4.1 EVALUATION OF THE DALLAS-FORT WORTH OZONE POLLUTION PLUME FAR DOWNWIND IN RURAL SOUTHERN OKLAHOMA

Mark E. Sather*
U.S. Environmental Protection Agency (EPA), Region 6, Dallas, Texas

ABSTRACT

Since 1999 the Oklahoma Department of Environmental Quality (ODEQ) has operated ambient ozone monitors in the south central part of Oklahoma, just north of the Red River border between Texas and Oklahoma and about 80 miles north of the central Dallas-Fort Worth area. This paper will provide detailed analyses of ambient ozone and related meteorological data from the Oklahoma Red River and select Dallas-Fort Worth sites for the time period 1999 to 2012. The analyses will include: (1) mapping 8-hour ozone exceedance days from the Oklahoma Red River ozone sites, (2) reviewing meteorological data for Red River 8-hour ozone exceedance days, (3) interpretation of detailed ozone diurnal profiles, and (4) conducting an ozone monitoring data trends study. The results of these analyses will improve understanding of the nature of the Dallas-Fort Worth ozone pollution plume far downwind in rural southern Oklahoma and will help in assessment of the effectiveness of current 8-hour ozone pollution controls being employed in the Dallas-Fort Worth 8-hour ozone nonattainment area.

1. INTRODUCTION

In order to better understand the influence of the Dallas-Fort Worth ozone pollution plume far downwind in rural southern Oklahoma during periods of predominant southerly wind flow, the Oklahoma Department of Environmental Quality (ODEQ) has deployed numerous ozone monitoring sites in south central Oklahoma (just across the Red River border with Texas) from 1999 to the present. The south central Oklahoma area is rural with low population density and a scarcity of major nitrogen oxides (NO_x) and volatile organic compound (VOC) stationary emission sources. Figure 1 displays the locations of all of the Oklahoma Red River ozone monitoring sites, each monitor's years of operation, and locations of the major NO_x and VOC stationary source emissions. The ODEQ has shut down the ozone monitoring sites at Terral, Lake Murray, Tishomingo, Kingston and Lake Texoma. Currently, ozone monitoring alternates every two years between the Healdton/Burneyville site pair and the Walters/Lake Waurika site pair. This paper updates an earlier analysis of the Red River ozone monitoring data (which focused on 1999-2006 data)[1] to 2012.

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* Corresponding author address: Mark E. Sather, U.S. EPA, Region 6, Air Quality Analysis Section, 1445 Ross Ave, Dallas, TX 75202; e-mail: sather.mark@epa.gov

The results of the analyses will help improve understanding of the highest ozone concentrations recorded in south central Oklahoma, and help in the assessment of the effectiveness of ongoing ozone precursor emission controls being employed in the Dallas-Fort Worth 8-hour ozone nonattainment area.

2. ANALYTICAL METHODS

All hourly ozone data analyzed for this paper were extracted from the U.S. Environmental Protection Agency (EPA) Air Quality System (AQS) database after data collection, validation, and upload by the ODEQ and the Texas Commission on Environmental Quality (TCEQ). Hourly ambient ozone precursor (i.e. NO_x and VOC), and meteorological data were also downloaded from AQS for the Fort Worth Meacham Field site. Hourly meteorological data were obtained from the University of Oklahoma-Oklahoma Climatological Survey for the Burneyville Mesonet site. The Burneyville Mesonet site is located 1,590 meters from the Burneyville ozone monitoring site (source: AQS). Geographic Information Systems (GIS), the 2008 National Emission Inventory (NEI), the 2010 Census data, and the National Oceanic and Atmospheric Administration (NOAA) HYSPLIT model[2] were used to construct Figures 1-3 in this paper. The NOAA HYSPLIT back trajectories were run for 24-hours at 100 meters above ground level and used EDAS meteorological data. Each 24-hour back trajectory began at the end hour of the daily maximum 8-hour ozone concentration for each modeled site.

