

***The Houston Pollution Problem:
An analysis of the primary and secondary regional pollution peak***

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Abstract

In the spring of 2006, a joint study was conducted in the Houston area to assess the secondary regional pollution peak that occurs at that time. The primary peak occurs in the summer and was heavily investigated during the summer of 2000. The possibility of contribution from Mexico and Central America was suggested. Data archives from summer 2000 showed frequent high pollution episodes, which correlated with stagnant weather patterns and high temperatures. During spring 2006, pollution episodes were less severe and frequent, but pollutant accumulation was noted. On March 15, a day when ozone peaked at 55 ppb and remained near 40 ppb well into the night, trajectories and surface analysis showed transport of air from the Gulf of Mexico and northern and central Mexico. This contrasted with March 6, where pollutants accumulated, with ozone peaking at 45 ppb, but reduced back to very low-levels in the evening. Continued analysis of the spring 2006 data will allow for a more definite assessment of the secondary regional pollution peak.

1. Introduction

Approximately an hour inland from the western Gulf of Mexico lays the Houston metropolitan area, the seventh most populous region in the United States¹. This massive region is also home to the largest petrochemical manufacturing area in the world and the Port of Houston, ranked first in the US for international commerce², both to the south and east of downtown Houston. The region is sprawled over 10 counties in southeastern Texas and has an extensive highway system, making the automobile the dominant mode of transport. Excessive automotive traffic combined with busy industry and local meteorology makes Houston a prime location for unhealthy air quality episodes. In fact, the region experiences unhealthy exposure to ozone and other pollutants frequently each year, with more occurrences during the summer months. The National Ambient Air Quality Standards (NAAQS), set by the US Environmental Protection Area (EPA), dictate levels of various pollutants that US cities must follow³. One standard, for example, indicates that ozone concentration averages over an 8 hour period may not exceed 80 parts per billion (ppb). However, locations in and around Houston can easily observe concentrations near 150 ppb, which is unhealthy for all people⁴.

A significant portion of the US experiences episodes of unhealthy pollution exposure, with one-third of the US experiencing unhealthy exposure to ozone (Kleinman et al., 2002). This exposure is in large part due to anthropogenic sources including emissions of volatile organic compounds (VOCs), carbon monoxide (CO) and nitrogen oxides (NOx) from industry, automobiles, and power plants, amongst other things (Lelieveld et al., 2000; Duncan et al., 1998; EPA 2000). Unhealthy air quality episodes can be identified by the general public by the

reduced visibility caused by light scattering from the pollutants (Dzubay et al., 1982). Air quality can be improved by the reduction of NO_x and VOC emissions, which in turn will also reduce the ozone byproduct (Duncan et al., 1998). If a region with air quality issues can identify the effect of each contribution to the unhealthy episodes, regulations of emissions can be established. Houston is a special case in that source emissions typically found in other cities exist in addition to emissions from the region's petrochemical industry causing extreme and rapid ozone formation. Such high amounts of NO_x and VOCs can be dumped into the air early, that once the solar processes to form ozone begin, they proceed rapidly (Kleinman et al., 2002). Even areas of the region with low ozone formation may experience an unhealthy exposure when the Gulf of Mexico sea breeze transports the high concentrations from the port and petrochemical industry areas north and west over the rest of Houston (Daum et al., 2004).

In the summer of 2000, a joint study called the Texas Air Quality Study (Texas AQS 2000) was conducted to identify and assess the air quality issue in southeastern Texas, including Houston⁵. From this study came many findings that explained the high pollution exposure and most notably the high ozone occurrences in the area. Indeed, the Port of Houston and associated Houston Ship Channel, along which most of the petrochemical industry is located, proved to be the culprit. A less significant contributor was simply the abundance of cars and trucks traversing Houston's extensive hub and spoke highway system (Daum et al., 2003).

Recently, in the early spring of 2006 another study, which was a conglomeration of the INTEX-B, IONS-06, Milagro, and NATIVE campaigns, was conducted with ground and air measurements of Houston regional air. At the surface, ozone and other pollutants were measured, while the DC-8 air plane operated by NASA flew above southeastern Texas to measure ambient air above the surface. Additionally, sondes were launched to measure profiles of the atmosphere from the surface to the upper atmosphere.

In the early spring, particularly in March, the Houston area experiences a second peak in pollution. While the summer peak is well understood, the cause of the spring peak is unknown. Air above the region is suggested to not only come from local production, but to also come from air that originated in Mexico and Central America. The Mexico City area experiences higher pollution during winter (Raga et al., 2000; Riveros et al., 1998) and early spring and biomass burning in Mexico and Central America is prevalent at the same time. This research:

- Reviews the data from summer 2000,
- Compares the spring 2006 conglomerate study data with summer 2000 data,
- Identifies two examples of the daily pollutant accumulation and dispersal from spring 2006.

Whereas, during the summer months, weather patterns in the latitude of Houston and Mexico City tend to be stagnant, spring is known for more defined air transport. This may validate the suggestion that Houston area ozone episodes during the spring are actually due to Mexico City pollution episodes.

2. Methodology

To conduct a comparison and analysis of the summer 2000 and spring 2006 observations required massive data collection. All summer 2000 data was obtained from the Texas AQS 2000⁶, which includes surface ozone (O₃), CO, sulfur dioxide (SO₂), and NO_x measurements. Data from the spring 2006 study was obtained from the following campaigns: INTEX-B⁷, IONS⁸, and NATIVE⁹. Flight data from the NASA DC-8 aircraft (part of INTEX-B) was derived from

flight summaries of missions between the Mexico City area, the Gulf of Mexico, and Houston. NATIVE provided ground-level measurements from southeastern Houston and IONS provided sonde and air trajectory data. Correlations between summer 2000 and spring 2006 high pollution level occurrences and observed atmospheric air rich in ozone, VOCs, and NOx were assessed.

3. Findings and Discussion
3.1 Texas AQS 2000

Texas AQS 2000 provided data for analysis of the summer air pollution situation in Houston. The study ran from August 15 to September 15 which saw a major poor air quality episode around the first of September. Pollution levels frequently exceeded the standards dictated by the EPA, including those for ozone and CO.

