheduled, the monitor was not operational, or the measurement was not valid.

*Three-year average of the routine every sixth day speciation analysis days

Abbreviations:

- PM_{2.5} Clinton FRM PM_{2.5} measurement
- OC IMPROVE calculation of organic carbon component of speciation data
- KI Measured potassium ion component of speciation data
- LAC IMPROVE calculation of light-absorbing carbon component of speciation data
- AS IMPROVE calculation of ammonium sulfate component of speciation data
- AN IMPROVE calculation of ammonium nitrate component of speciation data
- Soil IMPROVE calculation of soil component of speciation data

Clear Causal Relationship

Several analyses provide evidence that the high Houston Clinton PM_{2.5} concentration on May 20th was caused by smoke from fires in Mexico and Central America. Speciated PM_{2.5} data show an unusually high level of potassium ion consistent with heavy smoke as discussed in the Transported Pollution section above. The visible satellite imagery and aerosol model output provided in Appendix B show a daily record of smoke transport from numerous fires in Mexico and Central America, across the western Gulf of Mexico, and into the Houston area in this mid- to late-May period.

Back trajectories provide additional confirmation of the path of the air. Produced using the NOAA ARL HYSPLIT model, the backward-in-time trajectories show model-predicted paths of air parcels at three elevations. The back trajectories shown in Figure 17 (and also shown in Appendix B) clearly indicate that air arriving in the Houston area

mid-day on the proposed exceptional event day originated from the southeastern Mexico and Guatemala area (NOAA ARL, 2013). These back trajectories show good agreement with satellite tracking of the smoke, which further supports this relationship.

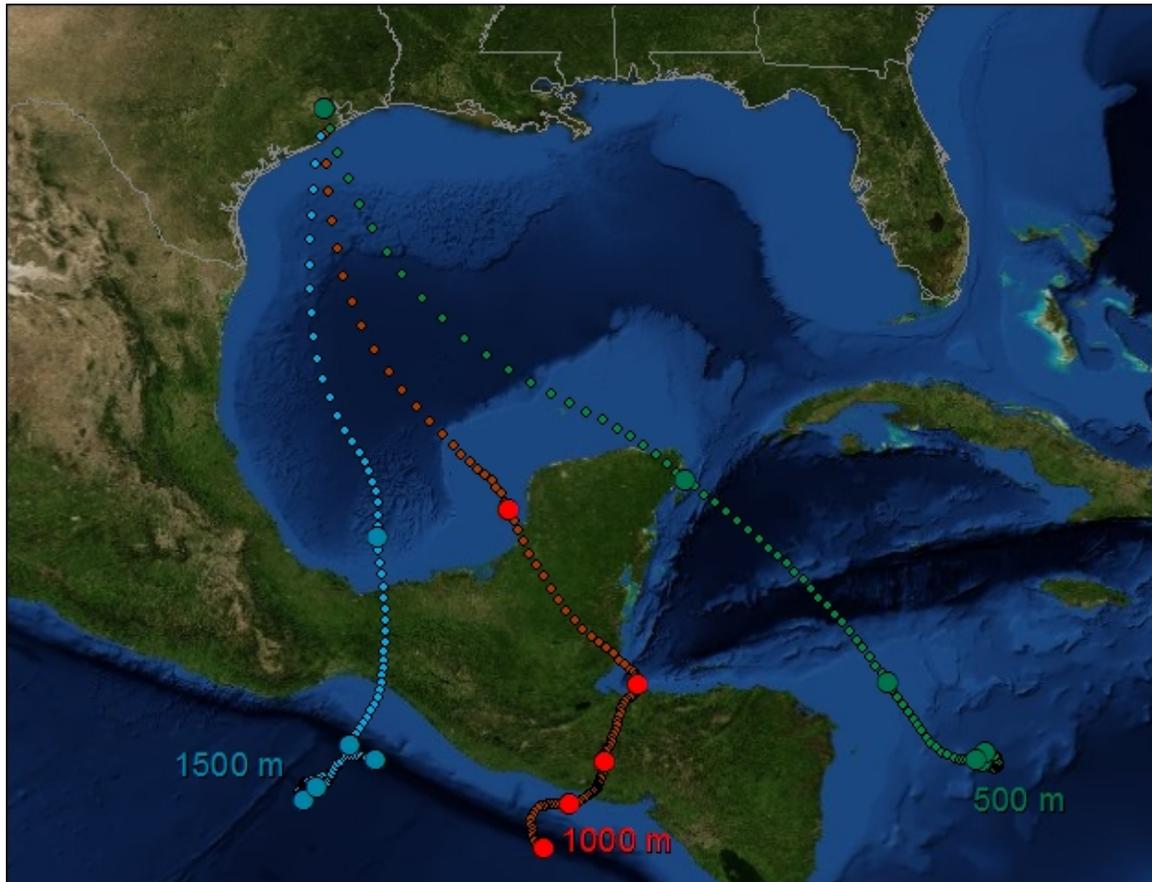


Figure 17. Plot of HYSPLIT model backward-in-time air parcel trajectory for the 2011 exceptional event day, for air arriving in Houston at noon Central Standard Time at 500 meters (green), 1,000 meters (red), and 1,500 meters (blue) above ground level. (NOAA ARL, 2013)

Figure 18 shows an example of NRL aerosol model output for May 20, 2011, showing the modeled smoke as it arrived in the Houston area. The model indicated smoke concentrations in the 16 to 32 $\mu\text{g}/\text{m}^3$ range along the Texas coast and extending into the Houston area. This model is designed to track smoke from fires indicated by satellite analyses. The model shows intense smoke reaching Texas at that time. Additional model output is provided in Appendix B.

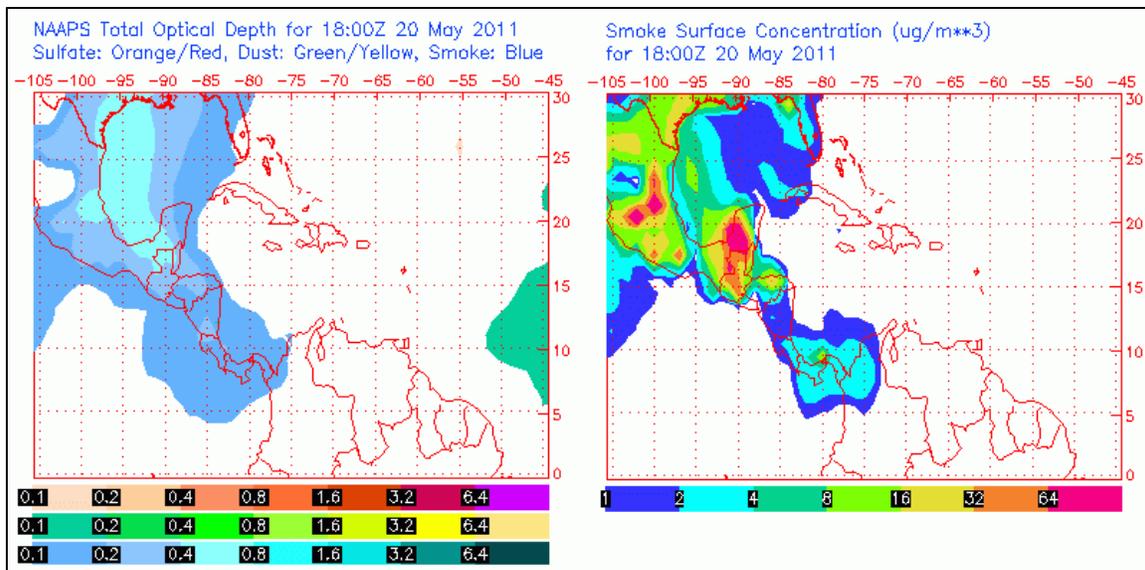


Figure 18. NRL aerosol model output showing aerosol optical depth (left panel) and smoke surface concentration (right panel), for the smoke arriving in Houston on May 20, 2011.

All together, the satellite imagery, aerosol model output, backward-in-time air trajectories, and speciated PM_{2.5} data provide clear evidence that increased PM_{2.5} concentrations at the Houston Clinton site on the proposed exceptional event day were caused by smoke from Mexico and Central America.

Event In Excess of Normal Historical Fluctuations

As mentioned in the Affects Air Quality section, the PM_{2.5} concentration during the proposed exceptional event day was well above normal historical measurements. Statistics for the Houston Clinton FRM PM_{2.5} monitor for 1,044 measurements over the three-year period from 2009 through 2011 show a 95th percentile concentration of 21.5 µg/m³. Figure 12 shows a comparison of the proposed exceptional event days to all Houston Clinton PM_{2.5} measurements for 2009 through 2011.

The proposed exceptional event day also represented the greatest incoming background level for 2011, based on the Houston area second lowest daily measurements as seen in Figure 19. The Houston Clinton PM_{2.5} concentration and estimated incoming background levels on May 20th were two to three times higher than levels in the intervening period.

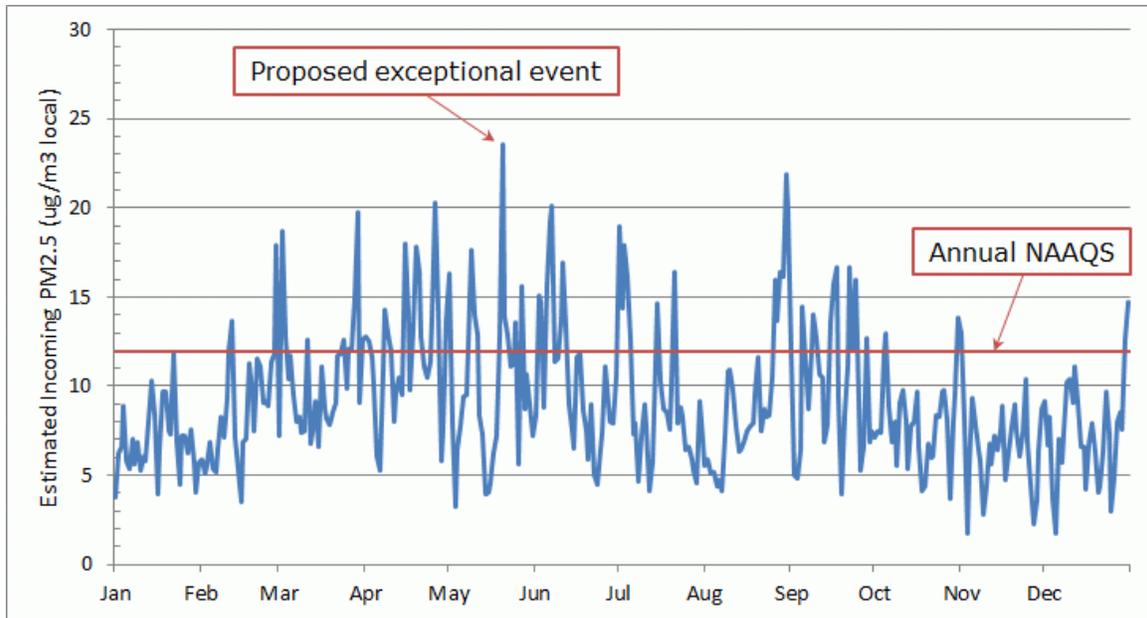


Figure 19. Houston area 2011 estimated incoming PM_{2.5} background level based on area second lowest daily measurement.

No Exceedance But For the Event

Title 40 CFR 50.14(c)(3)(iv)(D) states the demonstration to justify exceptional event designation shall provide evidence that “there would have been no exceedance or violation but for the event.” The TCEQ used both a mathematical and a modeling method for estimating the daily PM_{2.5} concentration at the Houston Clinton site but for the smoke on May 20, 2011.

The mathematical method for evaluation of the Clinton PM_{2.5} concentration but for the event first required calculation of the baseline incoming background concentration without the influence of the smoke event. As evidenced in previous sections, PM_{2.5} was elevated at all sites from May 19th through 25th in association with smoke from agricultural burning in Mexico and Central America. Table 4 shows the Houston area daily average PM_{2.5} measurements and Figure 21 illustrates the hourly PM_{2.5} measurements at the Clinton site. As shown in both Table 4 and Figure 20, there was a pre-event transition period on May 17th and May 18th as area PM_{2.5} levels slowly rose. Likewise, there was a transition period with continued incoming moderate smoke from May 21st through 25th. As shown in Figures 21 and 22, the Houston area second lowest PM_{2.5} values indicate that incoming regional background levels were more than four times higher on May 20th than days before (May 16th) and after (May 26th) the smoke event. Consequently, May 16th was used to indicate the initial

baseline incoming background level before the smoke event and May 26th was used to indicate the baseline incoming background level at the end of the event. The area second lowest daily measurements from May 16th and 26th were averaged to estimate the incoming baseline level for May 20th.

Table 4. Houston area daily average PM_{2.5} measurements (µg/m³) by site from May 16 through May 26, 2011.

	Type	05/16/11	05/17/11	05/18/11	05/19/11	05/20/11	05/21/11	05/22/11	05/23/11	05/24/11	05/25/11	05/26/11
Galveston	AC	5.6	5.8	7.6	14.7	23.7	14.9	14.5	<u>11.1</u>	12.0		14.1
Seabrook	AC	4.7	<u>6.2</u>	7.3	<u>12.8</u>	22.8	<u>13.9</u>	<u>12.9</u>	11.1	<u>11.3</u>	12.9	10.9
Clear Lake	AC										16.6	11.8
Deer Park	AS			<u>7.2</u>			16.3			11.8		
Deer Park	AC	<u>4.6</u>	6.4	7.1	12.8	<u>23.6</u>	13.4	12.3	10.6	11.0	<u>13.6</u>	11.2
Baytown	FRM						17.2					
Channelview	AC	4.5	8.1	8.4	14.1	26.9	16.1	14.9	13.0	14.1	18.2	10.2
Houston East	AC	5.3	8.9	9.7	17.0	31.4	18.5	16.0	14.3	14.0	19.2	11.8
Clinton	FRM	5.0	8.0	9.3	15.3	30.7	19.3	16.8	15.6	15.7	20.6	12.3
Clinton	AC	6.1	9.9	10.2	18.6	32.3	18.2	16.2	15.4	14.9	20.7	12.5
Park Place	AC	5.9	7.0	<u>7.2</u>	15.0	28.7	17.1	14.2	12.6	12.6	17.3	10.9
Aldine	FRM						18.2					
Aldine	AC	5.0	8.4	9.3	16.3	32.7	20.1	16.3	14.4	14.1	21.2	8.0
Kingwood	AC	4.7	7.1	7.7	14.4	29.1	16.2	15.1		14.7	22.1	<u>5.6</u>
Conroe	AC	5.2	8.5	8.2	13.5	30.6		14.7	11.7	15.5	24.2	5.2

Note: *Italics* indicate that a measurement is above the level of the annual PM_{2.5} NAAQS and blank entries indicate no sample was scheduled, the monitor was not operational, or the measurement was not valid. An underline with the concentration indicates this measurement was the area second lowest for the day.

Abbreviations:

- AC Acceptable continuous
- AS Acceptable speciated non-continuous
- FRM Federal Reference Method

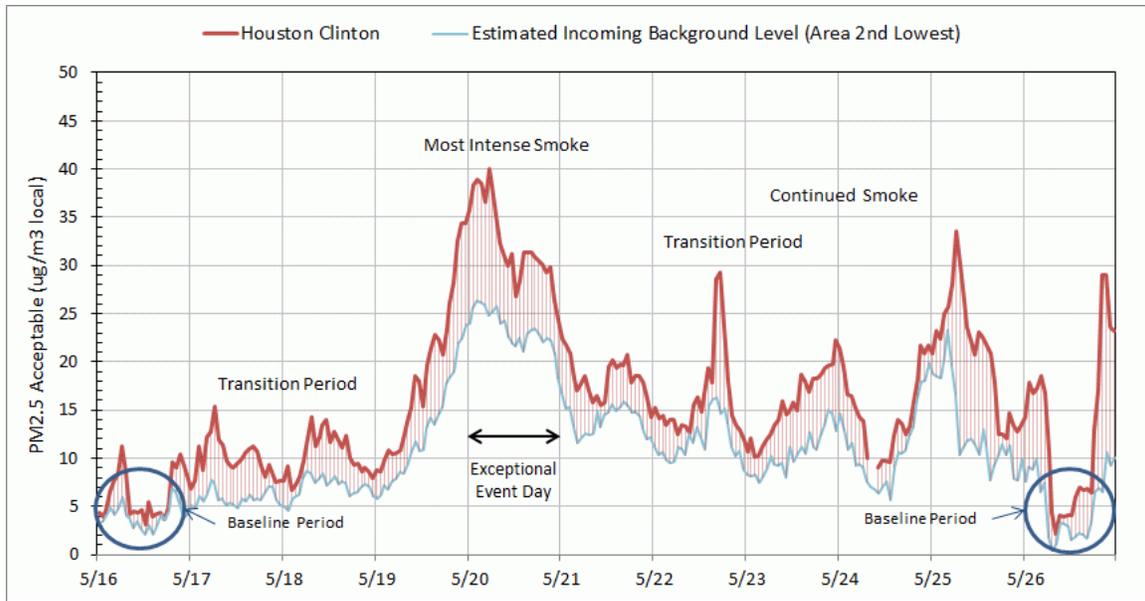


Figure 20. Houston Clinton hourly PM_{2.5} concentrations for Houston Clinton and estimated incoming background, May 16 through May 26, 2011.

Selection of these dates as being representative of the baseline background is corroborated by evaluation of organic carbon data and PM_{2.5} data from coastal sites. Figures 21 and 22 graphically show the high IMPROVE organic carbon estimate at the Clinton site corresponding with the increase in measured PM_{2.5} during the proposed smoke event. Figure 22 also shows measurements from South Texas coastal sites National Seashore and Isla Blanca for comparison, which demonstrate an extreme increase in PM_{2.5} concentrations on May 20th, followed by lower, sustained concentrations after May 21st. The incoming regional background levels were higher at these sites than in the Houston area and indicate that incoming background levels were higher on the west side of the Houston area.

The choice of the second lowest PM_{2.5} value for the baseline days is conservative for this event, since these values are higher than the lowest upwind measurement on both baseline days. On both baseline days the wind flow was generally from the north as can be seen in Figure 10. Since the baseline days represent days when the event is not present, the wind flow does not necessarily have to match the wind flow on the peak event day. Daily average measurements from all sites on these days are shown in Table 4. The lowest upwind concentration on May 16th was 4.5 µg/m³ at Channelview and the area second lowest was 4.6 µg/m³ at Deer Park. It is possible that local sources may have impacted the measurement at Deer Park on this

day, but that would increase the concentration and therefore increase the “but for” estimate by raising the baseline, so this approach is conservative. All area measurements were low on this pre-event day as can be seen in Figure 22 and Table 4. The lowest upwind measurement on May 26th was 5.2 $\mu\text{g}/\text{m}^3$ at Conroe and the area second lowest was 5.6 $\mu\text{g}/\text{m}^3$ at Kingwood. Because both the upwind site and the area second lowest sites had such similar concentrations, there is a greater degree of confidence that the selection of the background concentration is both representative and statistically appropriate. Furthermore, the use of the higher estimate of the baseline by selection of the area second lowest measurement increases the calculated “but for” concentration and is therefore more conservative than using measurements from the upwind site.