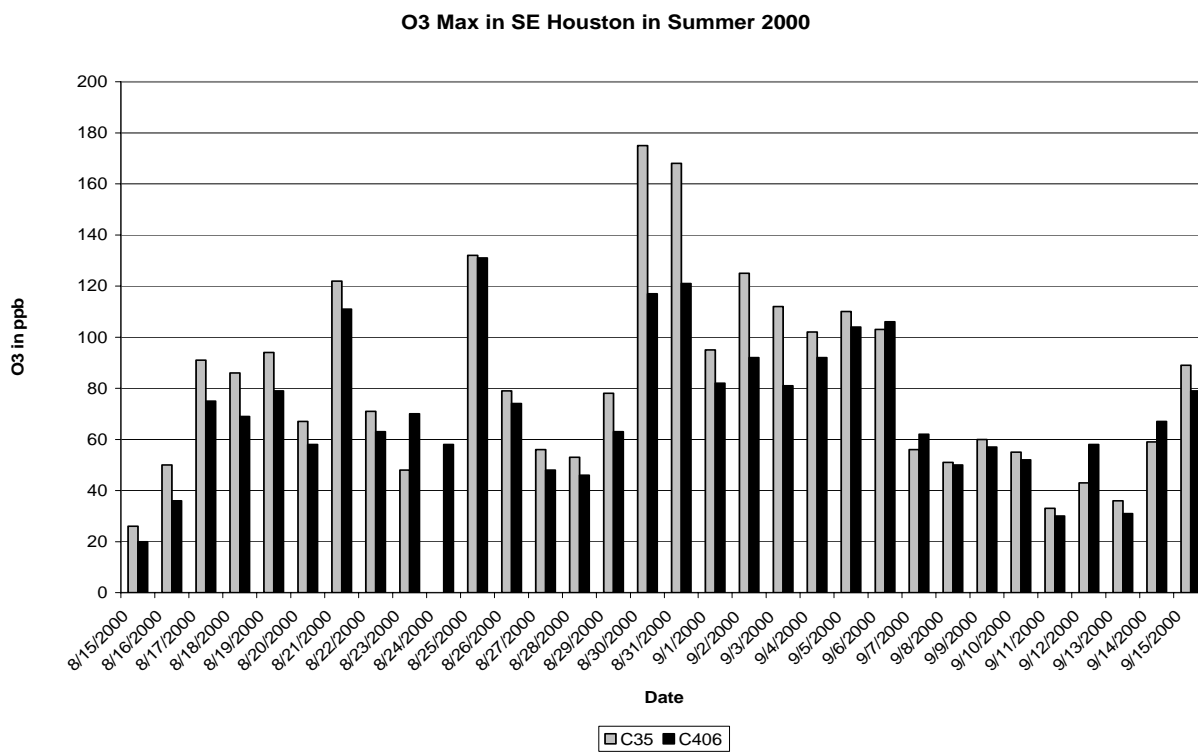


Figure 1: This table shows the daily maxima in ozone concentration at two reporting stations in SE Houston near the site of the 2006 NATIVE measurements.

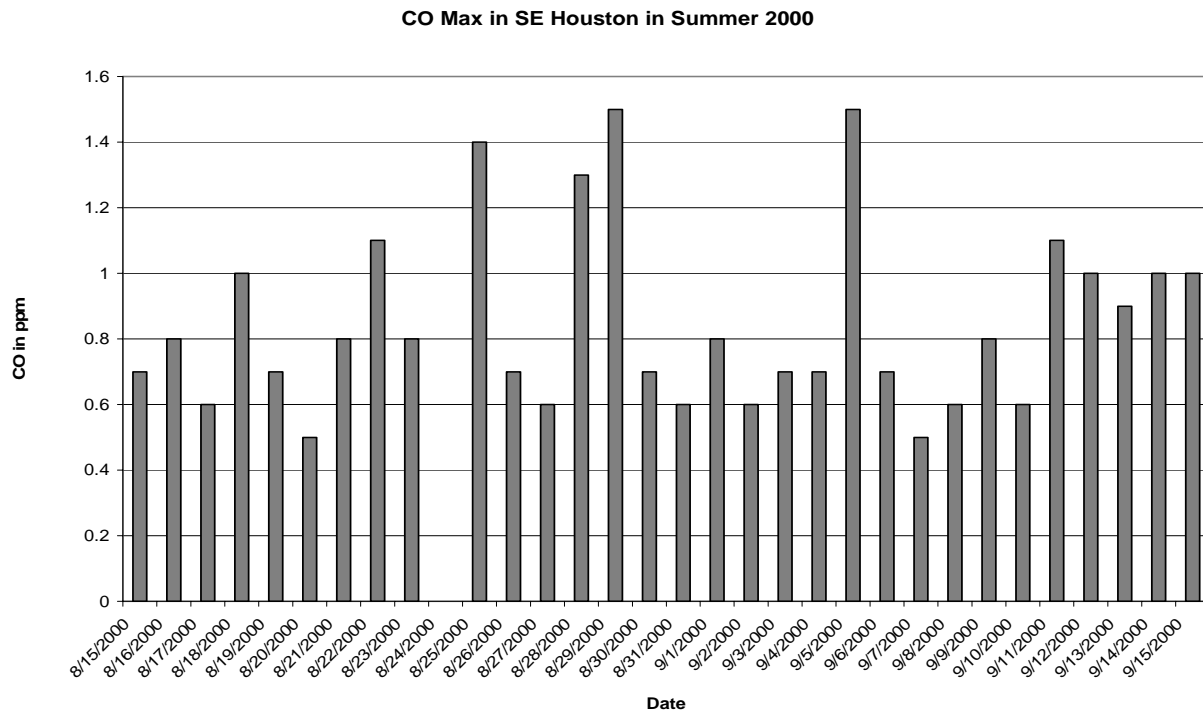


Figure 2: This table shows the daily maxima in CO concentration at the C35 reporting station in SE Houston near the site of the 2006 NATIVE measurements.

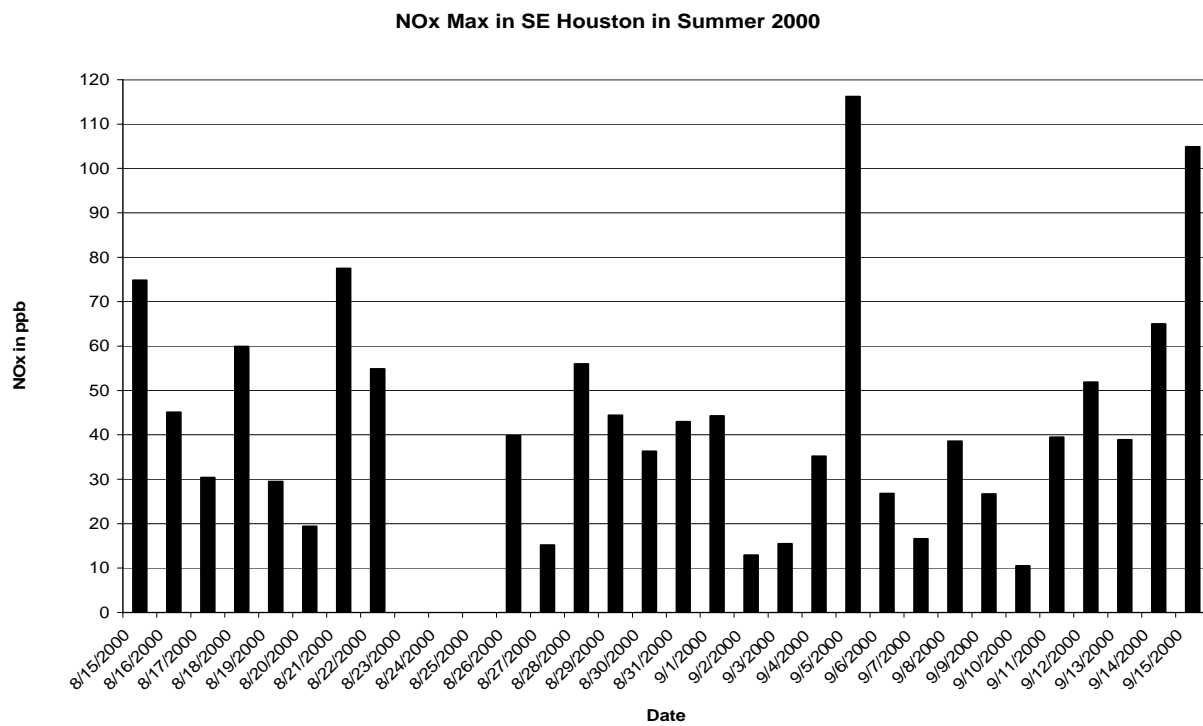


Figure 3: This table shows the daily maxima in NOx concentration at the C35 reporting stations in SE Houston near the site of the 2006 NATIVE measurements.

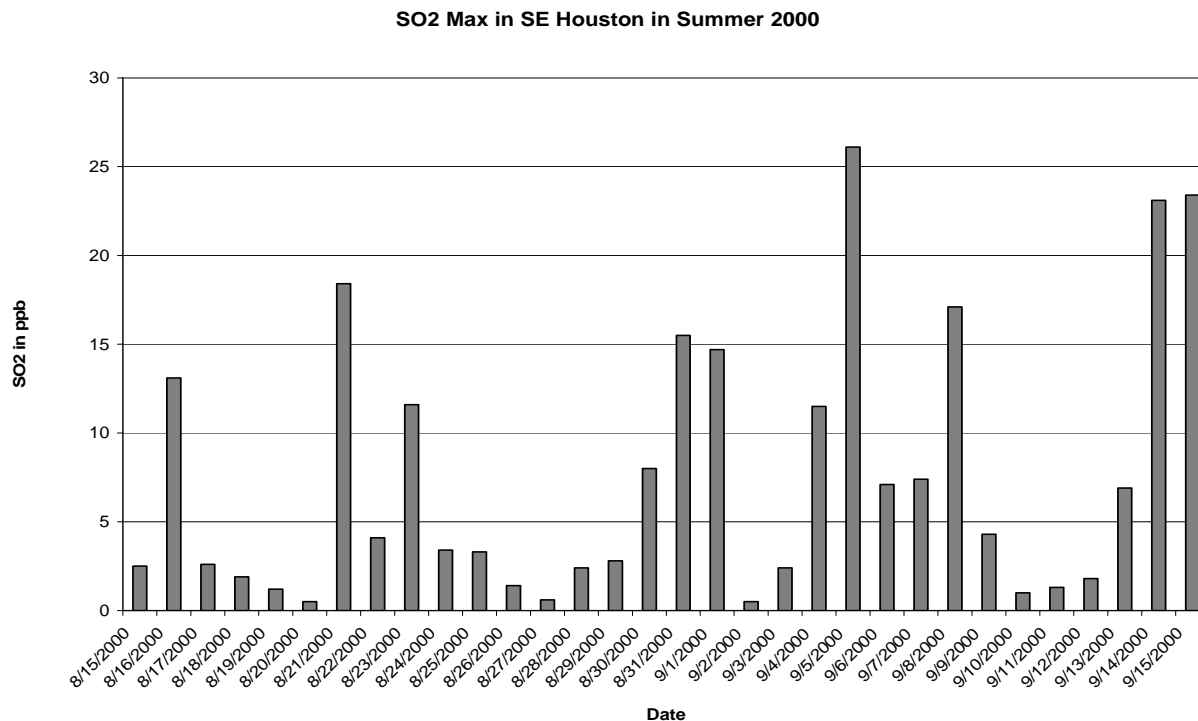


Figure 4: This table shows the daily 1-hour average maximums in sulfur dioxide (SO₂) concentration at the C406 reporting station in SE Houston near the site of the 2006 NATIVE measurements.

As shown in Figure 1, much of Texas AQS 2000 was marked with several periods of notably high ozone. For episodes in which high ozone was observed, higher amounts of SO₂, NO_x and CO were also observed. Higher chemical concentrations correlate with warmer temperatures and a stagnant summer pattern. For the periods of higher measurements, especially ozone, the readings indicated in Figures 1-4 are actually conservative because of their location in the city. Measurements at stations further south and east toward the Houston Ship Channel and directly downwind of the heavy industry actually recorded ozone and other pollutant levels much higher, near 150 and 200 ppb. These levels fall in the unhealthy category according to the EPA⁴. The pollution episode around September 1 correlates with a heat wave that struck the Houston area with full sunshine and temperatures above 100 degrees Fahrenheit. The weather pattern was stagnant with slow moving air throughout much of the atmosphere and no significant feature to scour out the accumulated pollution. This verifies the fact that high heat, typical of summer, combined with a stagnant weather pattern results in the worst pollution episodes.

3.2 Spring 2006

In the spring of 2006 a combination of data was collected to observe pollution in Houston and in the atmosphere over Mexico and southeastern Texas. Sondes were launched from Houston to give pollution profiles of the atmosphere. NATIVE measured ground level pollution. The NASA DC-8 plane was flown to follow air believed to be coming from Mexico. The spring study lasted three weeks in March. During the time period no ozone violations occurred at the ground level where NATIVE was located; however, there are periods of notable pollutant accumulation, especially with ozone.

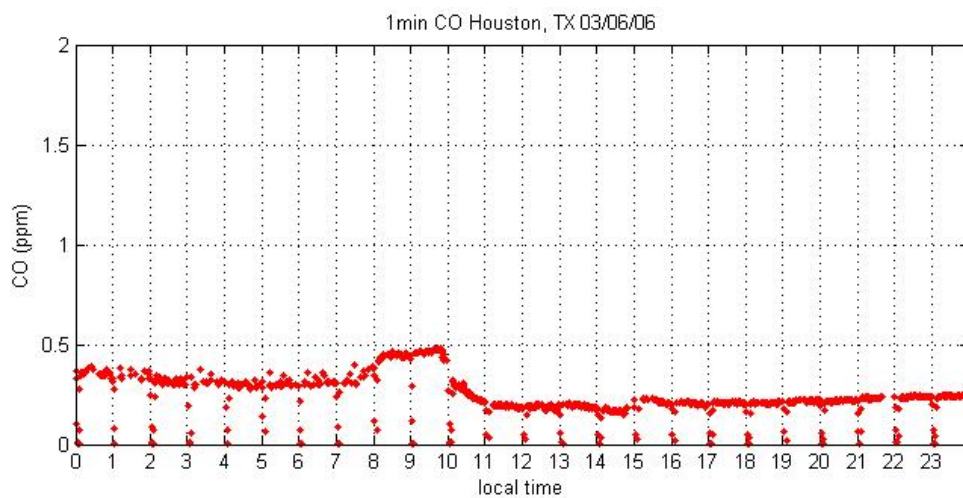


Figure 5 shows the carbon monoxide measurements from NATIVE on March 6, 2006, a typical day for pollution in the Houston area.