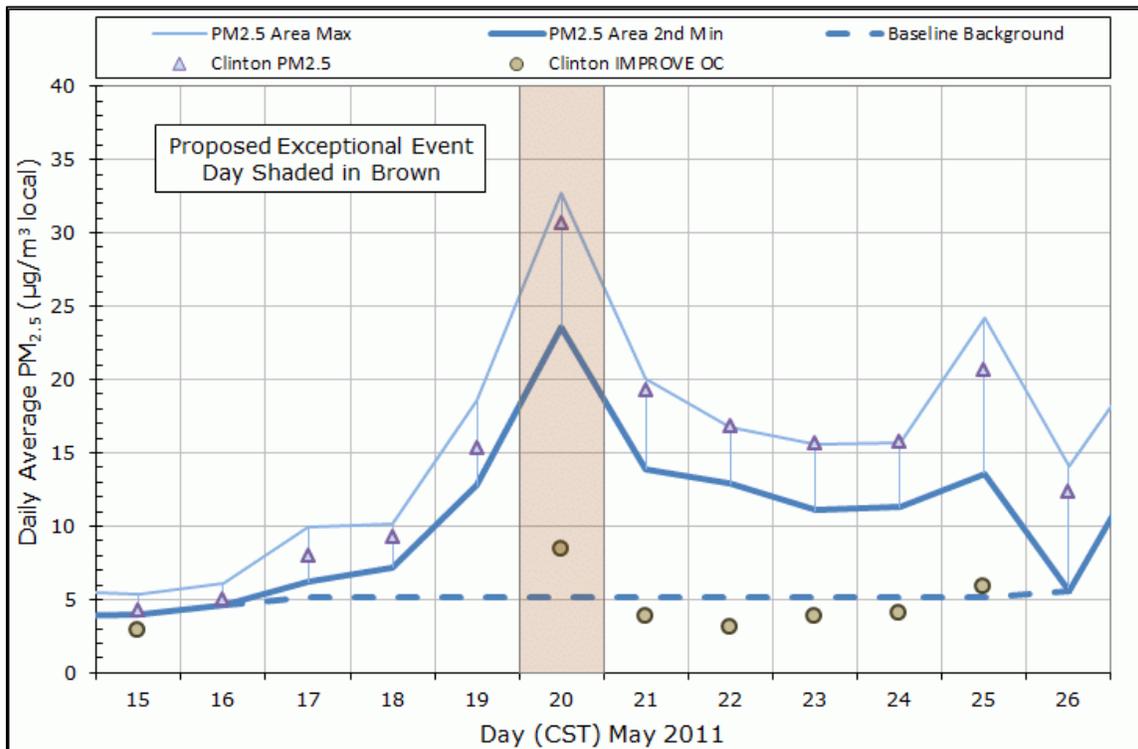


Figure 21. Houston area highest and second lowest daily average $\text{PM}_{2.5}$ with Clinton IMPROVE organic carbon, May 15 through May 26, 2011.

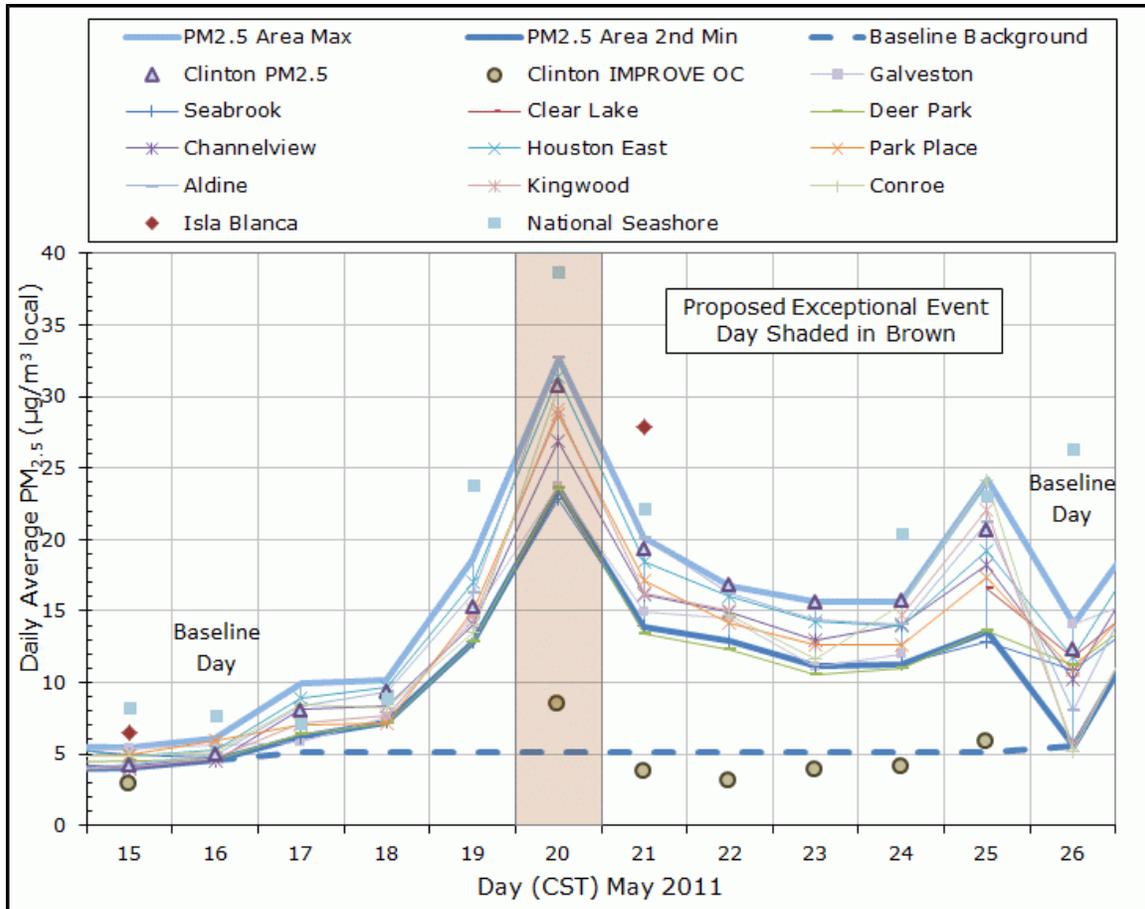


Figure 22. Houston area daily average PM_{2.5} and Clinton IMPROVE organic carbon, May 15 through May 26, 2011, along with Isla Blanca and National Seashore.

The second step in the mathematical “but for” calculation required estimating local contributions at the Clinton site. The local contribution for each day during the May 16th through 26th time period was calculated by subtracting the Houston area second lowest measurement from the Clinton PM_{2.5} measurement for that day, with the exception of May 20th. Because of a significant east-west gradient in the regional PM_{2.5} background levels on May 20th, the incoming background level affecting Clinton that day was estimated using the upwind Park Place measurement of 28.7 µg/m³, instead of the area second lowest measurement from Deer Park farther to the east. The Park Place monitor, which is upwind of Clinton on the event day, is susceptible to contributions from sources between the Park Place monitor and the coast; therefore, the measurement had to be adjusted in order to provide a conservative, yet representative surrogate value for local contribution at the Houston Clinton site. Consequently, the 2011 annual average of 9.1 µg/m³ for the Houston area daily second

lowest measurement was subtracted from the $11.1 \mu\text{g}/\text{m}^3$ annual average for Park Place, yielding $2.0 \mu\text{g}/\text{m}^3$. This $2 \mu\text{g}/\text{m}^3$ local contribution estimate was then subtracted from the Park Place value on May 20th, yielding an estimate of $26.7 \mu\text{g}/\text{m}^3$ for the incoming background level. Since wind speeds averaged over 14 miles per hour on May 20th the local contribution should not exceed this estimate because of strong dilution from the wind and therefore this approach is conservative. Thus, the Houston area source contribution to the Clinton concentration was calculated by subtracting the adjusted Park Place concentration of $26.7 \mu\text{g}/\text{m}^3$ from the Clinton concentration of $30.7 \mu\text{g}/\text{m}^3$, yielding $4.0 \mu\text{g}/\text{m}^3$. For the last step, the Clinton "but for" concentration was calculated by adding the $4.0 \mu\text{g}/\text{m}^3$ local contribution to the $5.1 \mu\text{g}/\text{m}^3$ baseline incoming background level, yielding a "but for" estimate of $9.1 \mu\text{g}/\text{m}^3$, which is well under the level of the annual $\text{PM}_{2.5}$ NAAQS.

Table 5 shows a summary of Houston daily $\text{PM}_{2.5}$ measurements for May 16th through 26th along with the Houston Clinton "but for" calculations. This analysis indicates that the daily average Clinton $\text{PM}_{2.5}$ concentration would not have exceeded the annual standard on the proposed exceptional event day of May 20th without the occurrence of this smoke event.

Table 5. Summary of Houston area daily average PM_{2.5} measurements (µg/m³) for May 16 through May 26, 2011, showing the Houston Clinton but for the smoke event calculation results.

	05/16/11	05/17/11	05/18/11	05/19/11	05/20/11	05/21/11	05/22/11	05/23/11	05/24/11	05/25/11	05/26/11
Houston area maximum	6.1	9.9	10.2	18.6	32.7	20.1	16.8	15.6	15.7	24.2	14.1
Houston area second lowest*	4.6	6.2	7.2	12.8	*26.7	13.9	12.9	11.1	11.3	13.6	5.6
Clinton FRM	5.0	8.0	9.3	15.3	30.7	19.3	16.8	15.6	15.7	20.6	12.3
PM _{2.5} difference between Clinton and area second lowest (local contribution)	0.4	1.8	2.1	2.5	4.0	5.4	3.9	4.5	4.4	7.0	6.7
Baseline incoming background	4.6	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.6
But for Event Clinton concentration	5.0	6.9	7.2	7.6	9.1	10.5	9.0	9.6	9.5	12.1	12.3

Notes:

* Except for May 20th where estimate from most representative upwind site was used.

Italics indicate that a measurement is above the level of the annual PM_{2.5} NAAQS.

Figure 23 shows the estimated Clinton “but for” concentration (triangles) and the estimated baseline incoming background level (blue line) for the period including the proposed exceptional event. The daily difference between these two estimates is the estimated local contribution to the PM_{2.5} measurement at Houston Clinton (pink vertical line). This analysis shows the Houston Clinton estimated “but for” concentration did not exceed the annual NAAQS on the proposed exceptional event day and therefore meets the “but for” requirement.

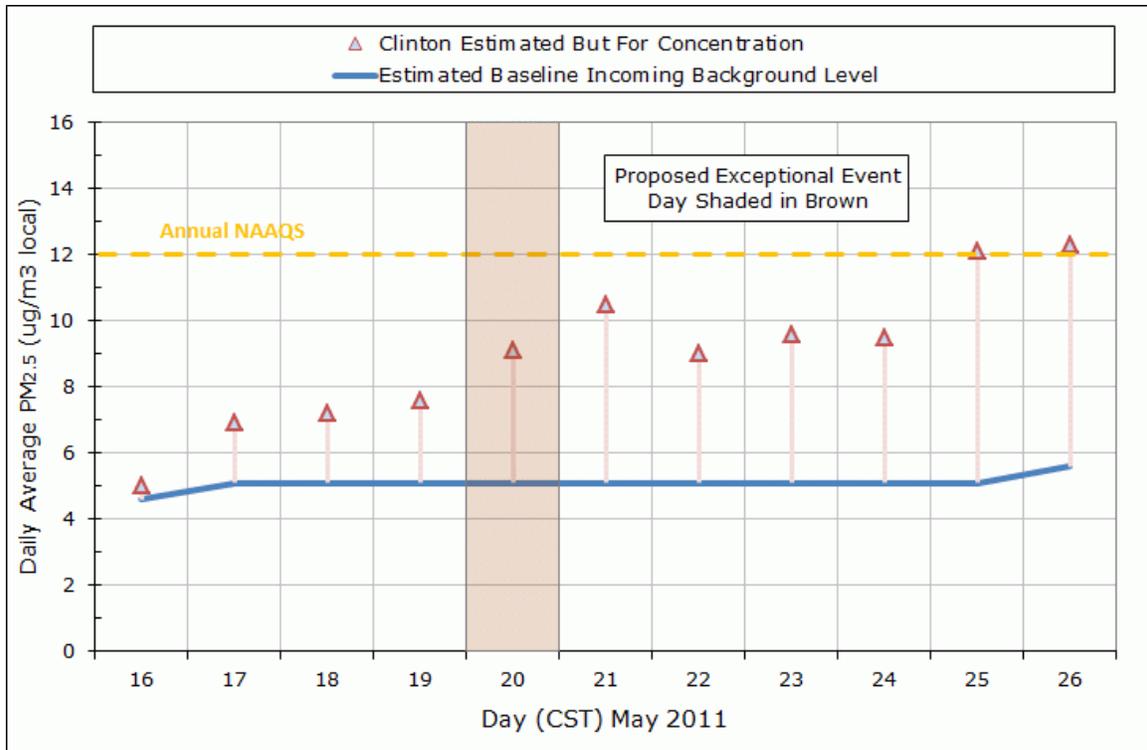


Figure 23. Houston Clinton daily estimated PM_{2.5} but for event concentrations May 16 through May 26, 2011.

The second method used to evaluate the “but for” Clinton concentration on May 20th was based on reviewing output from the real-time Community Multi-Scale Air Quality (CMAQ) modeling conducted by NOAA. NOAA has been testing a real-time version of the CMAQ model that would provide PM_{2.5} forecasts for each day and the next day with the intent of eventually displaying the model output to the public. Since 2010, TCEQ staff have participated in the evaluation of this model and routinely monitor the model PM_{2.5} forecasts. The CMAQ model relies on emissions input from annual emissions inventories and global baseline conditions at the model boundaries but does not include intermittent sources like large fires or sources from outside the United States such as smoke from agricultural burning in Mexico and Central America or African dust. However, since it includes emissions from routine local sources it is appropriate for predicting the local contribution of PM_{2.5}.

Figures 24 through 27 show the CMAQ model output of forecasted daily average PM_{2.5} concentrations for days preceding and including the proposed exceptional event day. The model output for May 20th shown in Figure 27 indicates that without smoke from Mexico and Central America (which is not included in the model) the PM_{2.5} daily

average concentration would have been less than $10 \mu\text{g}/\text{m}^3$. TCEQ staff have reviewed the daily performance of this model for over two years and have observed that it has a consistent high bias on model-predicted high days as evidenced in examples in Appendix C. Also, TCEQ staff reviewed reports of non-routine emission events from the State of Texas Environmental Electronic Reporting System and found no reports of significant particulate emissions for May 20th. Therefore, this model estimate very conservatively indicates that no exceedance of the annual NAAQS would have been measured on May 20th without the smoke event.

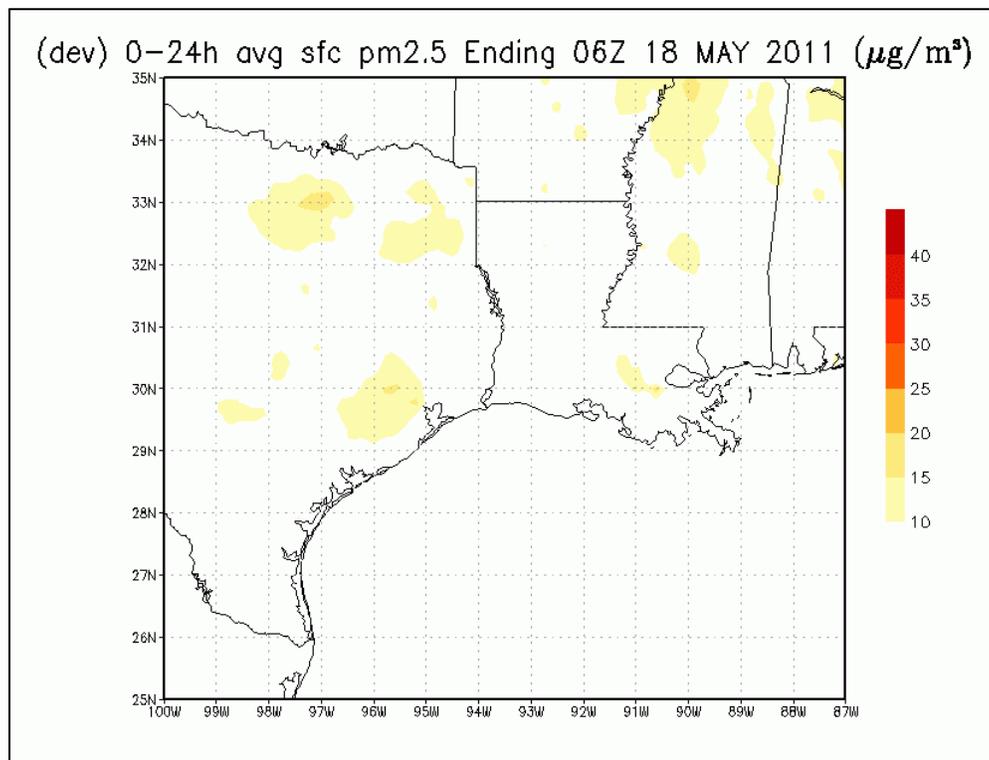


Figure 24. The CMAQ model output of daily $\text{PM}_{2.5}$ average for May 17, 2011 (24-hour period ending 0600 UTC May 18, 2011).

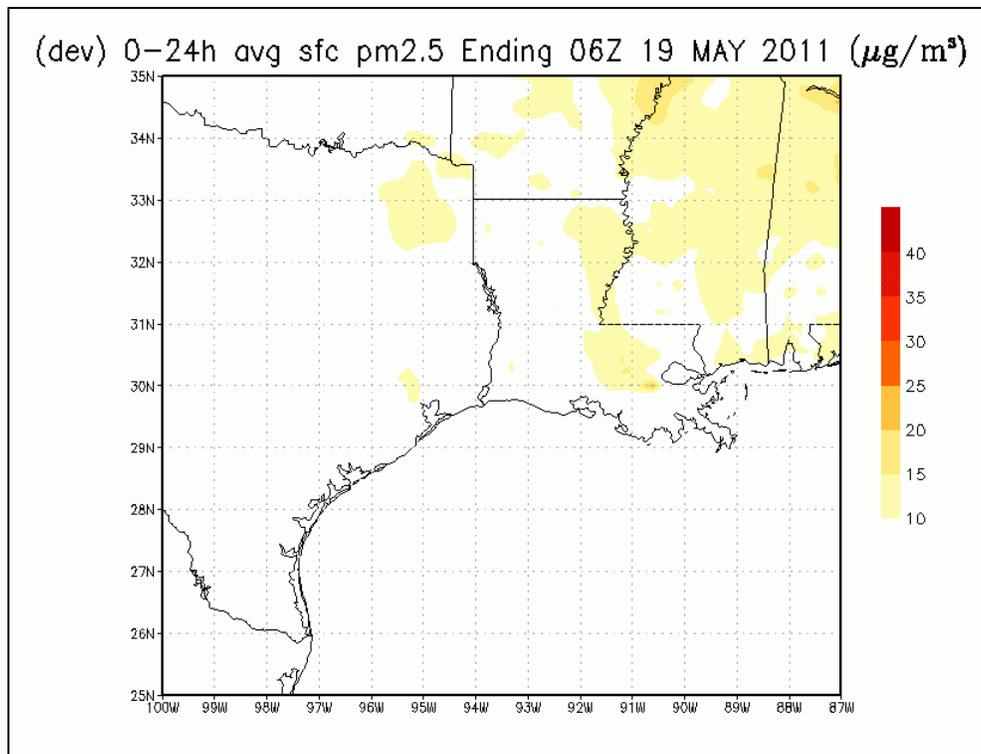


Figure 25. The CMAQ model output of daily $\text{PM}_{2.5}$ average for May 18, 2011 (24-hour period ending 0600 UTC May 19, 2011).

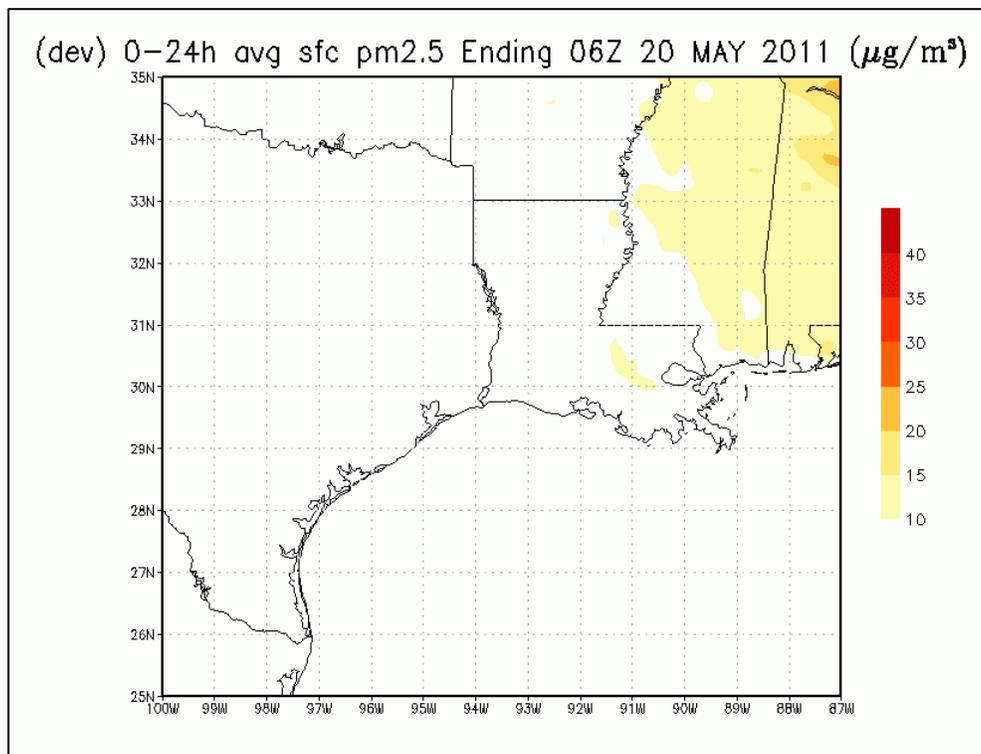


Figure 26. The CMAQ model output of daily $\text{PM}_{2.5}$ average for May 19, 2011 (24-hour period ending 0600 UTC May 20, 2011).