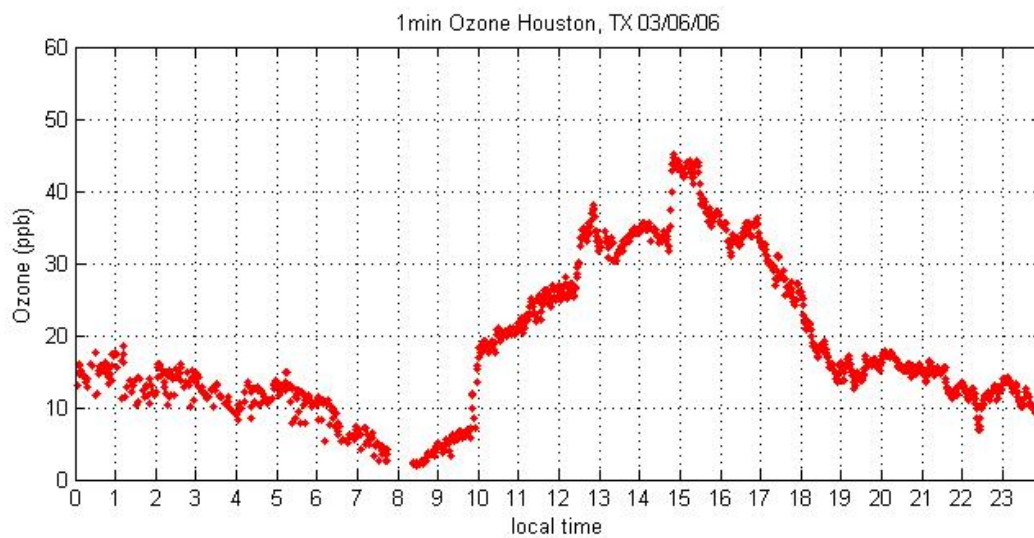


Figure 6 shows the ozone as measured by NATIVE on March 6, 2006.

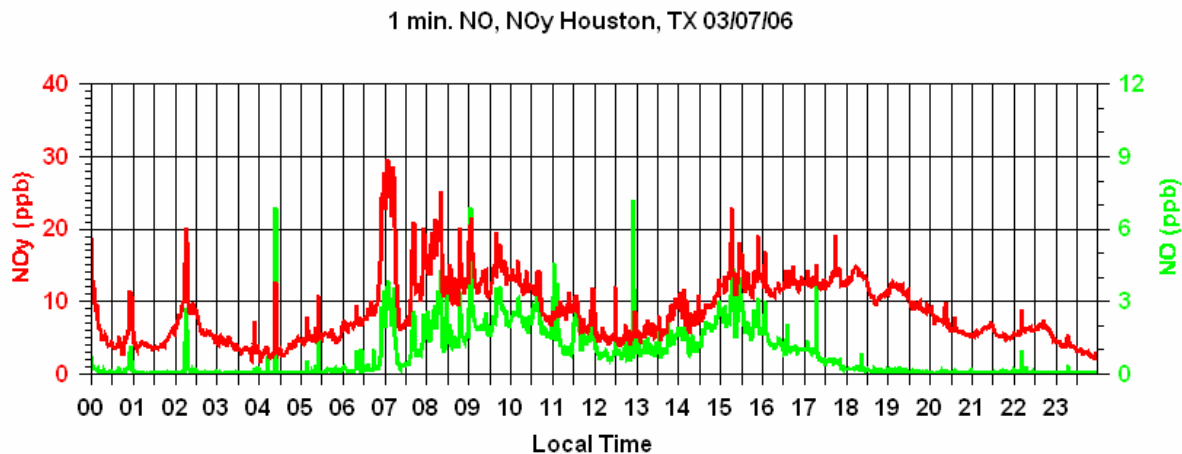


Figure 7 shows the nitric oxides as measured by NATIVE on March 6, 2006

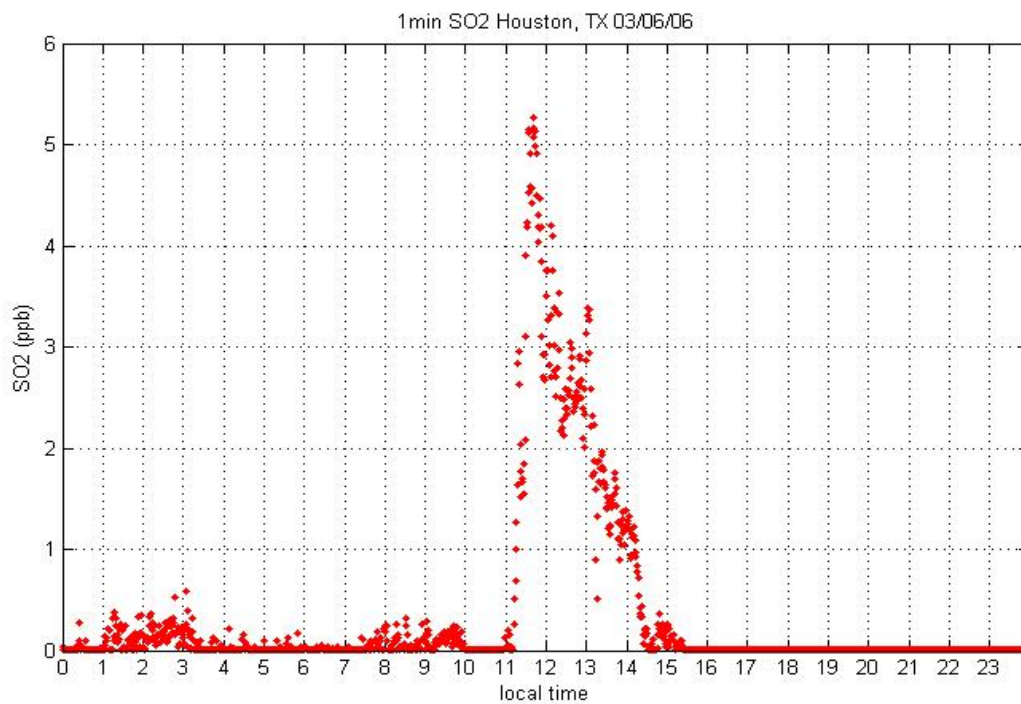


Figure 8 shows the SO₂ as measured by NATIVE on March 6, 2006

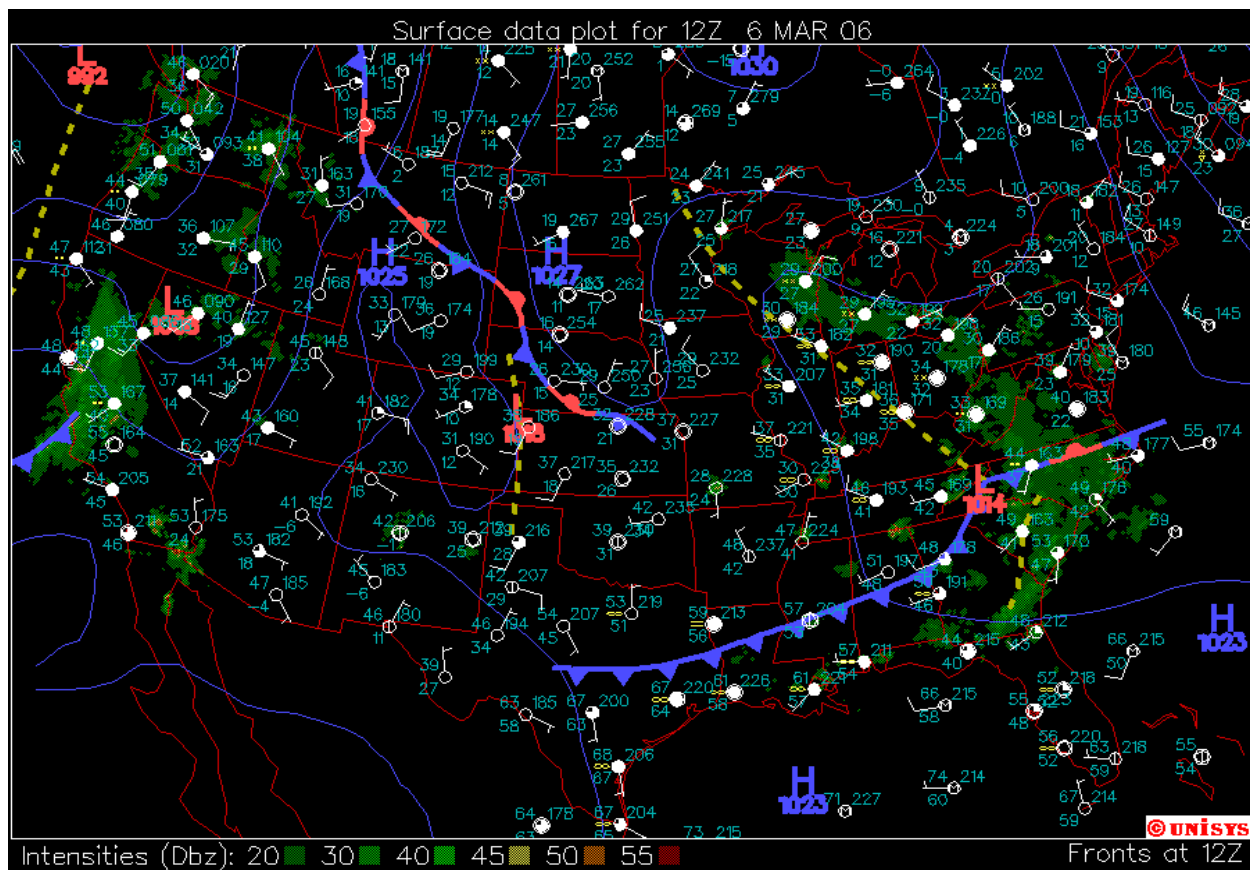


Figure 9 shows the surface weather map on March 6, 2006 by Unisys¹¹.

NOAA HYSPLIT MODEL
 Backward trajectories ending at 18 UTC 06 Mar 06
 EDAS Meteorological Data

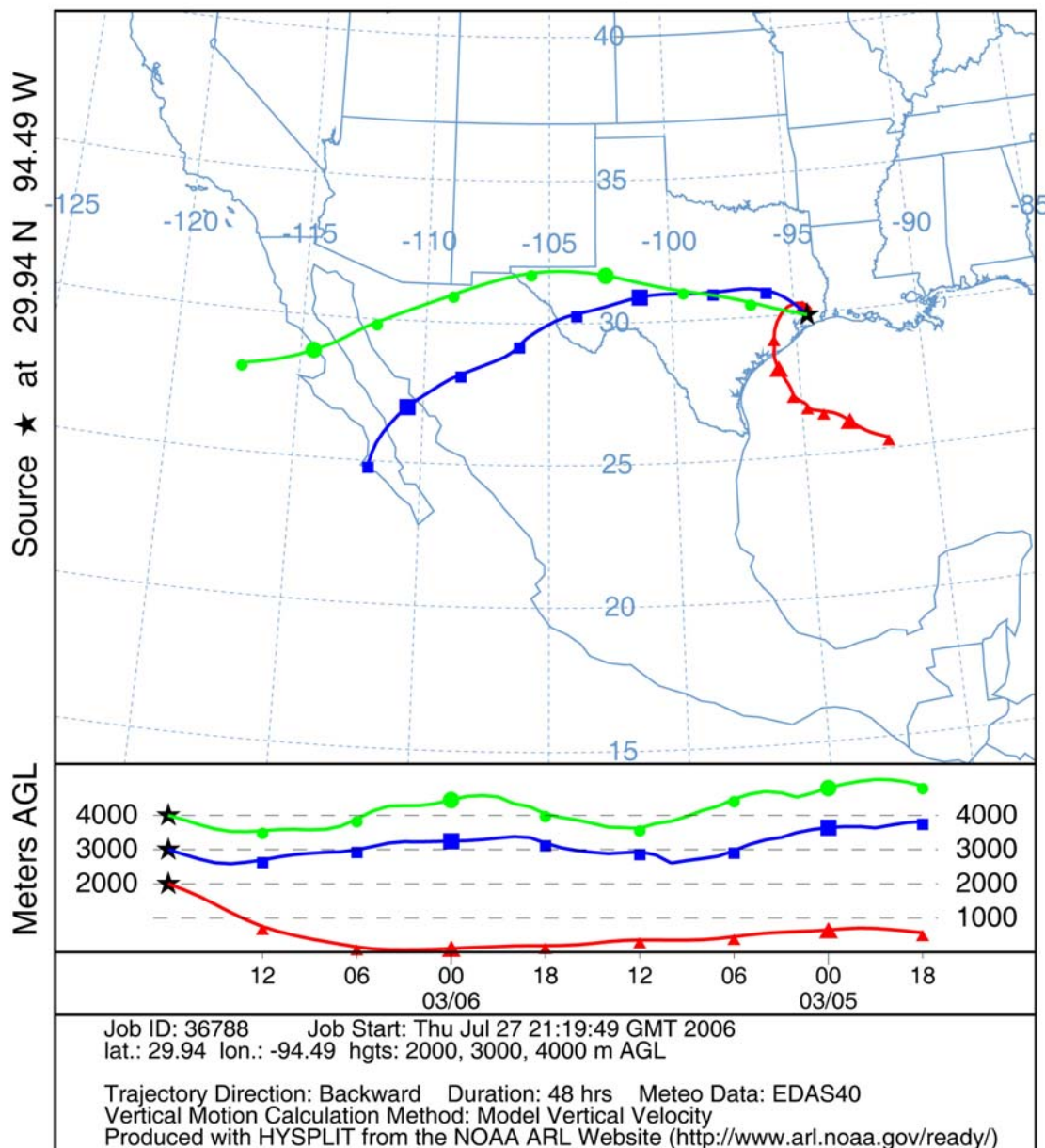


Figure 10 shows the back trajectory of air parcels over Houston using the HYSPLIT model.