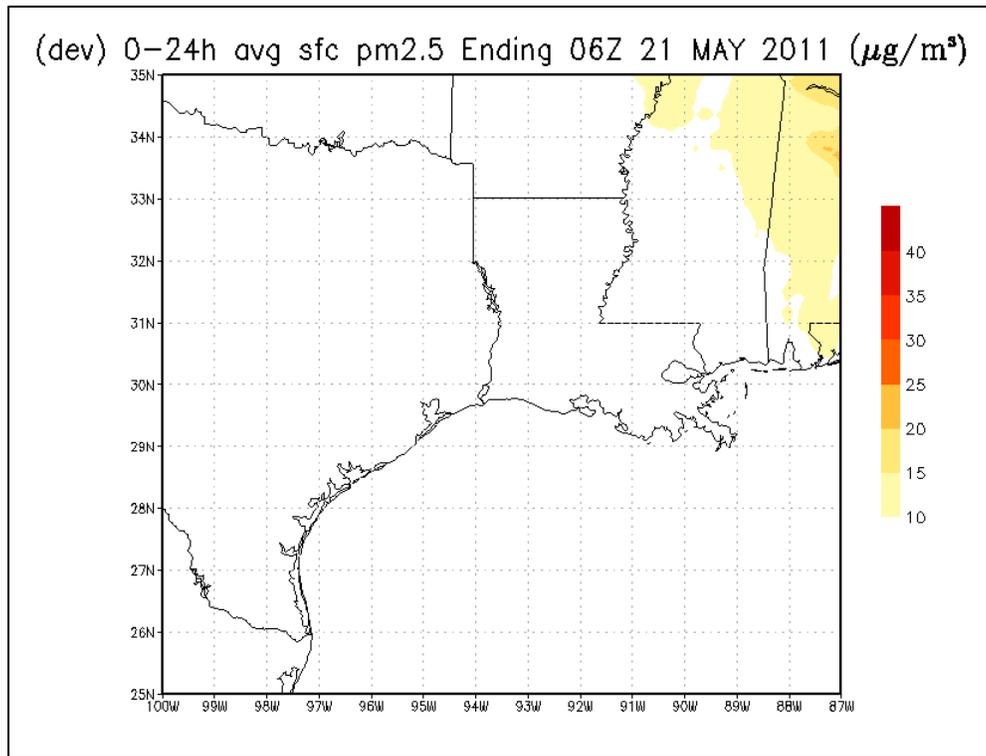


Figure 27. The CMAQ model output of daily PM_{2.5} average for May 20, 2011 (24-hour period ending 0600 UTC May 21, 2011). The model indicates the daily PM_{2.5} average concentration for all of the Houston area would have been under 10 $\mu\text{g}/\text{m}^3$ on May 20th without the influence of smoke from Mexico and Central America, which is not included in the model.

Mitigation of Exceptional Events

Title 40 CFR 51.930 requires that “a State requesting to exclude air quality data due to exceptional events must take appropriate and reasonable actions to protect public health from exceedances or violations of the national ambient air quality standards.” Three specific requirements are described in this regulation and are addressed individually below. Examples of the web page links are shown in Appendix D.

Prompt Public Notification

The first requirement is to “provide for prompt public notification whenever air quality concentrations exceed or are expected to exceed an applicable ambient air quality standard.” The TCEQ provides ozone, PM_{2.5}, and PM₁₀ AQI forecasts for the current day and the next three days for 14 areas in Texas including Houston. These forecasts are available to the public on the [Today's Texas Air Quality Forecast Web page](http://www.tceq.texas.gov/airquality/monops/forecast_today.html) of the TCEQ Web site (http://www.tceq.texas.gov/airquality/monops/forecast_today.html) and on the [EPA AIRNOW Web site](http://airnow.gov/) (<http://airnow.gov/>). The Today's Texas Air Quality web page forecast discussion for May 20, 2011, read:

Smoke from agricultural burning in Mexico and Central America is covering most of the eastern half of the state with "Moderate" fine particulate and levels could possibly reach "Unhealthy for Sensitive Groups" in parts of South and Southeast Texas today. Rain could help to locally reduce fine particulate levels in parts of Central, North Central, and Northeast Texas this afternoon and evening. Moderate to strong winds may cause light amounts of blowing dust in parts of far West Texas and the Panhandle, but probably not enough to raise PM₁₀ beyond the "Good" range. The strong winds could also exacerbate any wildfires in West Texas, causing elevated fine particulate levels near and well downwind of the fires. Elsewhere in West Texas, moderate winds and lower background levels should help to keep air quality in the "Good" range away from any wildfire smoke plumes.

The TCEQ also provides near real-time hourly PM_{2.5} measurements from monitors across the state, including Houston, that are available to the public on the [Current PM-2.5 Levels - Soot, Dust, and Smoke in Your Metro Area Web page](http://www.tceq.state.tx.us/cgi-bin/compliance/monops/texas_pm25.pl) of the TCEQ Web site (http://www.tceq.state.tx.us/cgi-bin/compliance/monops/texas_pm25.pl). Finally, the TCEQ publishes

an AQI Report on the [Air Quality Index Web page](http://www.tceq.state.tx.us/cgi-bin/compliance/monops/aqi_rpt.pl) of the TCEQ Web site (http://www.tceq.state.tx.us/cgi-bin/compliance/monops/aqi_rpt.pl) that displays the latest and historical daily AQI measurements. These measures allow the public to assess forecast, current, and past PM_{2.5} air quality levels.

Public Education

The second requirement is to “provide for public education concerning actions that individuals may take to reduce exposures to unhealthy levels of air quality during and following an exceptional event.” Links to TCEQ and EPA Web pages describing recommended actions for individuals to reduce exposure to PM_{2.5} whenever it is high (EPA2, 2013) are included on TCEQ web displays of forecast and measured AQI levels, including [TCEQ’s Air Pollution from Particulate Matter web page](http://www.tceq.texas.gov/airquality/sip/criteria-pollutants/sip-pm) (<http://www.tceq.texas.gov/airquality/sip/criteria-pollutants/sip-pm>) and [EPA’s AQI - A Guide to Air Quality and Your Health web page](http://www.airnow.gov/index.cfm?action=aqibasics.aqi) (<http://www.airnow.gov/index.cfm?action=aqibasics.aqi>). The EPA also provides similar links on the AIRNOW Web pages where TCEQ forecasts and current data are displayed.

The TCEQ also pursues outreach and educational opportunities in the Houston area through work with the Regional Air Quality Planning Committee (RAQPC) of the Houston-Galveston Area Council and through public informational meetings, including a recent meeting July 22, 2013, concerning the proposed PM_{2.5} NAAQS designation for the Houston area. The RAQPC holds monthly meetings that are open to the public and these meetings are attended by TCEQ staff.

Implement Measures to Protect Public Health

The third requirement is to “provide for the implementation of appropriate measures to protect public health from exceedances or violations of ambient air quality standards caused by exceptional events.” Since 2005, the TCEQ has pursued voluntary reduction efforts in the Houston Clinton vicinity that have greatly reduced local source impacts on PM_{2.5} at the Houston Clinton site as discussed in more detail in the Local Source Contributions section above. As a result, the local PM_{2.5} contributions at Houston Clinton have declined by as much as 50 percent from 2006 to 2011. The TCEQ will continue to seek efficient, timely, and effective voluntary control measures in the future as necessary.

Conclusion

The information provided in this document demonstrates that the proposed exceptional event flag for PM_{2.5} data at the Houston Clinton site on May 20, 2011, meets all of the requirements for exceptional events. The measured PM_{2.5} concentration on this day was well above the 95th percentile of measurements for 2009 through 2011 and thus affected air quality in excess of normal historical fluctuations. The level of PM_{2.5} transported into the Houston area on this day was heavily impacted by smoke from Mexico and Central America, which is a natural event and was not reasonably preventable. As indicated by satellite imagery, back trajectories, aerosol modeling, and measurement statistics, smoke transported from Mexico and Central America clearly caused an exceedance of the annual PM_{2.5} NAAQS on May 20, 2011, at the Houston Clinton site. Estimates of local contribution and incoming baseline background level, as well as the CMAQ PM_{2.5} model concentrations without the smoke from Mexico and Central America, indicate that PM_{2.5} on the proposed exceptional event day would not have exceeded the level of the annual NAAQS without the smoke event. The TCEQ therefore requests EPA's concurrence on this flag and to have the Houston Clinton PM_{2.5} measurement for this day removed from consideration when making attainment or nonattainment determinations for the annual PM_{2.5} NAAQS.

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Appendix A: Proposed 2011 Houston PM_{2.5} Exceptional Event Flag

Table A-1. Proposed 2011 Houston PM_{2.5} Exceptional Event Flag

Date	Site ID	Site Name	POC	PM _{2.5}	Flag	Flag Description
05/20/11	482011035	Clinton C403	1	30.7	RG	Forest fire Mexico/Central America

Abbreviations:

Site ID stands for EPA site identification number

POC stands for EPA Parameter Occurrence Code

PM_{2.5} stands for daily average concentration in micrograms per cubic meter local conditions

Appendix B: Source Analyses

Back Trajectories

Figures B-1 through B-6 show HYSPLIT back trajectories. Each trajectory plot shows the approximate path of air arriving in the Houston area at 1200 central standard time (CST) (or 1800 universal time coordinates [UTC]) at 500 meters, 1,000 meters, and 1,500 meters above ground level on the date indicated and going backward in time 120 hours. These trajectories indicate that most air arriving at Houston on May 20, 2011, above about 500 meters above ground level came from southeastern Mexico and Central America.

NOAA HYSPLIT MODEL
 Backward trajectories ending at 1800 UTC 20 May 11
 GDAS Meteorological Data

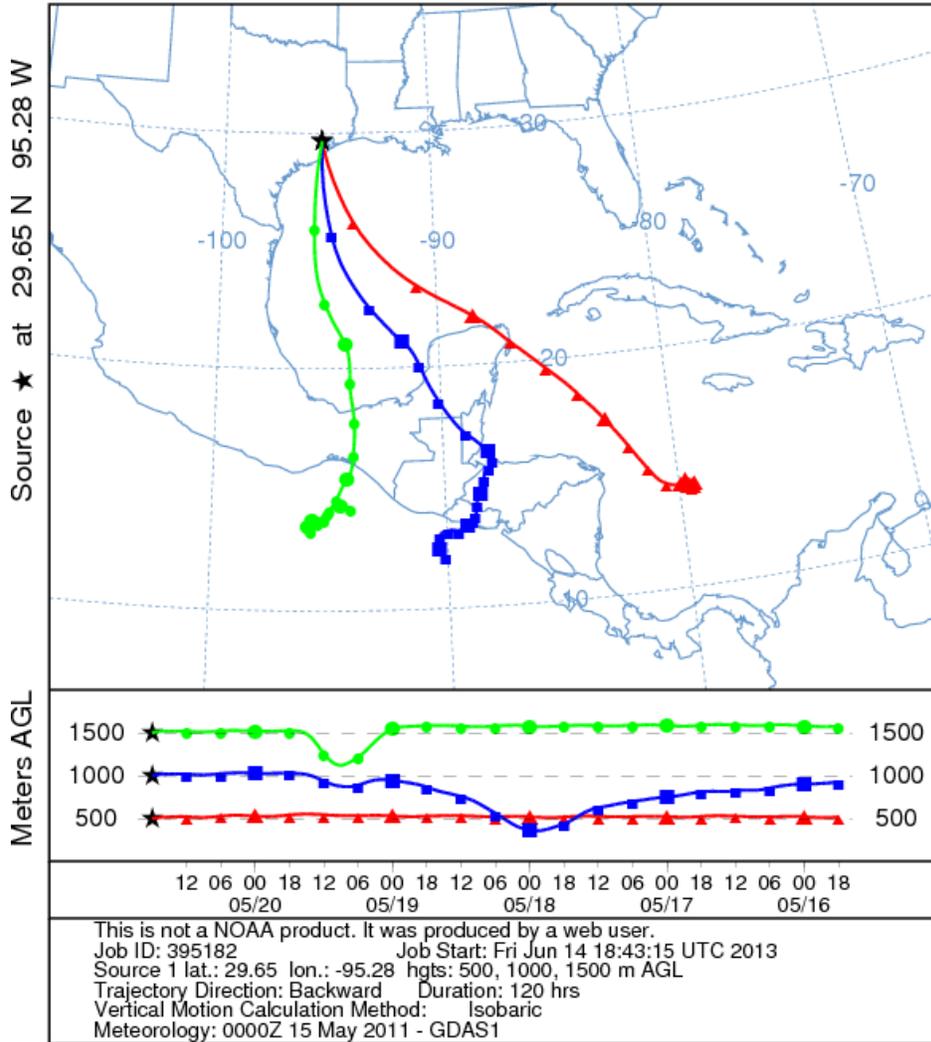


Figure B-1. Backward-in-time air trajectory for May 20, 2011.

NOAA HYSPLIT MODEL
 Backward trajectories ending at 1800 UTC 21 May 11
 GDAS Meteorological Data

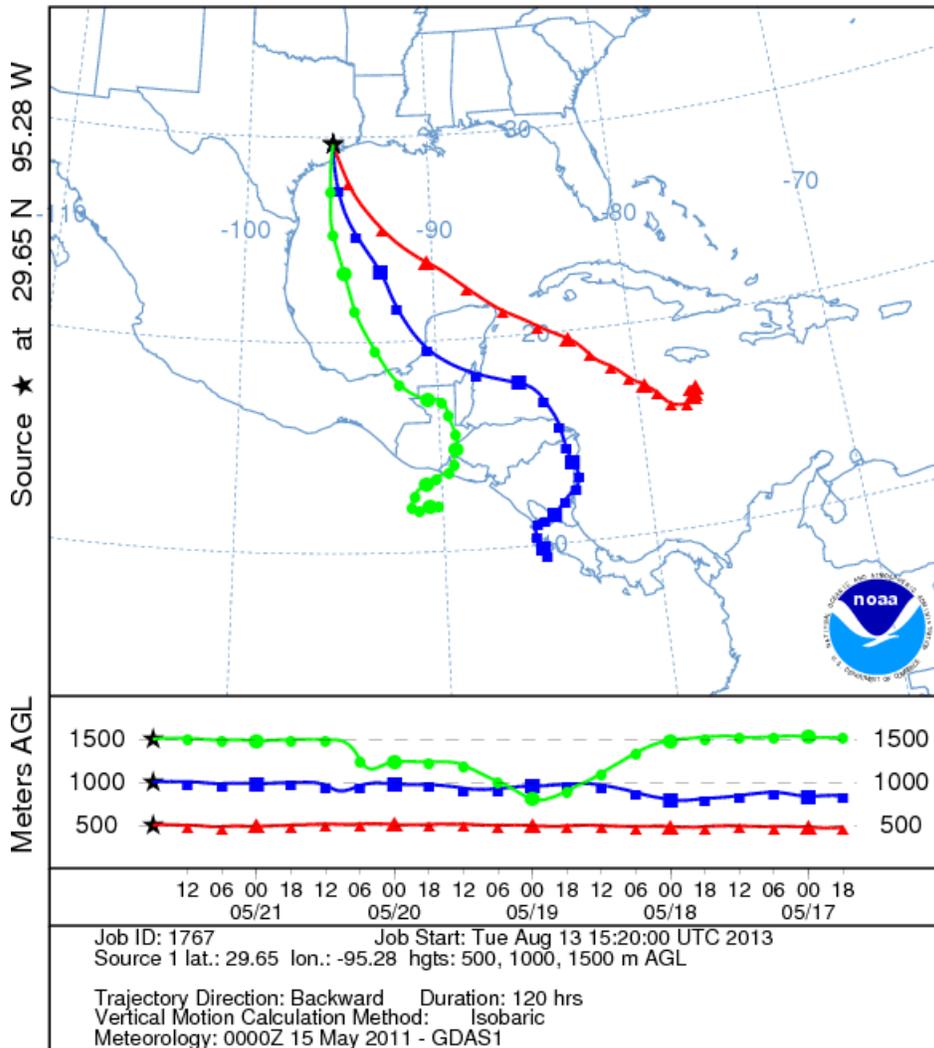


Figure B-2. Backward-in-time air trajectory for May 21, 2011.

NOAA HYSPLIT MODEL
 Backward trajectories ending at 1800 UTC 25 May 11
 GDAS Meteorological Data

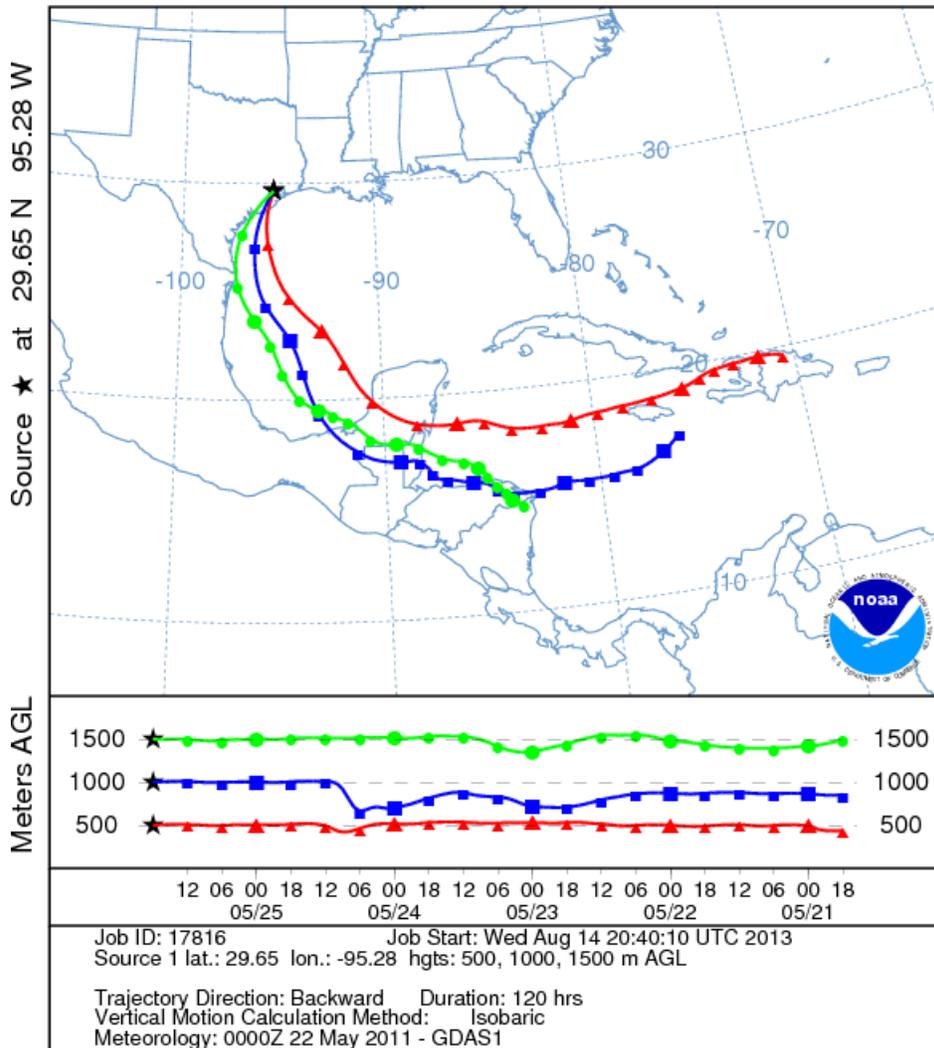


Figure B-6. Backward-in-time air trajectory for May 25, 2011.

Satellite Imagery

Figures B-7 through B-12 provide geostationary satellite images showing large and intense patches of smoke moving northwestward across the western Gulf of Mexico. The image times are listed in UTC which is six hours ahead of Central Standard Time. On these images, most clouds are bright white with sharp edges and ocean water is normally very dark away from clouds. Smoke in the air makes the ocean look much brighter when present, giving it a milky appearance with soft indistinct edges to the smoke area. The more intense smoke has a brownish tint on these false-color images. The satellite imagery corroborates well with the back trajectories shown previously.

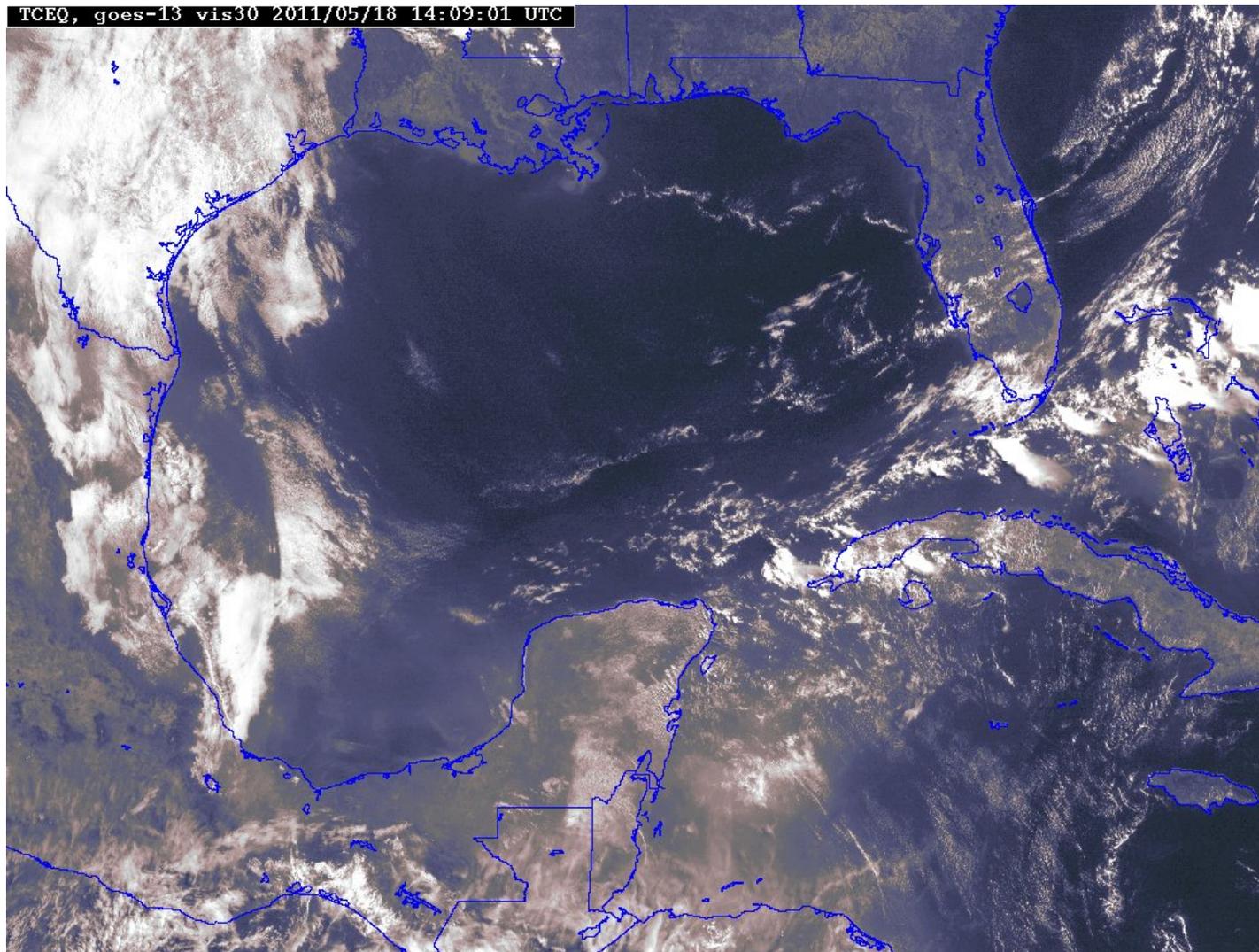


Figure B-7. Visible satellite image for 1409 UTC on May 18, 2011.

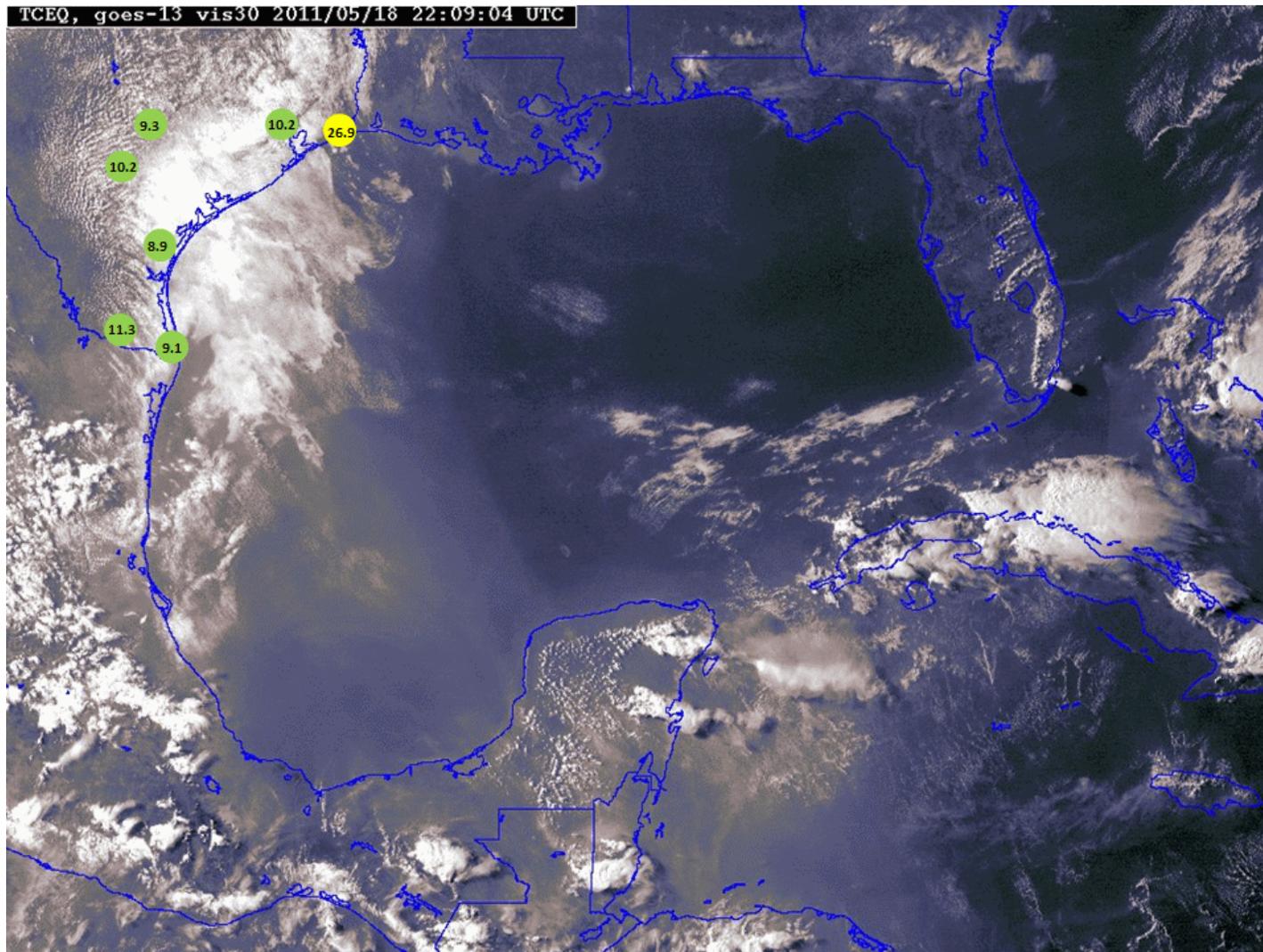


Figure B-8. Visible satellite image for 2209 UTC on May 18, 2011, including the highest area daily average PM_{2.5} concentration (µg/m³) for each area, which are indicated by a circle colored according to the EPA Air Quality Index.

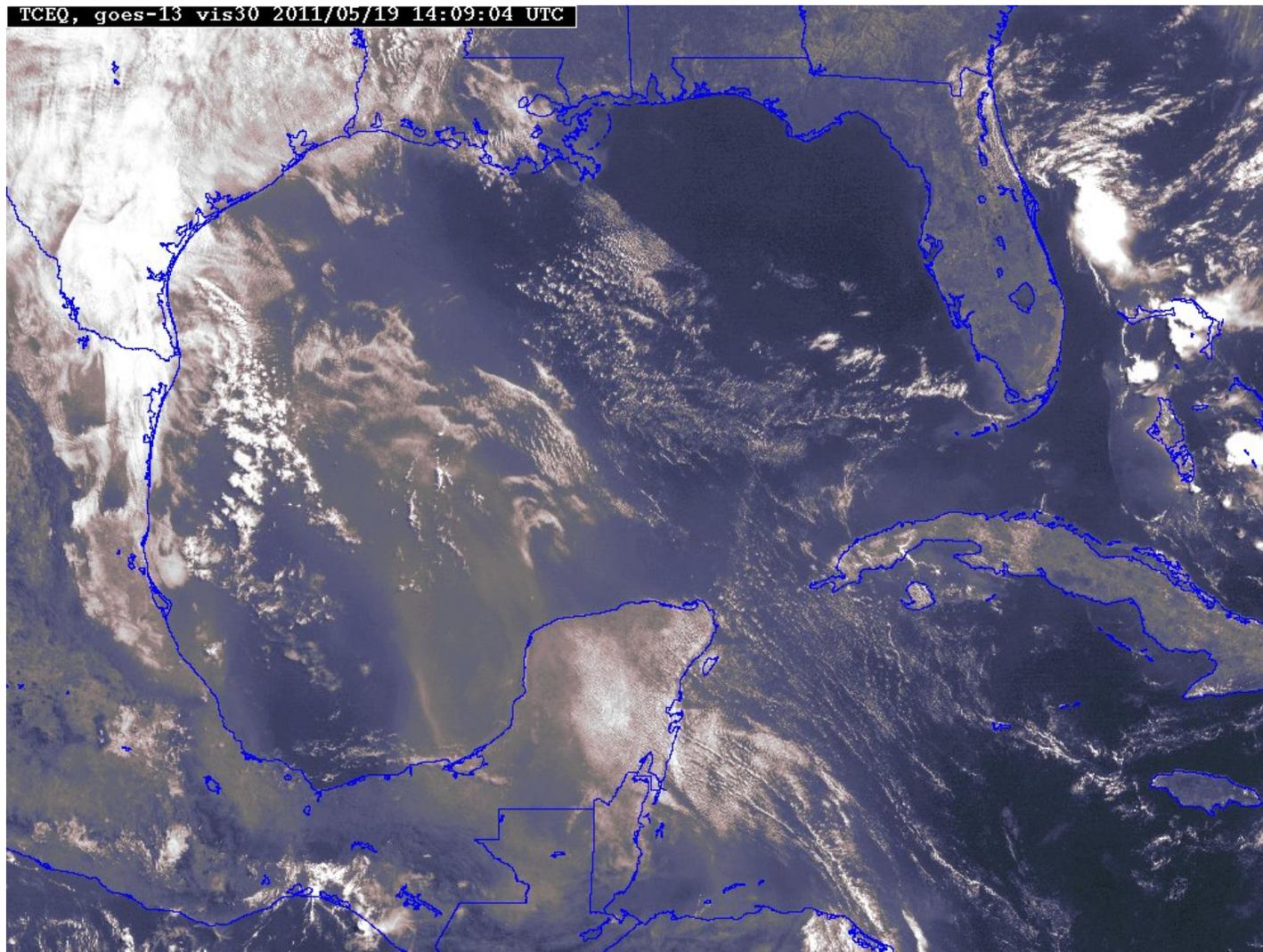


Figure B-9. Visible satellite image for 1409 UTC on May 19, 2011.

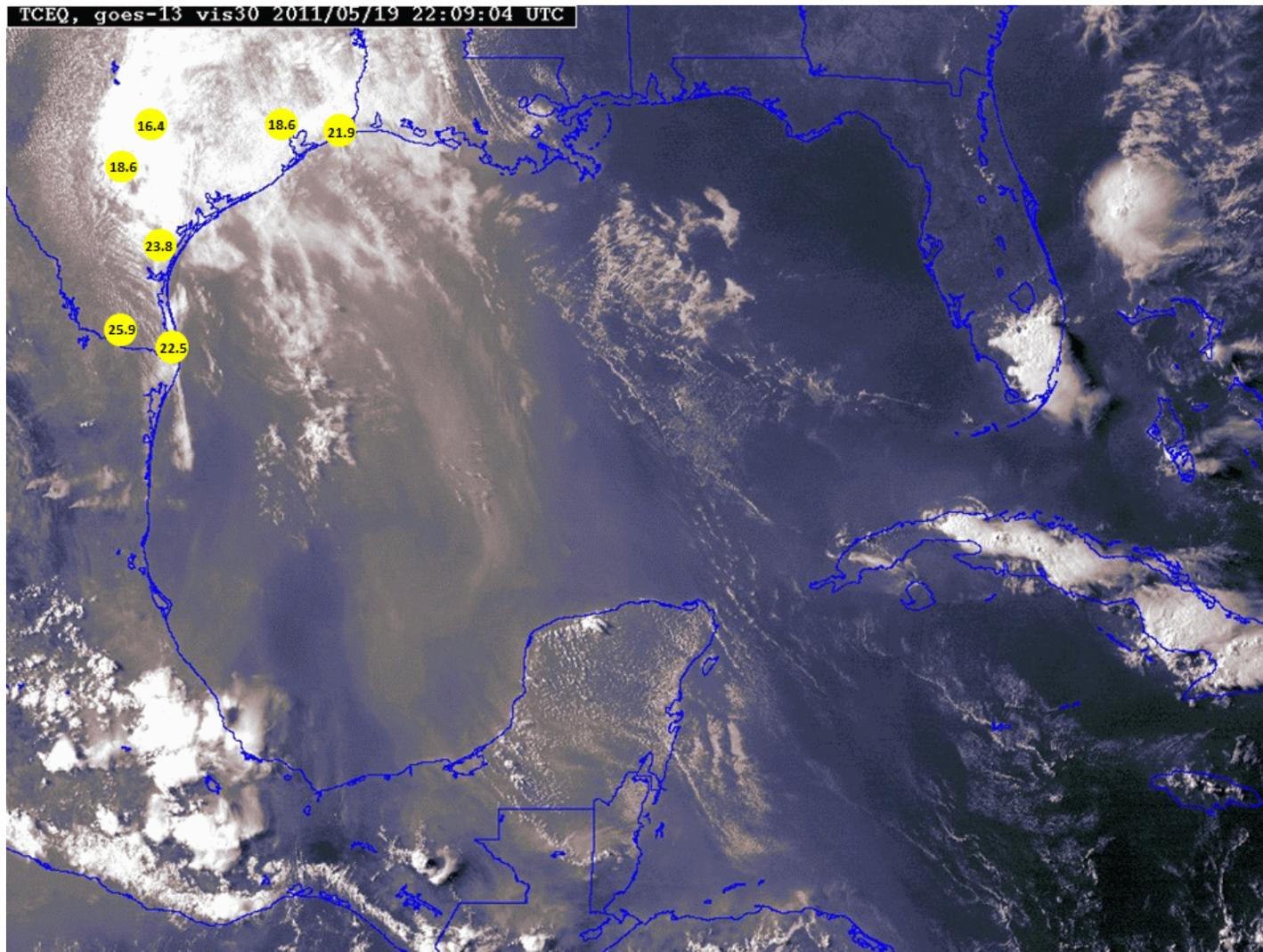


Figure B-10. Visible satellite image for 2209 UTC on May 19, 2011, including the highest area daily average PM_{2.5} concentration ($\mu\text{g}/\text{m}^3$) for each area, which are indicated by a circle colored according to the EPA Air Quality Index.

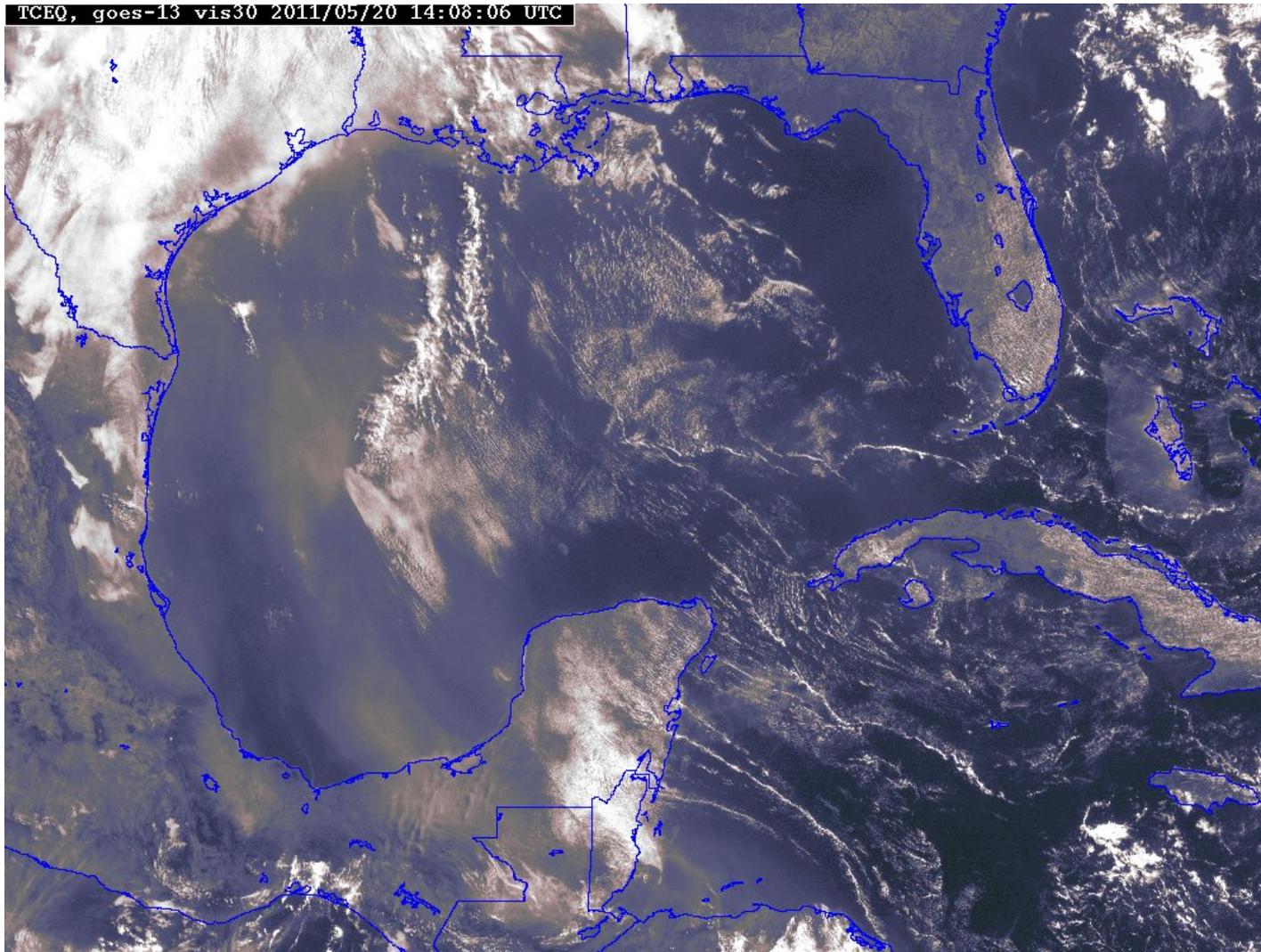


Figure B-11. Visible satellite image for 1408 UTC on May 20, 2011.