On March 6, 2006, a generally typical day was observed in the Houston area. The ozone precursor pollutants, specifically CO and the nitric oxides, peaked during the morning as the

morning rush hour took place and the industry geared up (Figure 5 & 7). Sulfur dioxide also peaked early in the day, though a little later than the rush hour (Figure 8). These emissions set the stage for ozone production in the afternoon. The ozone peaked in mid-afternoon near 45 ppb and then cleared out by evening as shown in Figure 6. Factors that help clear out the ozone and other pollutants are a strong meteorological pattern that transports the pollutants to other regions and convective processes which transport the pollutants into the free troposphere higher in the atmosphere. Sometimes the sea breeze from the Gulf of Mexico helps disperse higher, more dangerous concentrations of pollution over a wider region. These occurrences allow for healthy exposures to pollutants as opposed to a build-up of pollutants that can lead to high levels.

Figure 9 shows the national surface weather map for the day. A cold front was passing through the Houston metropolitan area. The winds were nearly calm, indicated by the lack of wind barbs on the station model. Usually, a light wind and stagnation would allow a build-up of pollutants, but passage of the cold front dispersed the afternoon peak build up. Cold fronts are followed by cooler and drier air, which is perfect for scouring out pollutant-rich, hazy air that was found in Houston on March 6. Figure 10 is an air trajectory analysis from the HYSPLIT model. This indicates the origin of the air at various levels in the atmosphere. On March 6, the model shows that the air over Houston was primarily from the Pacific Ocean. Because oceanic air is usually clean, most of the measured pollution on March 6 was from local sources.

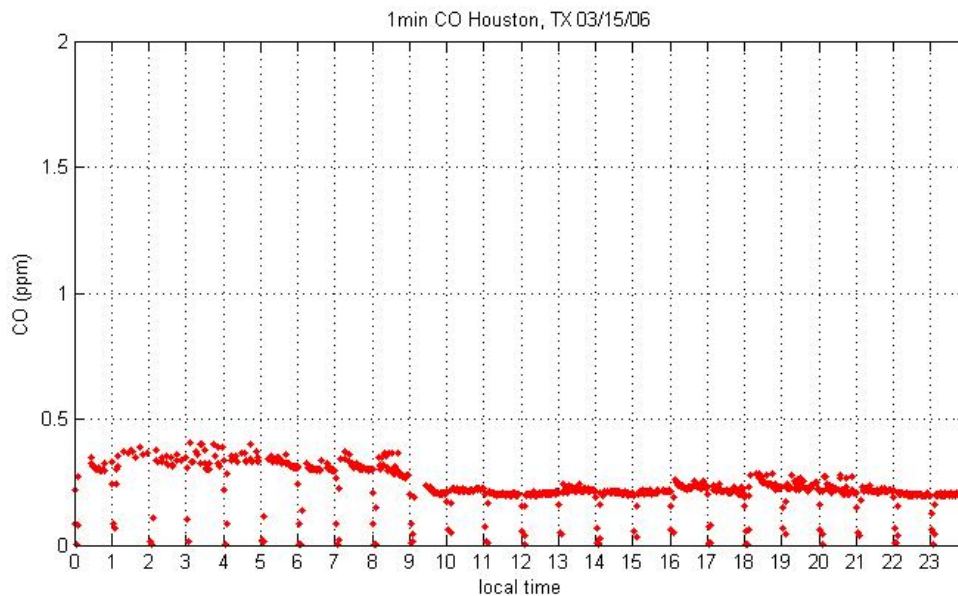


Figure 11 shows the carbon monoxide levels measured by NATIVE on March 15, 2006.

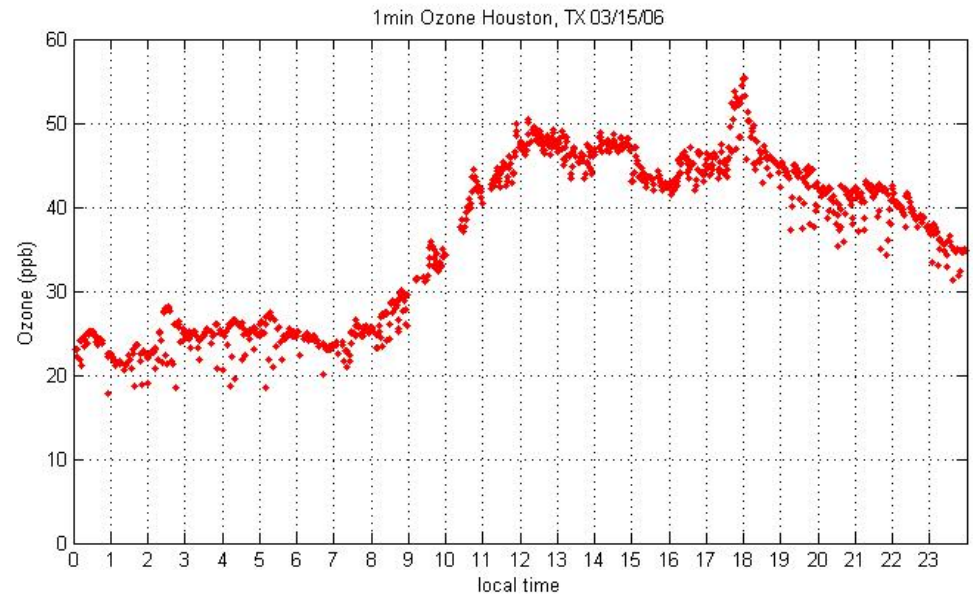


Figure 12 shows the ozone levels as measured by NATIVE on March 15, 2006.