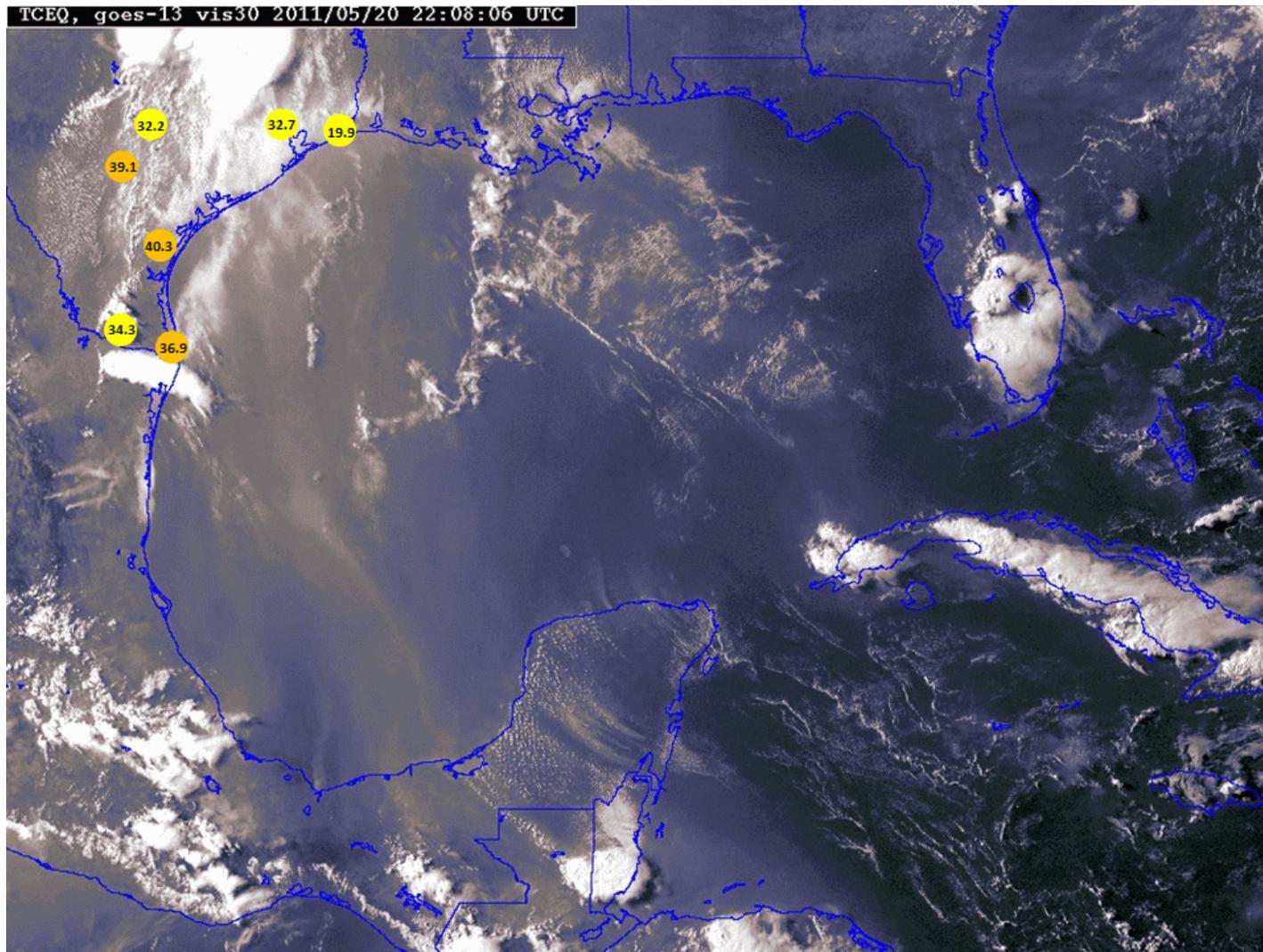
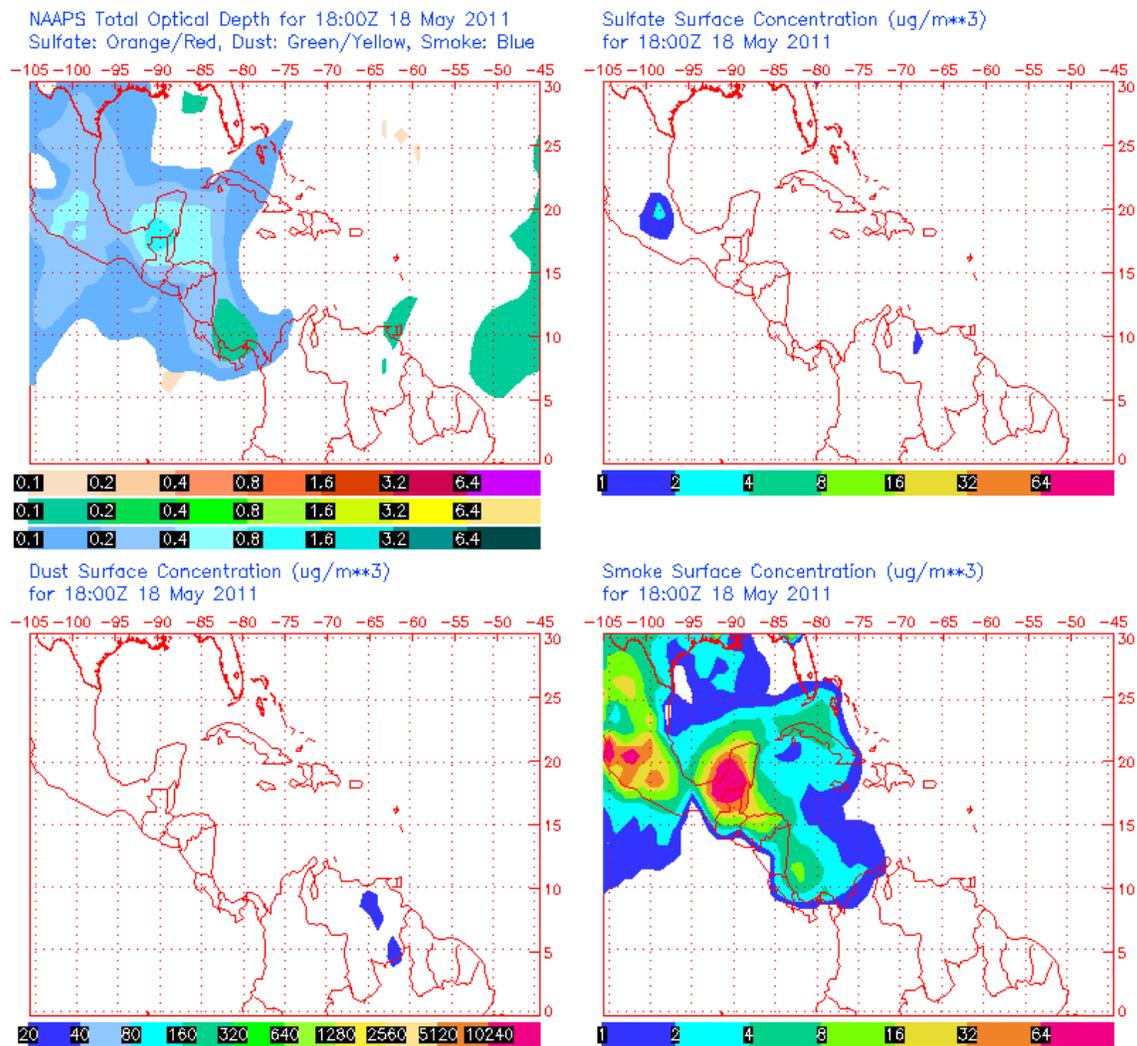


Figure B-12. Visible satellite image for 2208 UTC on May 20, 2011, including the highest area daily average PM_{2.5} concentration (μg/m³) for each area, which are indicated by a circle colored according to the EPA Air Quality Index.

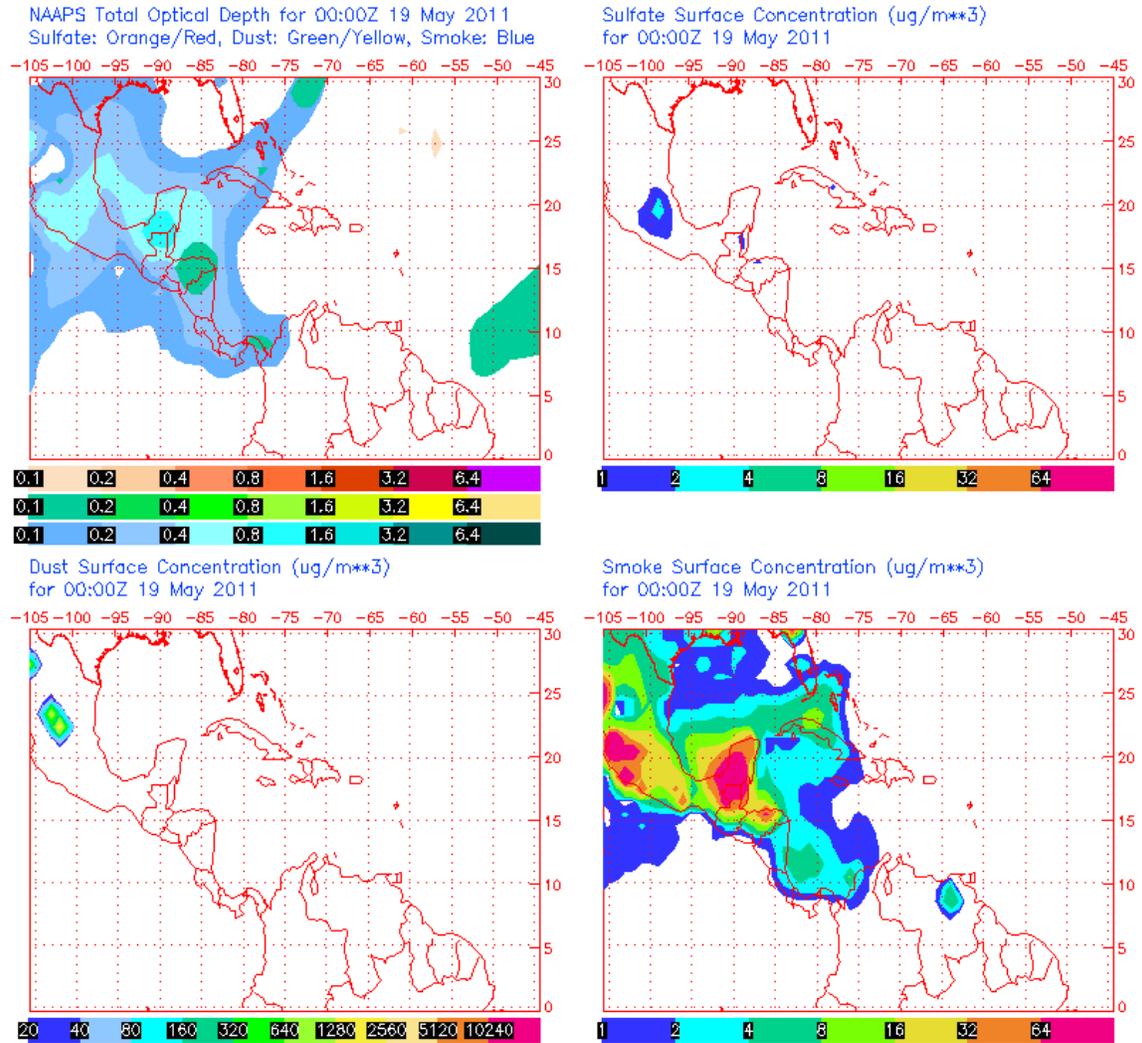
Aerosol Analyses

Figures B-13 through B-23 provide aerosol analyses from the Naval Research Laboratory (NRL) showing the smoke that arrived in the Houston area on May 20th as it progressed across the western Gulf of Mexico. The model derived optical depth from smoke is shown in shades of blue in the upper left panel of each figure and the model derived surface smoke concentration is shown in the lower right panel. Since this is a model, it cannot be expected to provide precise indications of smoke but should show the general pattern. These aerosol analyses corroborate well with the satellite imagery and back trajectories shown previously.



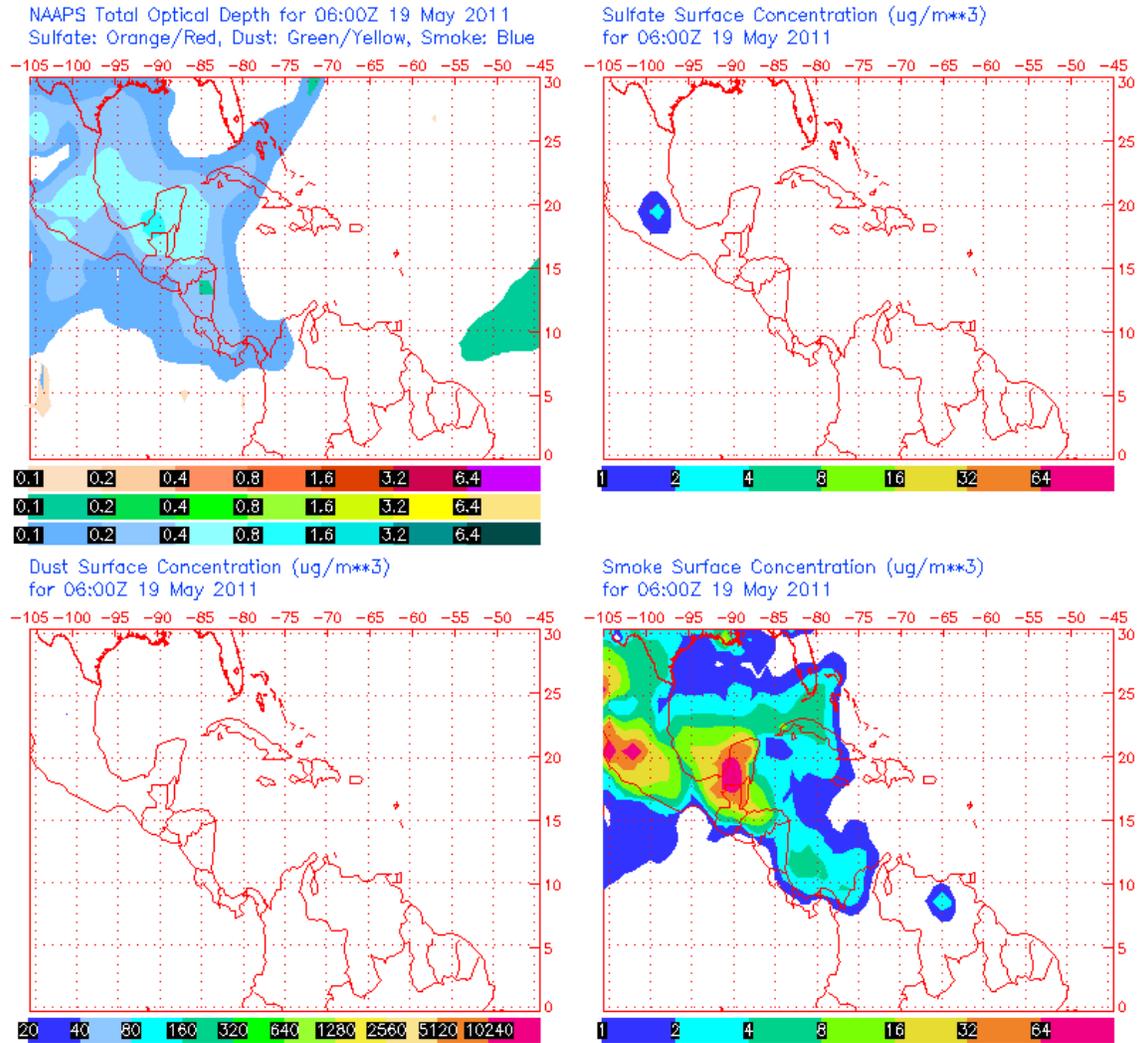
Thu May 19 03:55:20 2011 UTC NRL/Monterey Aerosol Modeling

Figure B-13. NRL aerosol analysis for 1800 UTC on May 18, 2011, showing heavy smoke from fires in southeastern Mexico and Central America.



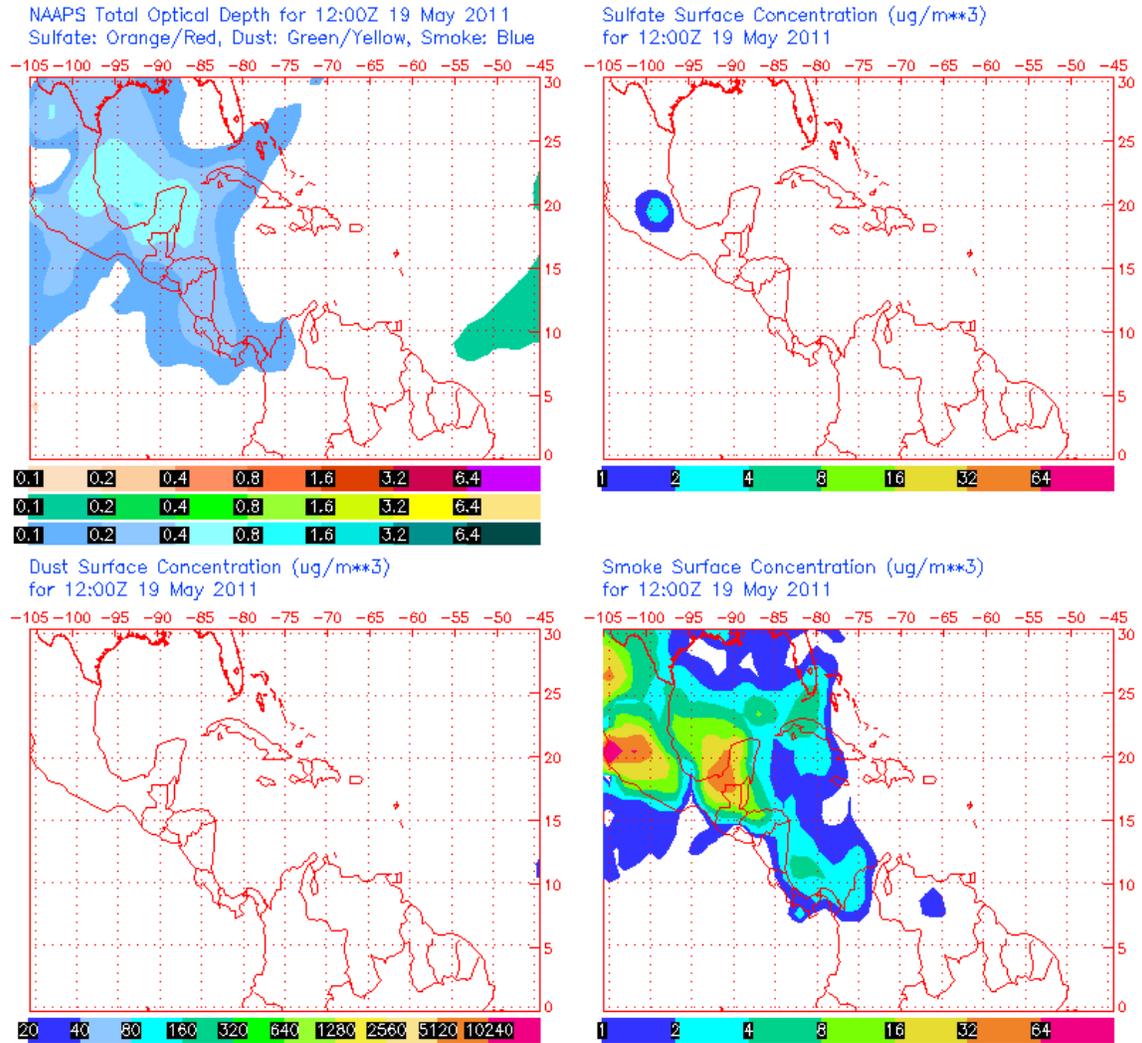
Thu May 19 09:55:21 2011 UTC NRL/Monterey Aerosol Modeling

Figure B-14. NRL aerosol analysis for 0000 UTC on May 19, 2011, showing heavy smoke from fires in southeastern Mexico and Central America.



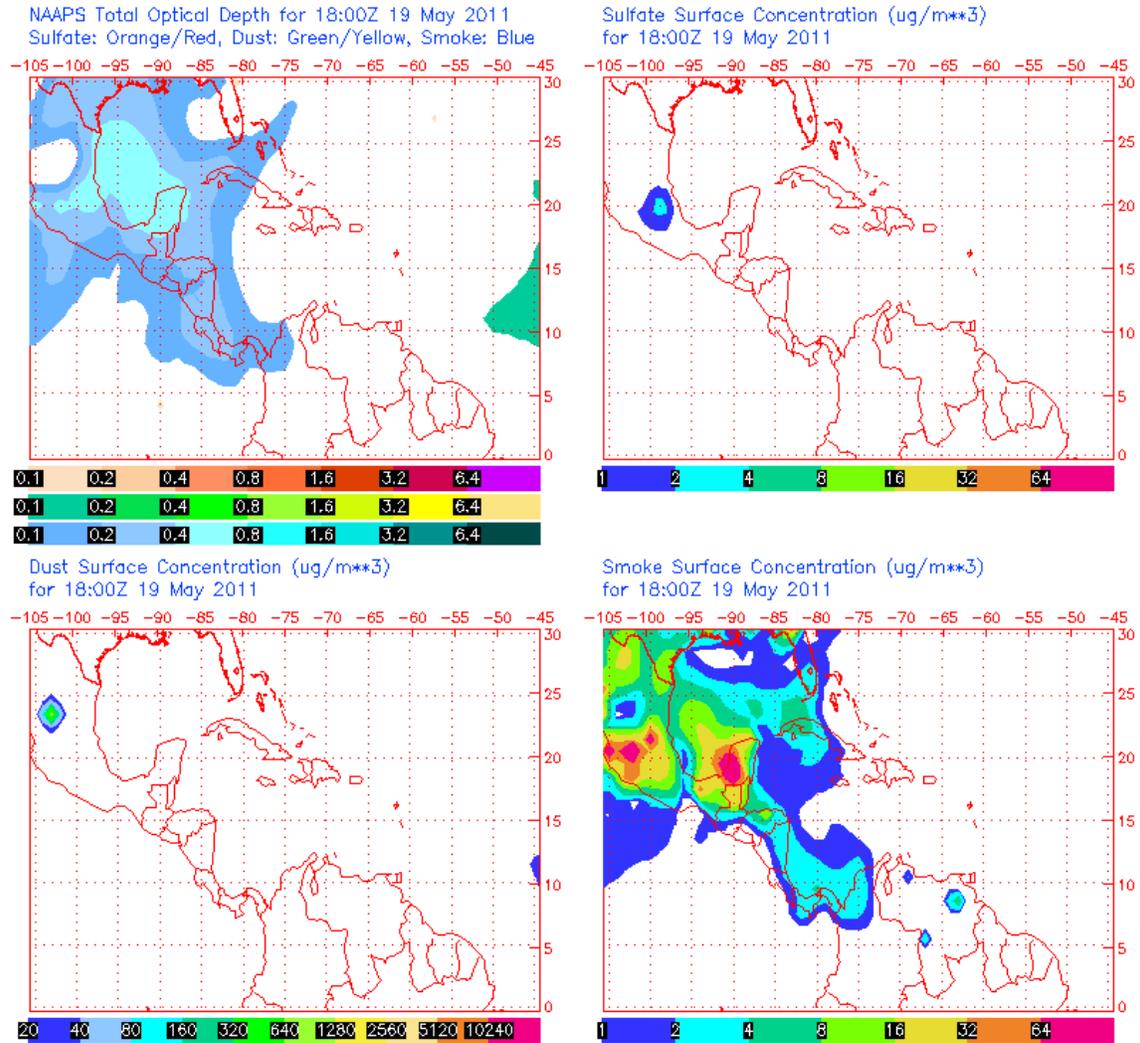
Thu May 19 15:55:20 2011 UTC NRL/Monterey Aerosol Modeling

Figure B-15. NRL aerosol analysis for 0600 UTC on May 19, 2011, showing heavy smoke from fires in southeastern Mexico and Central America.



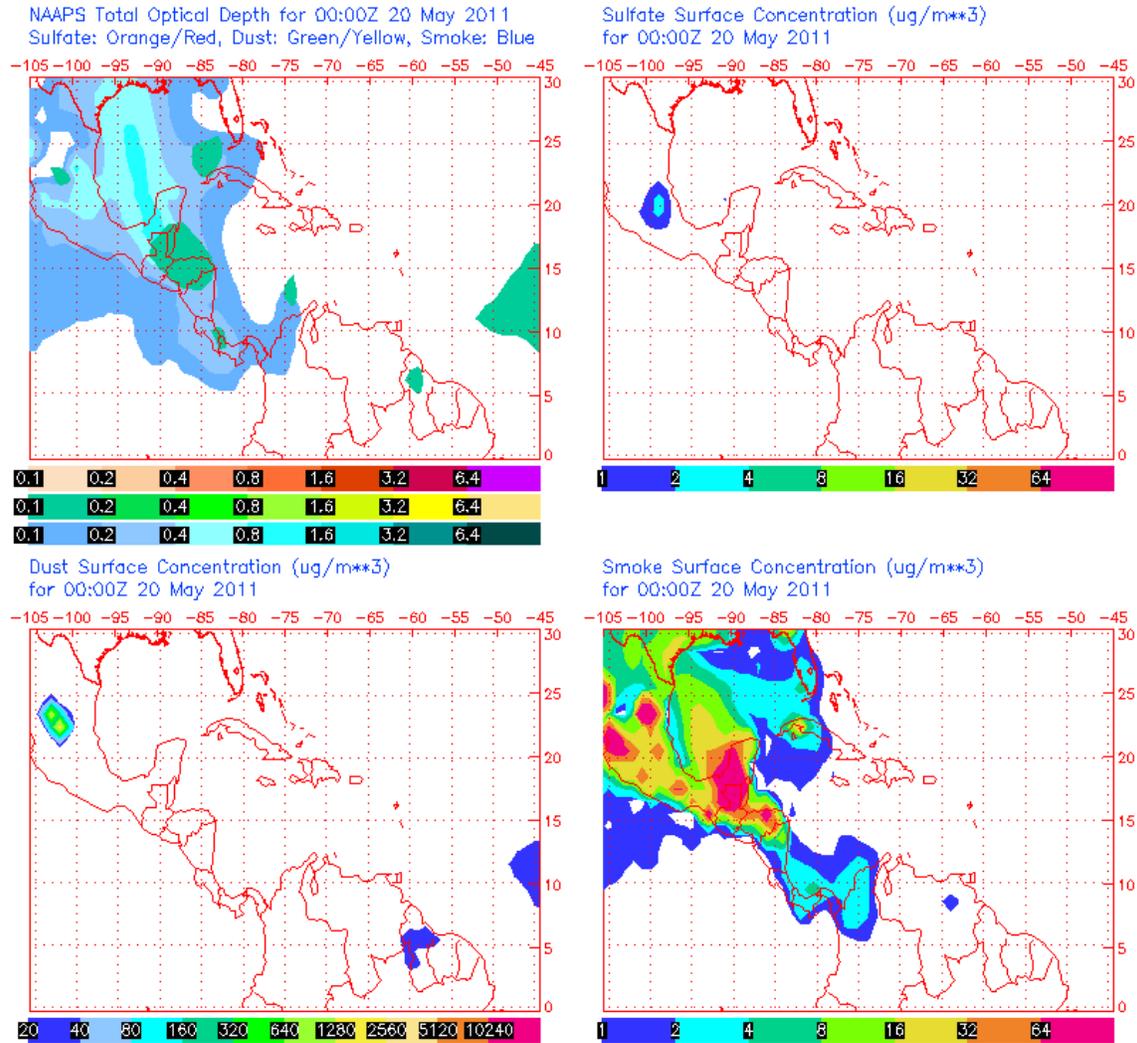
Thu May 19 21:55:20 2011 UTC NRL/Monterey Aerosol Modeling

Figure B-16. NRL aerosol analysis for 1200 UTC on May 19, 2011, showing heavy smoke from fires in southeastern Mexico and Central America.



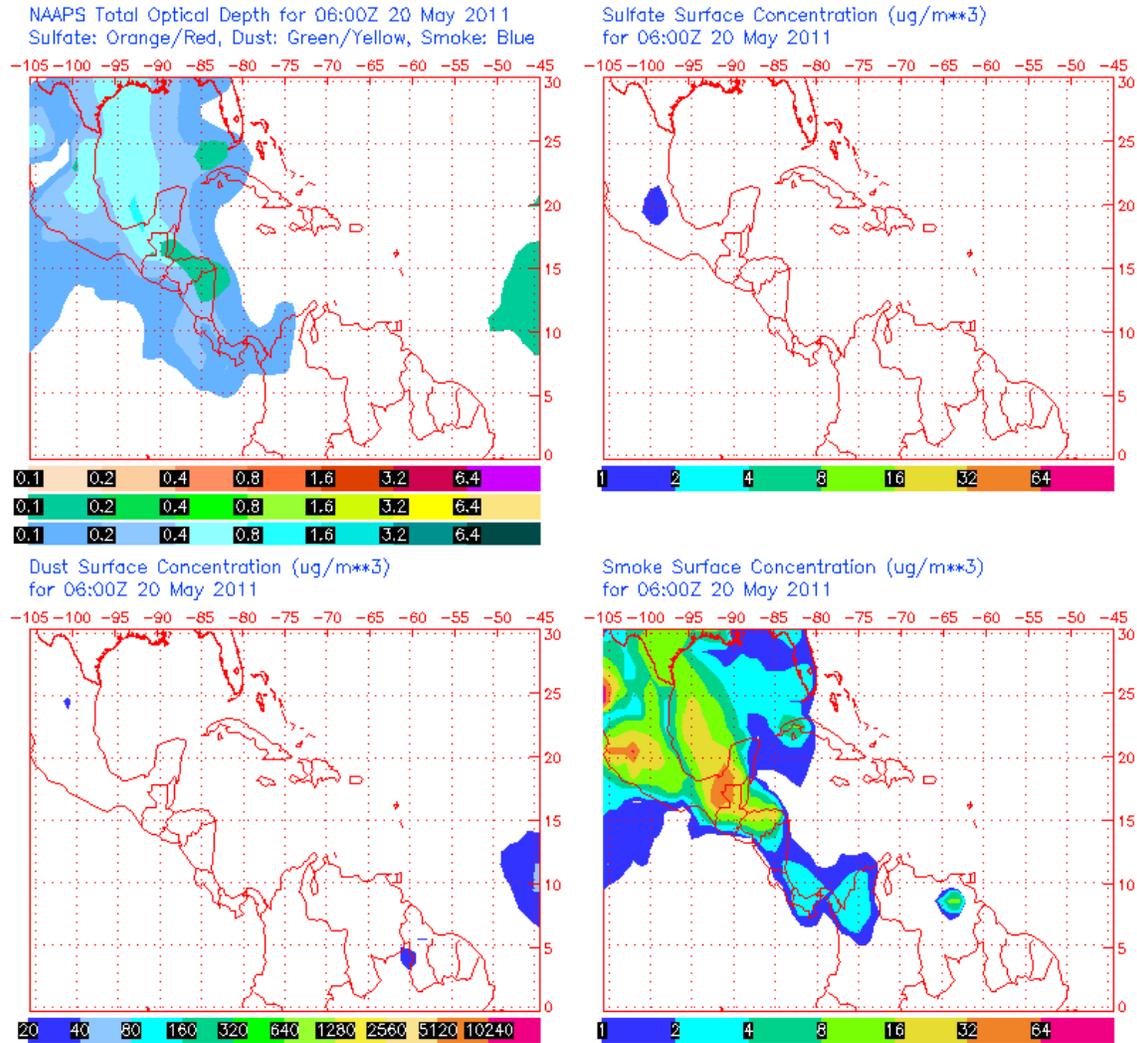
Fri May 20 03:55:20 2011 UTC NRL/Monterey Aerosol Modeling

Figure B-17. NRL aerosol analysis for 1800 UTC on May 19, 2011, showing heavy smoke from fires in southeastern Mexico and Central America extending across the southwestern Gulf of Mexico into South Texas.



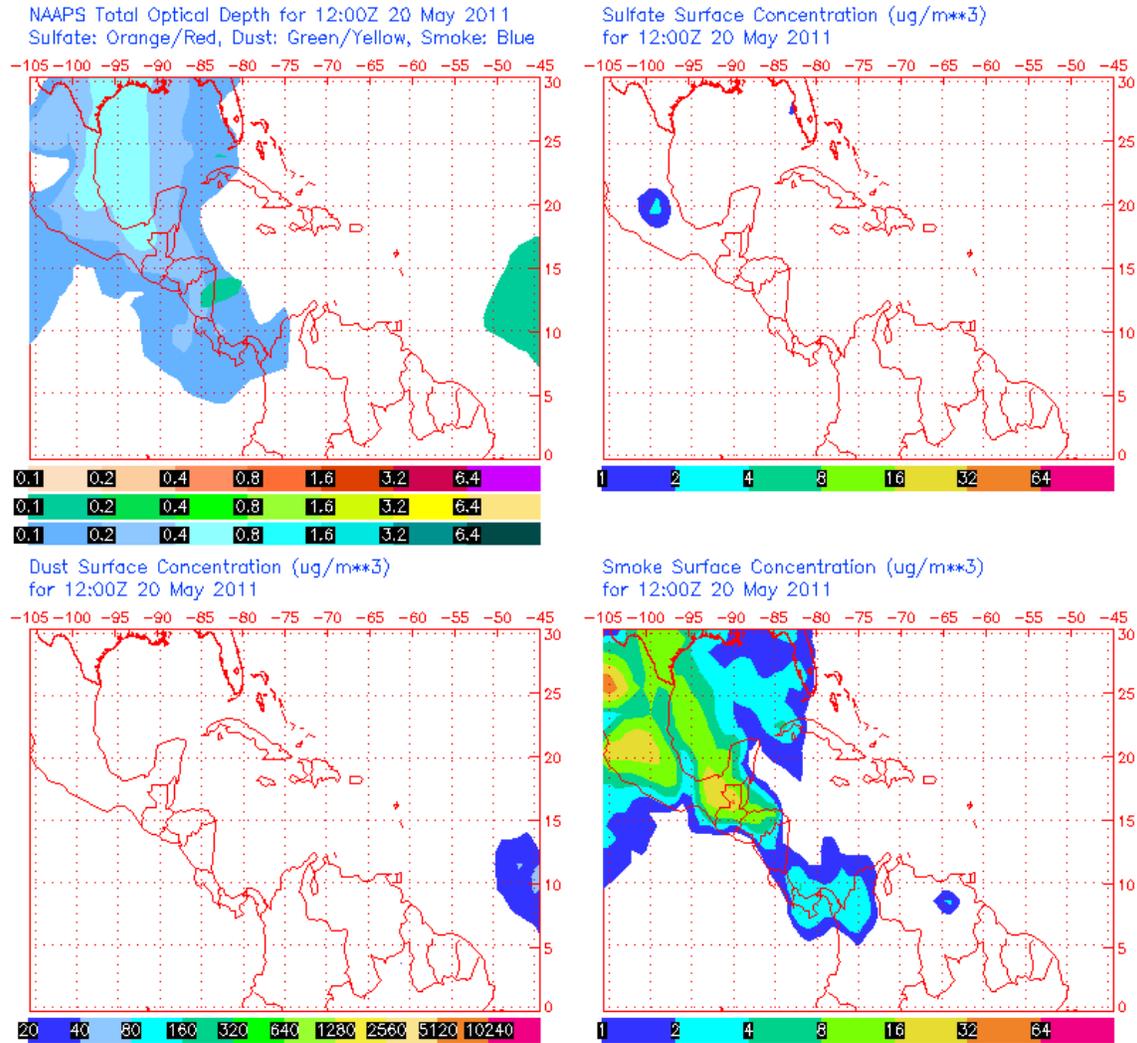
Fri May 20 09:55:21 2011 UTC NRL/Monterey Aerosol Modeling

Figure B-18. NRL aerosol analysis for 0000 UTC on May 20, 2011, showing heavy smoke from fires in southeastern Mexico and Central America extending across the southwestern Gulf of Mexico into the southern half of Texas.



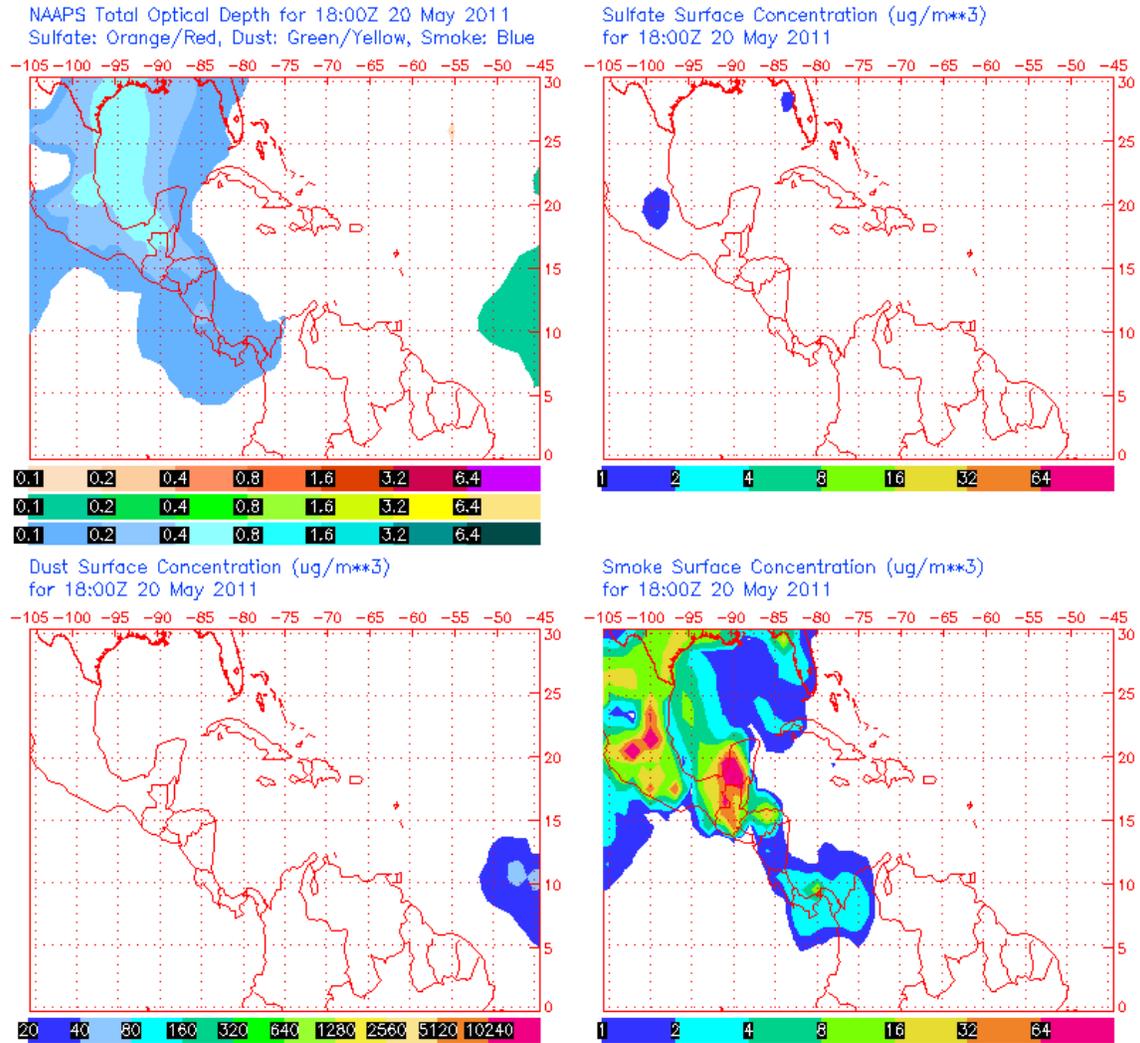
Fri May 20 15:55:20 2011 UTC NRL/Monterey Aerosol Modeling

Figure B-19. NRL aerosol analysis for 0600 UTC on May 20, 2011, showing heavy smoke from fires in southeastern Mexico and Central America extending across the southwestern Gulf of Mexico into the southern half of Texas.