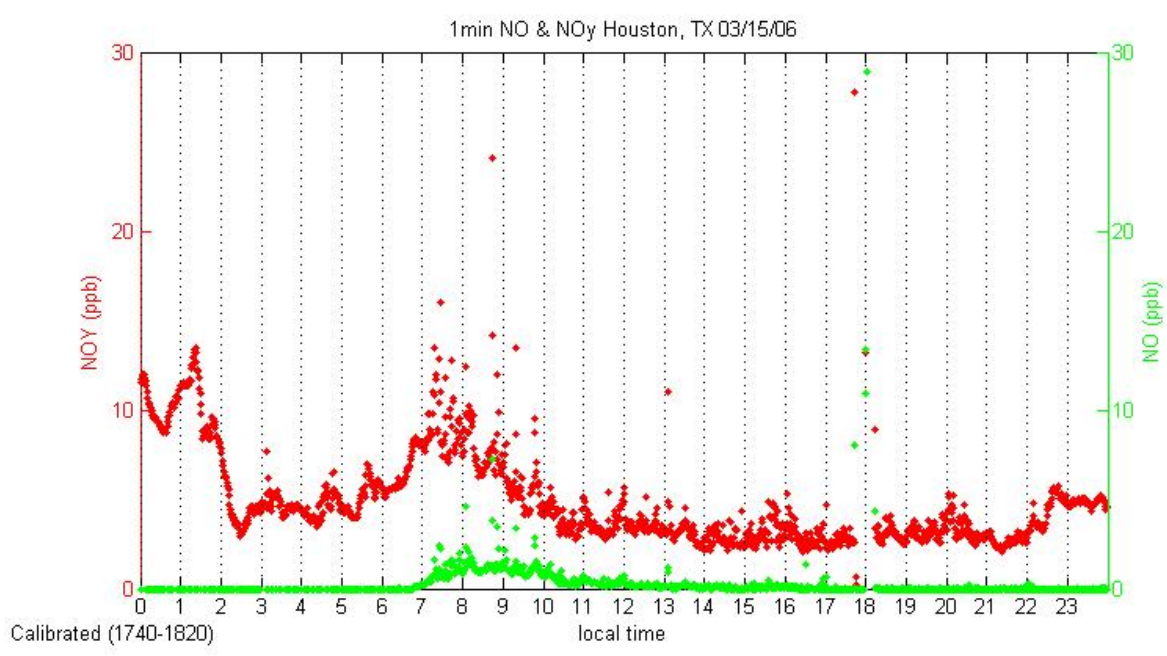


Figure 13 shows the nitric oxides as measured by NATIVE on March 15, 2006

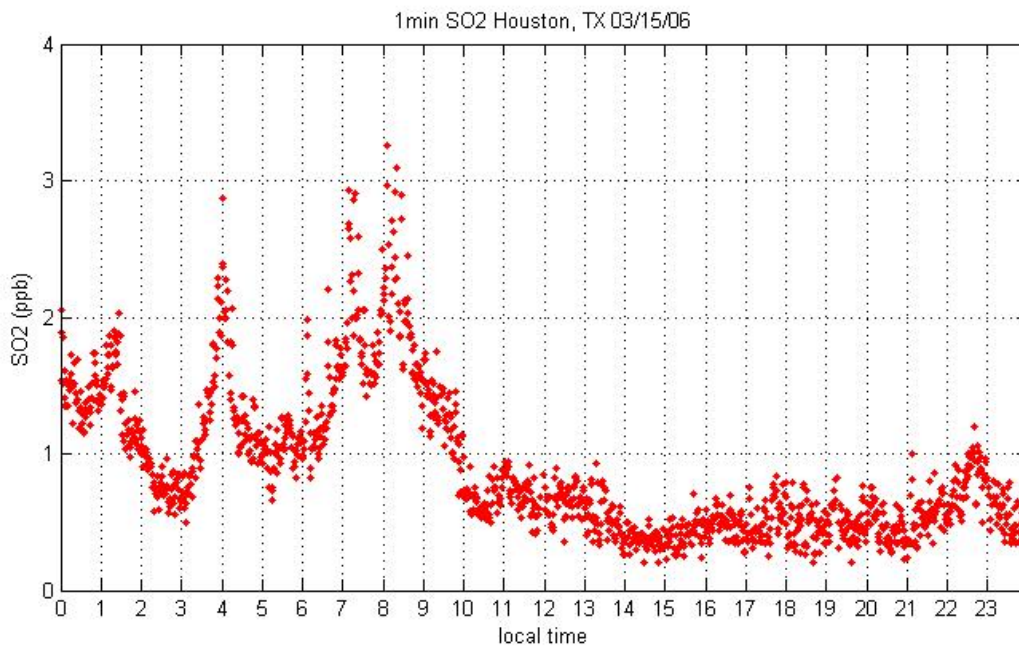


Figure 14 shows the SO₂ as measured by NATIVE on March 15, 2006

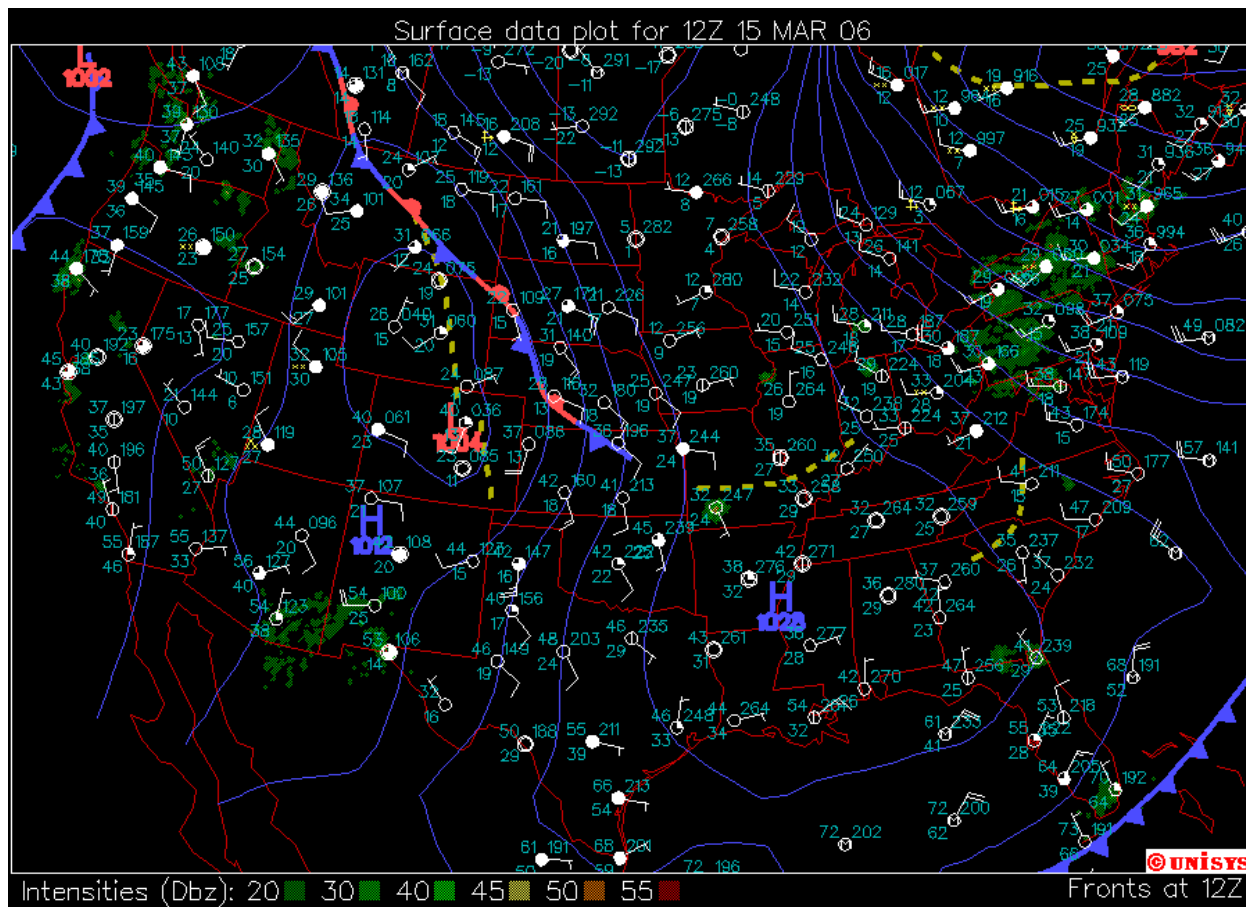


Figure 15 the surface weather map on March 15, 2006 by Unisys¹¹.

NOAA HYSPLIT MODEL
 Backward trajectories ending at 18 UTC 15 Mar 06
 EDAS Meteorological Data

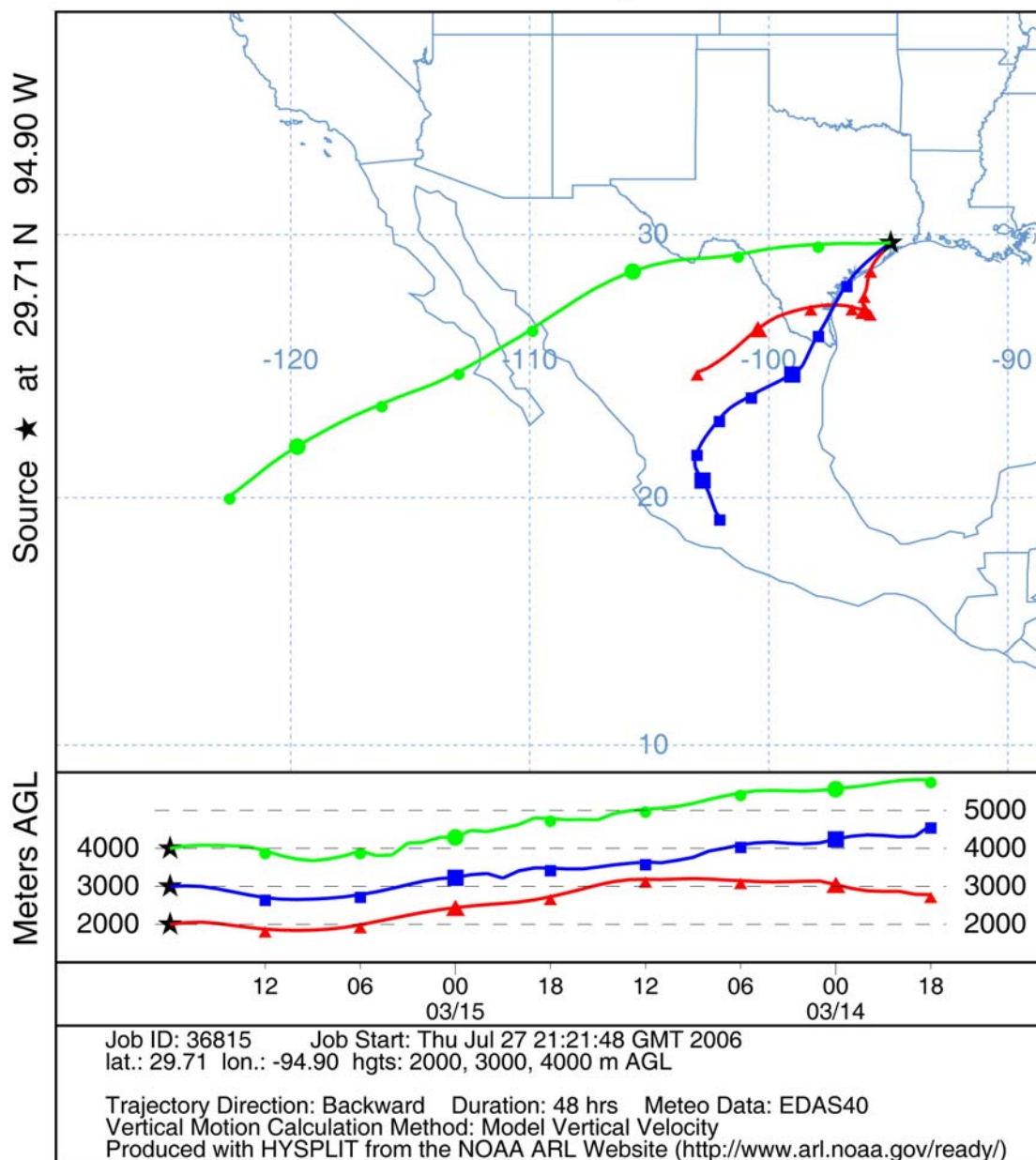


Figure 16 shows the back trajectory of air parcels over Houston using the HYSPLIT model.

March 15 was an example of pollutant accumulation in the Houston area indicative of the springtime secondary peak. The CO emission levels were higher in the morning hours than on

March 6 and there was a small, but steady increase in CO levels during the evening (Figure 11). The nitric oxides and SO₂ also showed the peak as expected during the morning rush hour time frame, although both pollutants also showed some early morning activity (Figures 13 & 14). The ozone peaked in the afternoon as expected with a reading of 55 ppb, very similar to March 6 (Figure 12). As the evening progressed, however, the ozone levels did not reduce back to the morning levels. The ozone levels dropped from the mid-afternoon peak, but remained relatively high, near 40 ppb. On the next day, this remnant ozone could pose a problem as more emissions can accumulate, especially CO to create more ozone.

Figure 15 shows the national surface weather map for March 15. According to the map, a ridge of high pressure was over the southeastern US. Winds in Houston, indicated by the wind barb were out of the northeast at the time of map analysis; however, surrounding stations reported a light southerly and southeasterly wind. These winds would mean that air from the Gulf of Mexico was moving over eastern Texas at the surface. The back trajectory from this day shows that the air was generally coming from northern Mexico and central areas of Mexico.

4. Summary & Future Research

Summer 2000 shows the primary peak in regional pollution for the Houston area. Stagnant weather patterns and high heat and sunshine make production of ozone and accumulation of ozone, nitric oxides, carbon monoxide, and sulfur dioxides a frequent occurrence. The concentrations of these pollutants reach unhealthy levels with no relief until a significant pattern scours out the air. During the spring, the weather patterns are more defined. As the spring 2006 indicates, accumulation of pollutants tends to be less severe because the temperatures are lower and the passage of cold fronts and other weather features are more frequent.

Houston does experience a second regional pollution peak, however, with suspicion of contributions from Mexico and Central America. Currently, the analysis has not led to a definitive conclusion of outside contributions to Houston pollution during the early spring. The examples presented in the research are rather ambiguous can neither confirm nor reject the suggestion of Mexico City and Central American influence on Houston. More in-depth analysis is underway and will continue using the spring 2006 data. If Mexico City pollution outflow and biomass burning outflow from Central America and Mexico proves to directly affect Houston's early spring pollution peak, the pollutants would transport over Houston well above the surface and mix down to the surface as daytime heating progresses.

5. References & Citations

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- 6 <http://www.tceq.state.tx.us/>
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- 9 <http://www.meteo.psu.edu/%7Ebtaubman/Webpage/native.html>
10 Meteorology Department, Penn State University, 503 Walker Building, University Park,
PA 16802-5013; 814-865-0479, fax-814-865-3663; anne@met.psu.edu
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