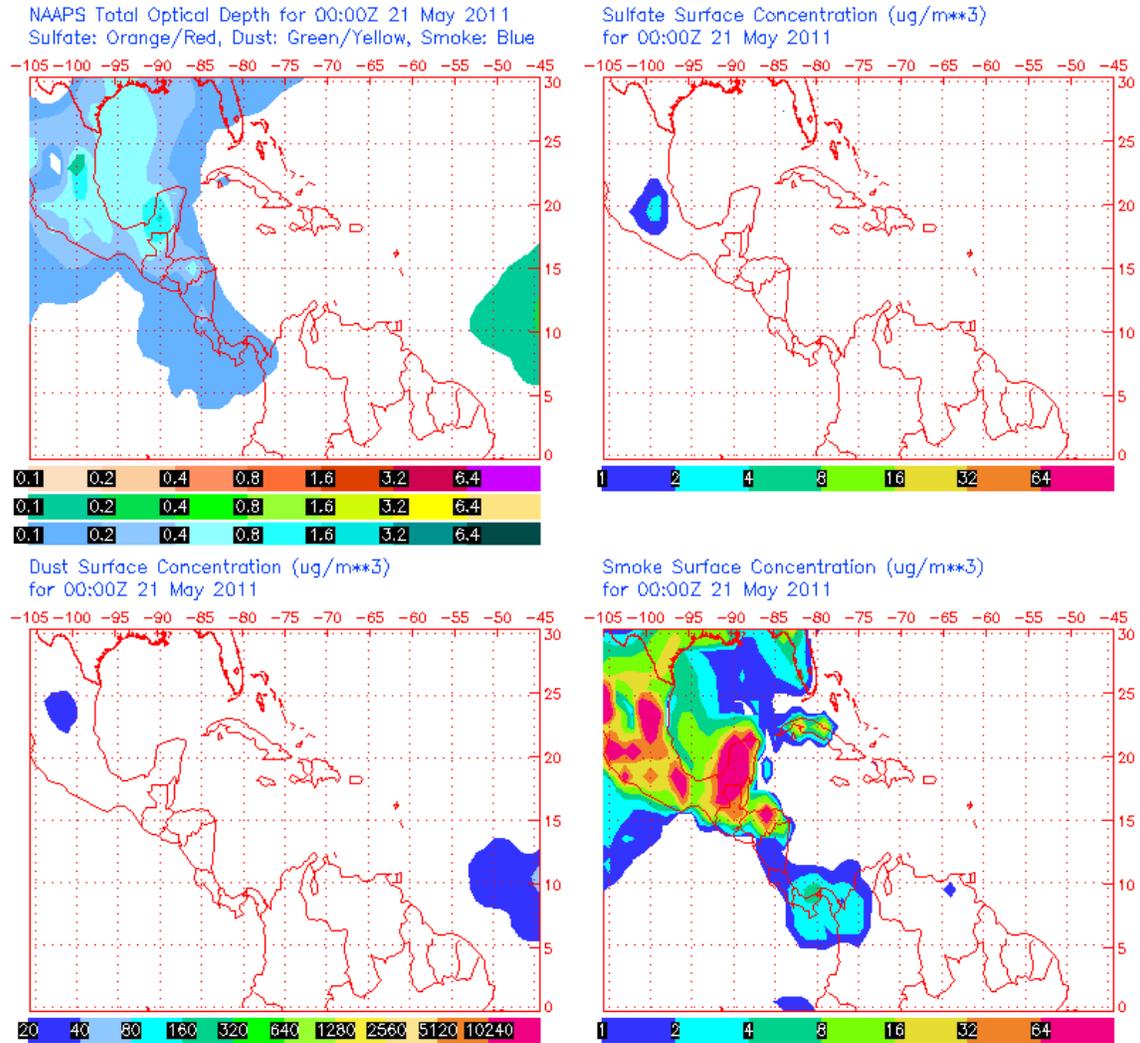
Fri May 20 21:55:20 2011 UTC NRL/Monterey Aerosol Modeling

Figure B-20. NRL aerosol analysis for 1200 UTC on May 20, 2011, showing heavy smoke from fires in southeastern Mexico and Central America extending across the southwestern Gulf of Mexico into the southern half of Texas.



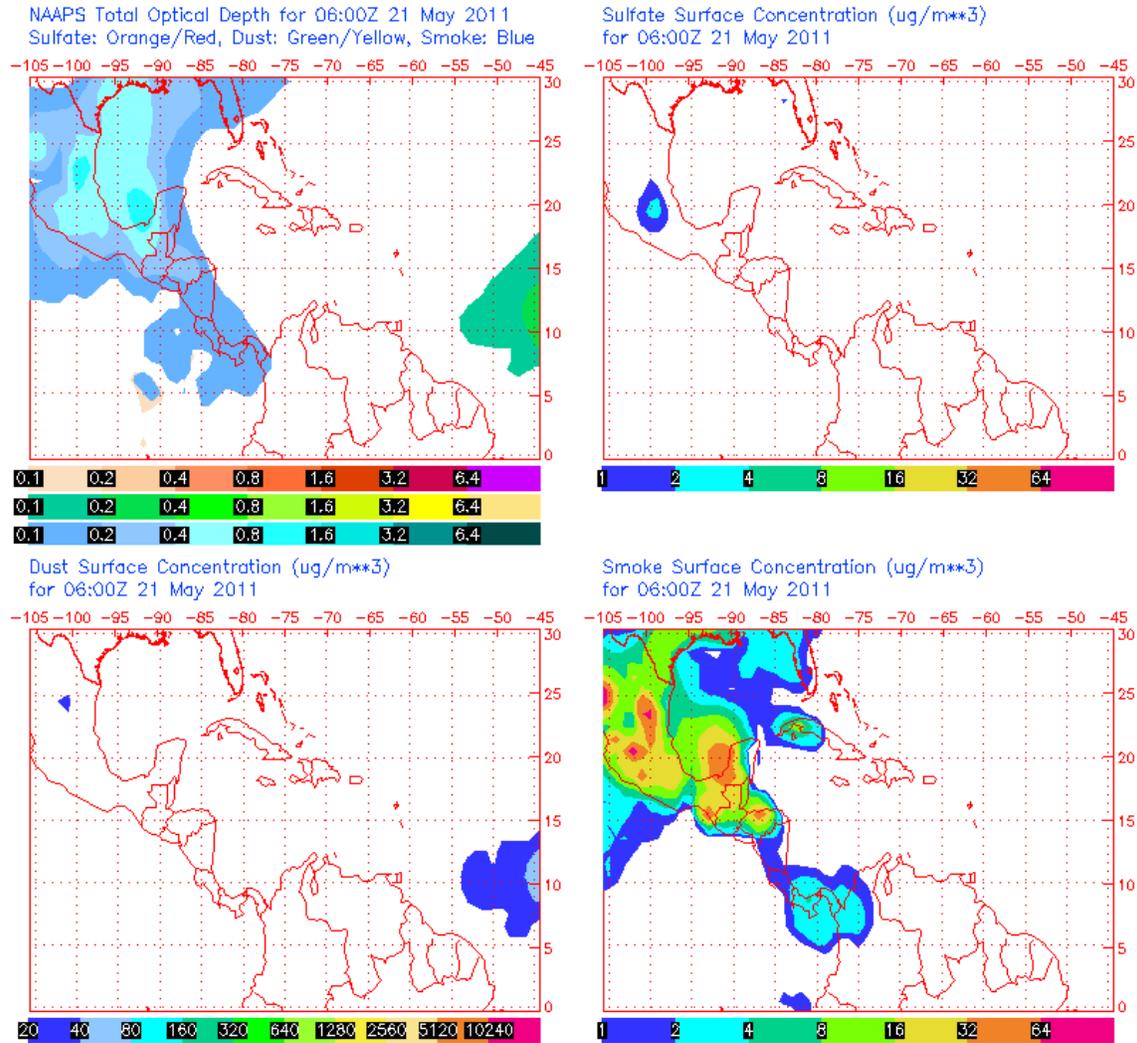
Sat May 21 03:55:21 2011 UTC NRL/Monterey Aerosol Modeling

Figure B-21. NRL aerosol analysis for 1800 UTC on May 20, 2011, showing heavy smoke from fires in southeastern Mexico and Central America extending across the southwestern Gulf of Mexico into the southern half of Texas.



Sat May 21 09:55:21 2011 UTC NRL/Monterey Aerosol Modeling

Figure B-22. NRL aerosol analysis for 0000 UTC on May 21, 2011, showing heavy smoke from fires in southeastern Mexico and Central America extending across the southwestern Gulf of Mexico into the southern half of Texas.



Sat May 21 15:55:19 2011 UTC NRL/Monterey Aerosol Modeling

Figure B-23. NRL aerosol analysis for 0600 UTC on May 21, 2011, showing heavy smoke from fires in southeastern Mexico and Central America extending across the southwestern Gulf of Mexico into the southern half of Texas.

Appendix C: CMAQ Model Evaluation

Figures C-1 through C-4 show examples of cases where the Community Multi-Scale Air Quality (CMAQ) model indicated high PM_{2.5} concentrations in the Houston area. The comparisons with actual concentrations show that the location of high particulate due to local emissions is generally correct, but there is strong evidence of a consistent high bias by about a factor of two on the high side. Thus, if routine local emissions were causing PM_{2.5} to exceed the level of the annual NAAQS for a daily average, the model should indicate a concentration much higher than the annual NAAQS for that day. A check of the State of Texas Environmental Electronic Reporting System found no reports of unusual particulate related emissions events on May 20, 2011. Therefore, the model prediction for May 20, 2011, which does not show the daily average exceeding the level of the annual NAAQS in the Houston area, very strongly indicates that no exceedance of the annual NAAQS would have been measured on May 20, 2011, without the smoke event.

(dev) 0-24h avg sfc pm2.5 Ending 06Z 12 JAN 2010 ($\mu\text{g}/\text{m}^3$)

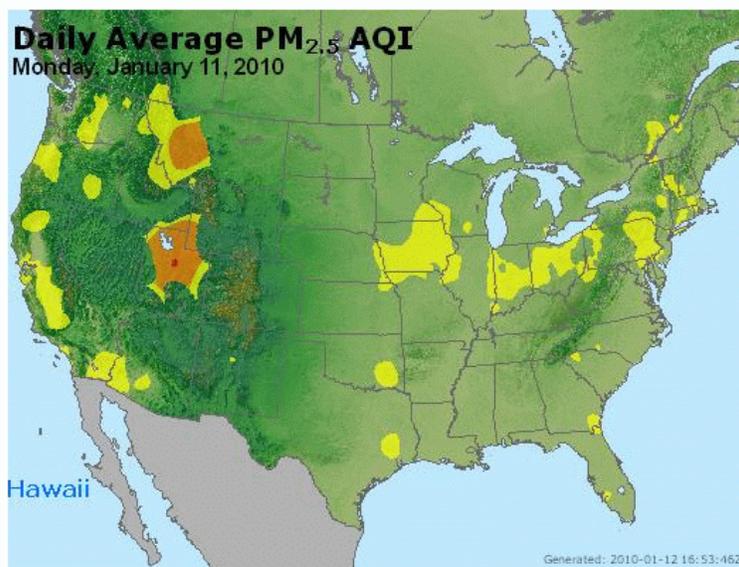
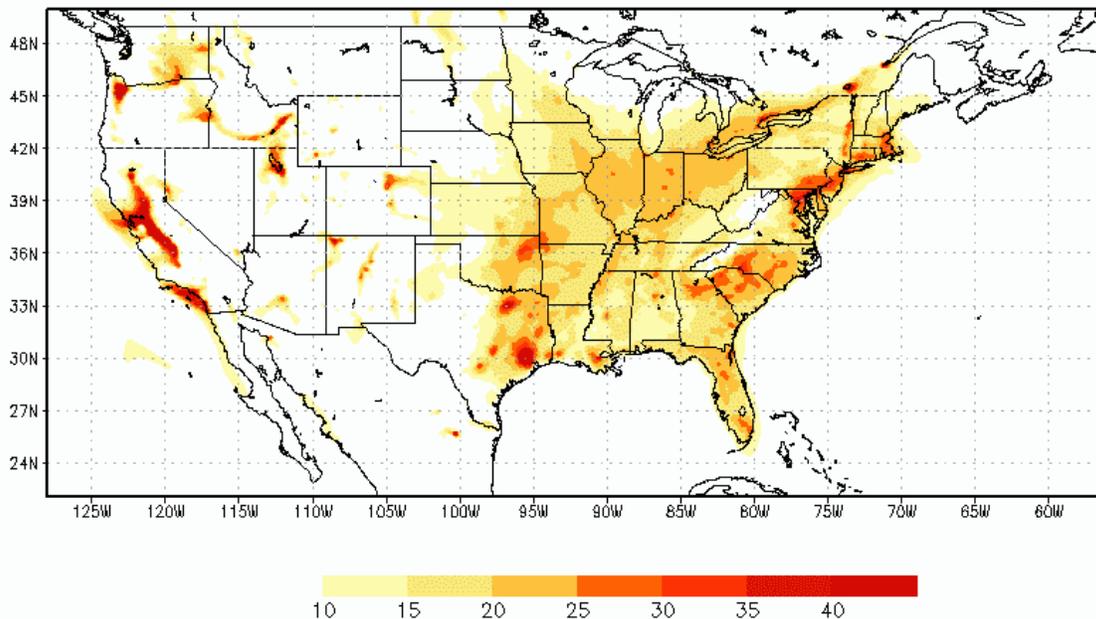


Figure C-1. Comparison of CMAQ model-predicted $\text{PM}_{2.5}$ concentrations versus actual measured AQI levels on January 11, 2010. The yellow areas on the AQI map indicate 2010 AQI Moderate $\text{PM}_{2.5}$ daily averages between 15.5 and $35.4 \mu\text{g}/\text{m}^3$. The CMAQ model predicted widespread concentrations well above $40 \mu\text{g}/\text{m}^3$ in Houston on this day, when actual measured AQI levels were Moderate.

(dev) 0-24h avg sfc pm2.5 Ending 06Z 13 JAN 2010 ($\mu\text{g}/\text{m}^3$)

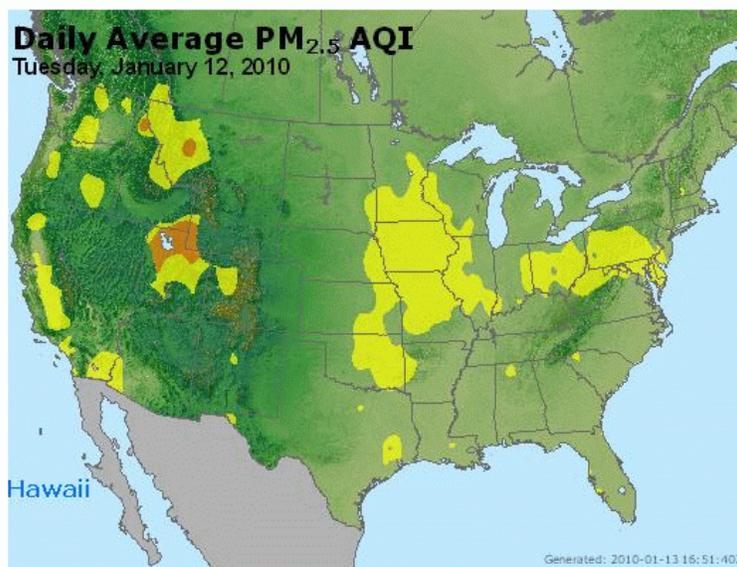
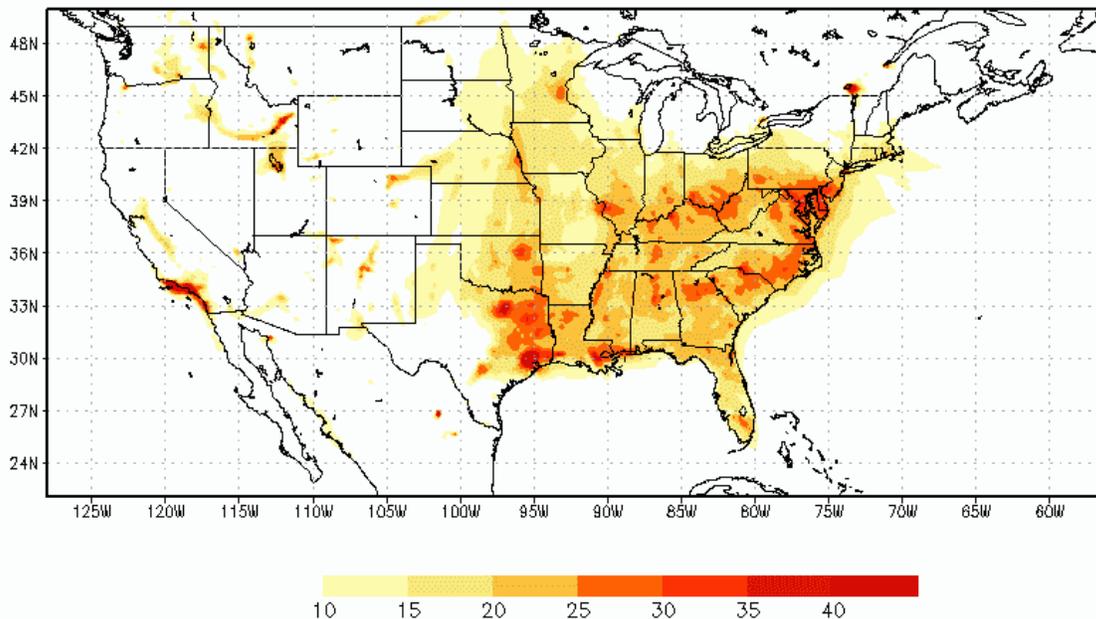


Figure C-2. Comparison of CMAQ model-predicted PM_{2.5} concentrations versus actual measured AQI levels on January 12, 2010. The yellow areas on the AQI map indicate 2010 AQI Moderate PM_{2.5} daily averages between 15.5 and 35.4 $\mu\text{g}/\text{m}^3$. The CMAQ model predicted concentrations well above 40 $\mu\text{g}/\text{m}^3$ in Houston on this day, when actual measured AQI levels were Moderate.

(dev) 0-24h avg sfc pm2.5 Ending 06Z 14 JAN 2010 ($\mu\text{g}/\text{m}^3$)

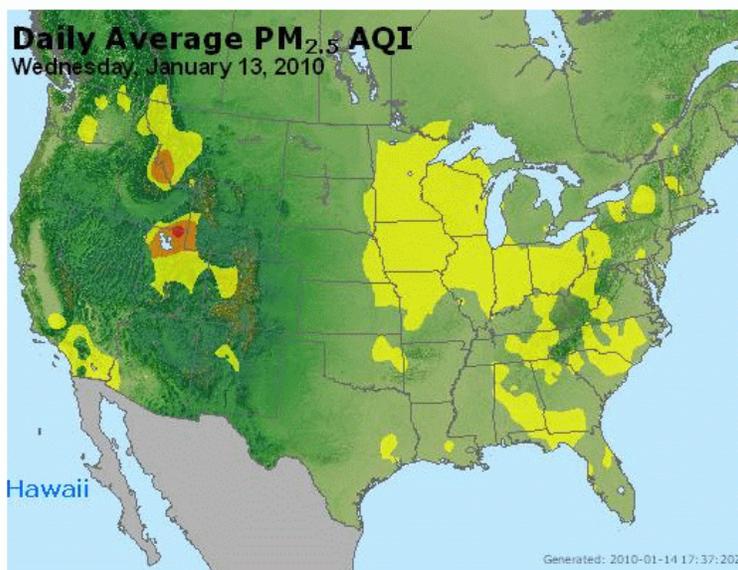
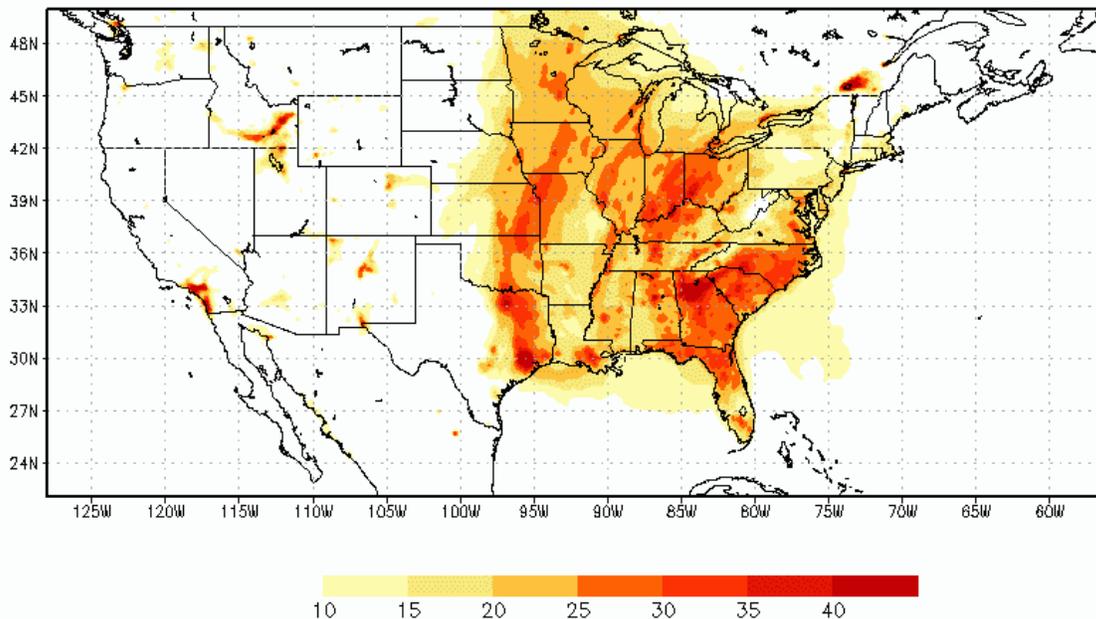


Figure C-3. Comparison of CMAQ model-predicted PM_{2.5} concentrations versus actual measured AQI levels on January 13, 2010. The yellow areas on the AQI map indicate 2010 AQI Moderate PM_{2.5} daily averages between 15.5 and 35.4 $\mu\text{g}/\text{m}^3$. The CMAQ model predicted widespread concentrations well above 40 $\mu\text{g}/\text{m}^3$ in Houston on this day, when actual measured AQI levels were Moderate.

(dev) 0-24h avg sfc pm2.5 Ending 06Z 15 JAN 2010 ($\mu\text{g}/\text{m}^3$)

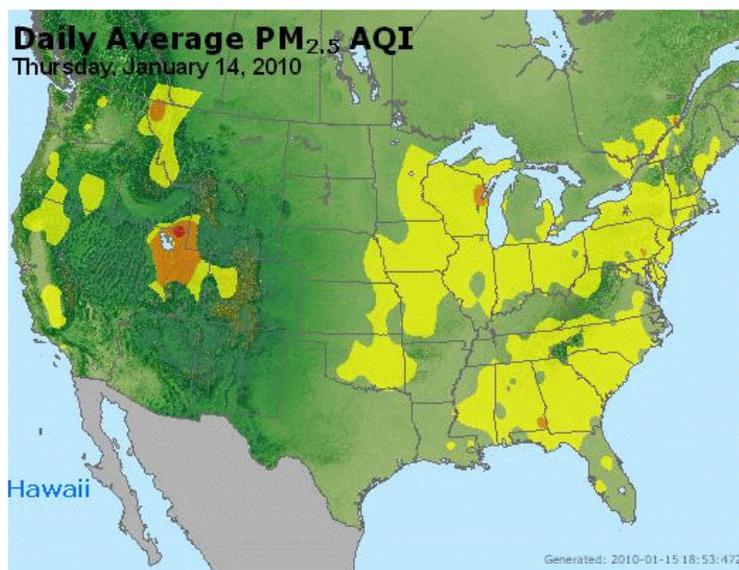
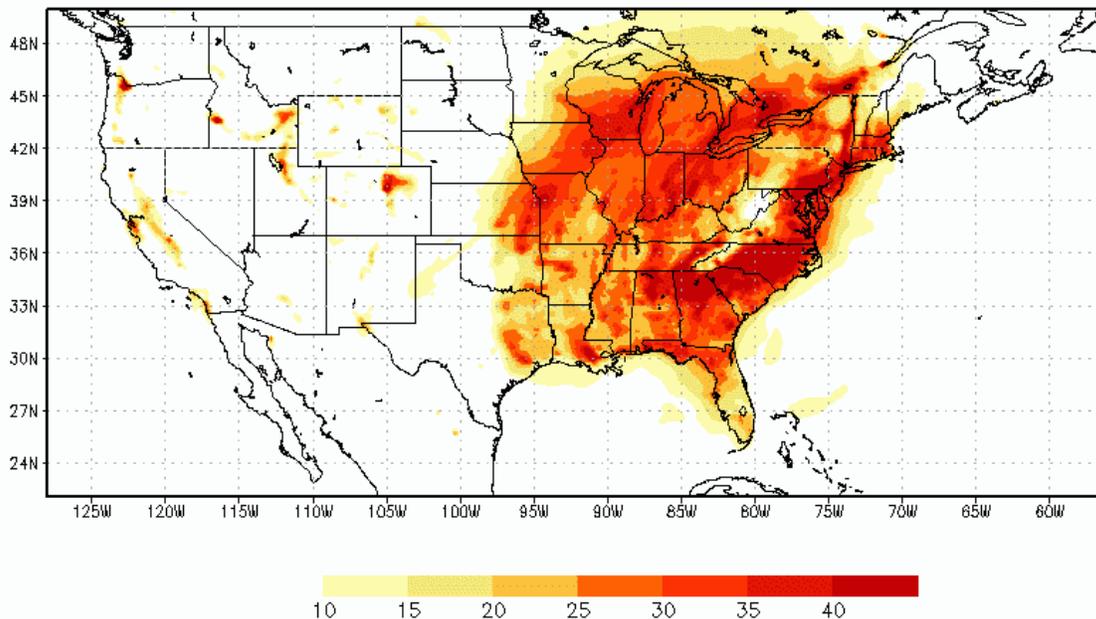


Figure C-4. Comparison of CMAQ model-predicted PM_{2.5} concentrations versus actual measured AQI levels on January 14, 2010. The yellow areas on the AQI map indicate AQI 2010 Moderate PM_{2.5} daily averages between 15.5 and 35.4 $\mu\text{g}/\text{m}^3$. The CMAQ model predicted widespread concentrations well above 35 $\mu\text{g}/\text{m}^3$ in Houston on this day, when actual measured AQI levels were Good.

Appendix D: Web Page Examples

Figures D-1 through D-6 show examples of web pages cited by links in the Mitigation of Exceptional Events section.

Today's Texas Air Quality Forecast

The latest forecast for air quality conditions in Texas' metropolitan areas.

August 23, 2013

Related Current Data

- [Air Quality Index \(AQI\) Report](#)
- [Map of Current PM2.5 Levels](#)
- [Map of Current Ozone Levels](#)
- [Current Satellite Images](#)
- [Real-Time Winds Aloft](#)

Related Information

- [Ozone: The Facts](#)
- [Texas Air Monitoring Data](#)
- [EPA AIRNow Air Quality Forecasts](#) [Exit...](#)
- [NOAA/EPA Ozone Model Forecasts](#) [Exit...](#)
- [NRL Aerosol Model Forecasts](#) [Exit...](#)

**Air Quality Index (AQI)
Forecast**

Air Quality Index Scale

Good	Moderate	Unhealthy Sensitive	Unhealthy	Very Unhealthy	Hazardous
------	----------	---------------------	-----------	----------------	-----------

Forecast Region (Click name for AIRNOW version)	Fri 08/23/13	Sat 08/24/13	Sun 08/25/13	Mon 08/26/13
Austin	Good	Good	Good	Good
Beaumont-Port Arthur	Good	Good	Good	Good
Brownsville-McAllen	Good	Good	Good	Good
Corpus Christi	Good	Good	Good	Good
Dallas-Fort Worth	Ozone	Ozone	Ozone	Ozone
El Paso	Good	Good	Good	Good
Houston	Ozone	Good	Good	Good
Laredo	Good	Good	Good	Good
Lubbock	Good	Good	Good	Good
Midland-Odessa	Good	Good	Good	Good
San Antonio	Good	Good	Good	Good
Tyler-Longview	Ozone	Good	Good	Good
Victoria	Good	Good	Good	Good
Waco-Killeen	Good	Good	Good	Good

Discussion

Friday 8/23/13

Winds may be light enough and incoming background levels high enough for ozone to reach "Moderate" levels on the southwest and west side of the Houston area, on the northwest side of the Dallas-Fort Worth area, and in the Tyler-Longview area with highest concentrations this afternoon and into the early evening. Elsewhere in the state, moderate winds and lower incoming background levels should help to keep air quality in the "Good" range.

Saturday 8/24/13

Winds may be light enough and incoming background levels high enough for ozone to reach "Moderate" levels on the northwest side of the Dallas-Fort Worth area with highest concentrations in the afternoon and early evening. Elsewhere in the state, moderate winds and lower incoming background levels should help to keep air quality in the "Good" range.

Sunday 8/25/13 Outlook

Winds may be light enough and incoming background levels high enough for ozone to reach "Moderate" levels on the northwest side of the Dallas-Fort Worth area with highest concentrations in the afternoon and early evening. Elsewhere in the state, moderate winds and lower incoming background levels should help to keep air quality in the "Good" range.

Monday 8/26/13 Outlook

Winds may be light enough and incoming background levels high enough for ozone to reach "Moderate" levels on the northwest side of the Dallas-Fort Worth area with highest concentrations in the afternoon and early evening. Elsewhere in the state, moderate winds and lower incoming background levels should help to keep air quality in the "Good" range.

Tuesday 8/27/13 Extended Outlook

Winds may be light enough and incoming background levels high enough for ozone to reach "Moderate" levels on the north and northwest side of the Dallas-Fort Worth area with highest concentrations in the afternoon and early evening. Elsewhere in the state, moderate winds and lower incoming background levels should help to keep air quality in the "Good" range.

Figure D-1. Sample of the TCEQ Today's Texas Air Quality Forecast.

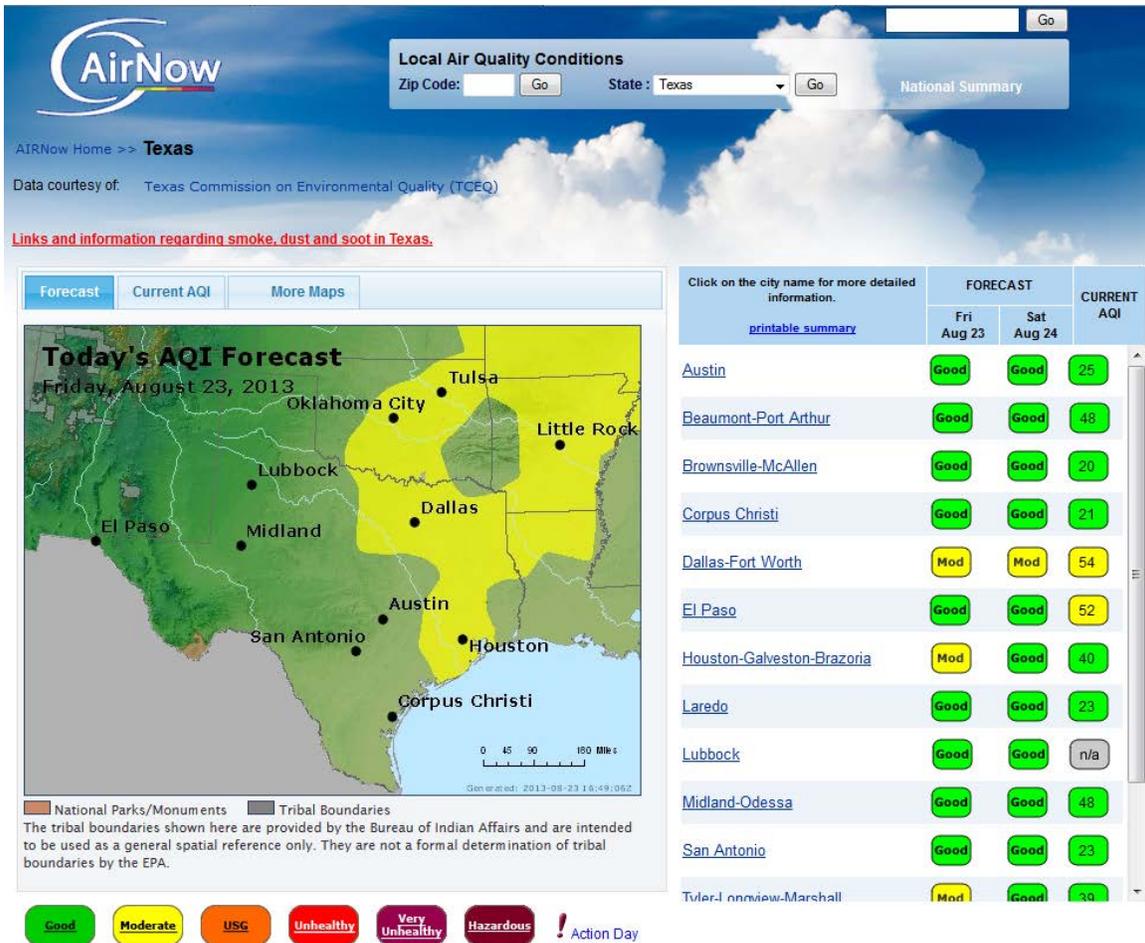


Figure D-2. Sample of the EPA AIRNOW web page.

Air Quality Index



How clean is the air in your metropolitan area? The U. S. Environmental Protection Agency (EPA) has provided a scale called the Air Quality Index (AQI) for rating air quality. This scale is based on the National Ambient Air Quality Standards (NAAQS) and is described in the Code of Federal Regulations, Part 58, Appendix G. This report is based on the AQI standards.

Interpreting the AQI

Reporting for August 23, 2013 as of 12:12 pm CDT																
Metropolitan Area or Non-Metropolitan County	Air Quality	Critical Pollutant	Air Quality Index Rating													
			Ozone			Carbon Monoxide	Sulfur Dioxide	Nitrogen Dioxide		PM-10 (Std Cond)	PM-2.5 (Lcl Acpt)					
			1-Hour	8-Hour	8-Hour	1-Hour	1-Hour		24-Hour †	24-Hour †						
			AQI	ppb	AQI	ppb	AQI	ppm	AQI	ppb	AQI	ppb	AQI	µg/m ³ (25° C)	AQI	µg/m ³ LC
Amarillo -- Region 1																
Amarillo	Good	PM-2.5												36	8.6	
Lubbock -- Region 2																
Lubbock ¹	††														§	
Abilene -- Region 3																
Wichita Falls	Good	PM-2.5												35	8.4	
Dallas-Fort Worth -- Region 4																
Dallas ¹	Moderate	PM-2.5	*	56	27	32	2	0.2	5	3	14	15		53	13.3	
Fort Worth-Arlington	Good	PM-2.5	*	51	28	33	2	0.2			25	27		36	8.7	
Navarro County ¹	Good	PM-2.5	*	39	19	23			6	4		§		30	7.1	
Tyler-Longview-Marshall -- Region 5																
Longview-Marshall	Good	PM-2.5	*	52	19	23			1	1	11	12		34	8.3	
Tyler	Good	Ozone	*	39	21	25					4	4				
El Paso-Juarez -- Region 6																
Brewster County	Good	Ozone	*	36	25	30									25	5.9
El Paso	Good	PM-2.5	*	43	27	32	5	0.4	1	1	22	23	20	21.2	31	7.4
Juarez ¹	Good	Ozone	*	28	17	20	3	0.3								
Odessa-Midland -- Region 7																
Odessa-Midland	Good	PM-2.5												38	9.2	
Waco -- Region 9																
Killeen-Temple	Good	Ozone	*	35	14	16										
Waco	Good	PM-2.5	*	38	21	25	1	0.1	2	1	5	6		28	6.6	
Beaumont-Port Arthur -- Region 10																
Beaumont-Port Arthur	Good	PM-2.5	*	46	17	20	2	0.1	3	2	16	17		46	11.1	
Austin -- Region 11																
Austin-San Marcos ¹	Good	PM-2.5	*	43	17	20	1	0.1	2	1	12	13		19	4.5	
Fayette County	Good	Ozone	*	32	14	16								14	3.4	
Houston-Galveston-Brazoria -- Region 12																
Brazoria	Good	Ozone	*	40	14	16					13	14				
Galveston-Texas City	Good	Ozone	*	36	23	27			1	1	14	15		17	4.0	
Houston ¹	Good	PM-2.5	*	48	14	16	4	0.3	6	4	22	24		33	8.0	

Figure D-4. Sample of a portion of the TCEQ Air Quality Index Report.

Air Pollution from Particulate Matter

General information on particulate matter (PM), and TCEQ planning that addresses the PM National Ambient Air Quality Standards (NAAQS).

- [Particulate Matter \(PM\): The Facts](#)
- [Latest air quality planning that addresses the PM NAAQS](#) **NEW**
- [Related Web pages and publications](#)
- [Get more information on the Texas SIP and contact the TCEQ](#)

Particulate Matter (PM): The Facts

What is PM?

Particulate matter (PM) is a mix of small particles and liquid droplets. These particles can be made up of acids, organic chemicals, metal, dust, or soil. Particulates are different in several ways including size.

PM₁₀ is sometimes referred to as coarse particles. They consist of particles that are less than 10 micrometers in diameter but greater than 2.5 micrometers in diameter.

PM_{2.5} are fine particles and are the smallest particles that are regulated. They consist of particles that are 2.5 micrometers and smaller in diameter. By comparison, the average diameter of human hair is 70 micrometers.

The Federal Clean Air Act requires the United States Environmental Protection Agency (EPA) to set air quality standards, including those for PM, to protect both public health and the public welfare (e.g., visibility, crops, and vegetation).

What are the health effects of PM?

Particle size is directly related to its potential for causing health problems. Small particles less than 2.5 micrometers in diameter can be inhaled deeper into the lungs. Scientific studies have linked exposure to high concentrations of some types of PM with a variety of problems, including:

- irregular heartbeat;
- aggravated asthma;
- decreased lung function;
- increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing;
- nonfatal heart attacks; and
- premature death in people with heart or lung disease.

These associations are much less certain at concentrations below the current standard set by the EPA for PM in ambient air.

How does PM affect the environment?

PM can contribute to haze, which reduces visibility. When PM is present in the air, it can absorb sunlight, and it can reflect sunlight. This reduces clarity in the air and can cause haze. Humid air can also combine with PM to further reduce visibility. PM from the air can deposit on water and soil harming ecosystems, soil, and crops. PM can stain and damage stone and other materials, including culturally important objects such as statues and monuments.

Where can I see daily PM levels in my area?

The TCEQ has multiple monitors that directly measure PM concentrations throughout the state. The TCEQ also offers air quality forecasts that include PM. The public can sign up for these to be delivered via e-mail using the Agency's GovDelivery system.

The EPA provides a web site that monitors and forecasts the quality of the air using a scale called the Air Quality Index (AQI). The AQI is based on the National Ambient Air Quality Standards (NAAQS) for the six criteria pollutants. The AQI is on a scale of 0 to 500, with 100 corresponding to the NAAQS set by the EPA. A higher AQI value means a larger level of air pollution and a greater potential health concern. These forecasts can be found on the EPA's Air Now Web page (<http://airnow.gov/>). [Exit...](#)

You can also sign up to receive e-mail alerts about PM through the EPA's EnviroFlash web site (<http://www.enviroflash.info/>). [Exit...](#)

Figure D-5. Sample of a portion of the TCEQ particulate matter web page.

AirNow Local Air Quality Conditions

Zip Code: Go State: Alabama Go National Summary

Air Quality Index (AQI) - A Guide to Air Quality and Your Health

AQI
AIR QUALITY INDEX

The AQI is an index for reporting daily air quality. It tells you how clean or polluted your air is, and what associated health effects might be a concern for you. The AQI focuses on health effects you may experience within a few hours or days after breathing polluted air. EPA calculates the AQI for five major air pollutants regulated by the Clean Air Act: ground-level ozone, particle pollution (also known as particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide. For each of these pollutants, EPA has established national air quality standards to protect public health. Ground-level ozone and airborne particles are the two pollutants that pose the greatest threat to human health in this country.

How Does the AQI Work?

Think of the AQI as a yardstick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 300 represents hazardous air quality.

An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, which is the level EPA has set to protect public health. AQI values below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is considered to be unhealthy-at first for certain sensitive groups of people, then for everyone as AQI values get higher.

Understanding the AQI

The purpose of the AQI is to help you understand what local air quality means to your health. To make it easier to understand, the AQI is divided into six categories:

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
<i>When the AQI is in this range:</i>	<i>...air quality conditions are:</i>	<i>...as symbolized by this color:</i>
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Each category corresponds to a different level of health concern. The six levels of health concern and what they mean are:

- "Good" AQI is 0 - 50. Air quality is considered satisfactory, and air pollution poses little or no risk.
- "Moderate" AQI is 51 - 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.

Publications

- Air Quality Index - A Guide to Air Quality and Your Health (PDF, 12pp., 629KB, about PDF)
- Air Quality Guide for Ozone
- Air Quality Guide for Particle Pollution
- Other AIRNow Publications
- Other AIRNow Publications - En Español
- AQI Calculator: AQI to Concentration
- AQI Calculator: Concentration to AQI
- Order any of our AIRNow publications from EPA's NSCEP

Figure D 6. Sample of a portion of the EPA Air Quality Index guide.