3. RESULTS AND DISCUSSION

3.1 Back Trajectory Mapping of 8-hour Ozone Exceedance Days at Oklahoma Red River Ozone Sites

Back trajectory mapping using NOAA's HYSPLIT model was completed for 187 8-hour ozone exceedance days from all Red River ozone sites during the period 1999-2012. An 8-hour ozone exceedance day consisted of days with maximum 8-hour ozone concentrations greater than the 2008 8-hour ozone National Ambient Air Quality Standard (NAAQS) of 75 ppb. This was in addition to the previously run 57 back trajectory maps completed for an earlier Red River ozone analysis project for the years 1999-2006.[1] The earlier analysis just looked at 8-hour ozone exceedance days above the old 1997 8-hour ozone NAAQS of 84 ppb. Thus, 244 8-hour ozone exceedance days at the Red River ozone monitors pictured in Figure 1 were mapped using the NOAA HYSPLIT model for the period 1999-2012. A total of

224 days (92%) had air masses track back to the Dallas-Fort Worth area, with 20 days (8%) having air masses track back through other areas of Oklahoma, including the Tulsa and Oklahoma City areas. A southeasterly wind flow component was observed for most of the southerly back trajectories, representing 92% of the total southerly back trajectories (205 out of 224 days). Figure 2 displays a common southeasterly back trajectory map from the Red River area on an 8-hour ozone exceedance day. On this day, August 29, 2011, the peak 8-hour ozone concentration was recorded at the Healdton site (96 ppb), located about 70 miles northwest of Pilot Point, currently the most northern Dallas-Fort Worth area ozone monitoring site. The HYSPLIT 24-hour back trajectory was run at 100 meters above ground level and did not appreciably change in altitude as it passed back to the southeast over the Dallas-Fort Worth area. The ozone concentrations were over the 75 ppb standard in the northern part of the Dallas-Fort Worth area, peaked at the Healdton site far downwind across the Red River, and then began to decrease further downwind to the north and northwest, although ambient ozone concentrations there continued to read over the 75 ppb standard. Figure 3 shows an example of a northerly back trajectory. In this example, ozone concentrations increased from north of Oklahoma City to the south of Oklahoma City, and then peaked at the Red River sites about 70 miles further downwind at Healdton (84 ppb) and Walters (85 ppb).

3.2 Review of Meteorological Data

Detailed meteorological data analyses were conducted for both the Burneyville Mesonet site and the Fort Worth Meacham Field site. The highest temperatures (i.e. ambient temperatures greater than or equal to 90 degrees Fahrenheit) and the lowest wind speeds (i.e. resultant wind speeds less than 5 mph) were analyzed because of their importance in ozone formation and accumulation.[3] Resultant wind direction readings were also analyzed to help assess the origination of ozone precursor and ozone air parcels arriving at the Red River ozone sites. Summary statistics were produced for each meteorological parameter for the hours 0500-1900 LST during June-August for all monitoring years at both the Burneyville and Fort Worth Meacham Field sites. These statistics were then compared to those derived from analysis of meteorological data on the 69 8-hour ozone exceedance days at the Burneyville ozone site. In addition, resultant wind speeds were analyzed during the morning commute hours (0500-0800 LST) and the late morning/afternoon air mass movement hours (0800-1900 LST).

Table 1 displays the results of the meteorological data analyses. Cells shaded in gray will be discussed in detail here. First, the percentage of time ambient temperatures were equal to, or greater than, 90 degrees F was higher on Burneyville 8-hour ozone exceedance days (at Burneyville, 48% of the time vs. 40% of the time on an average summer day; at Fort Worth Meacham Field, 45% of the time vs. 39% of the time on an average summer day). Higher temperatures can promote more atmospheric chemistry. Second, morning commute wind speeds were statistically significantly lower on 8-hour ozone exceedance days at both the Fort Worth Meacham Field and Burneyville Mesonet sites. This allowed for increased buildup of ozone precursors in both the Dallas-Fort Worth core and close to the Red River area on 8-hour ozone exceedance days. Note the increase in total non-methane organic compounds (TNMOC) and NO_x ambient concentrations from 0500-0800 LST on 8-hour ozone exceedance days at the Fort Worth Meacham Field site in the last two rows of Table 1. Afternoon wind speeds were also lower at the Fort Worth Meacham Field site on 8-hour ozone exceedance days but not at Burneyville. The Burneyville Mesonet site recorded the same afternoon average resultant wind speed (7.9 mph) on both exceedance days and average summer days, supporting the hypothesis that the afternoon ozone concentrations recorded at Burneyville are largely from previously photochemically formed ozone concentrations far upwind of the site, such as from the Dallas-Fort Worth area and sometimes from other areas in Oklahoma such as Oklahoma City or Tulsa. Finally, 8-hour ozone exceedance days at Burneyville were dominated by southeasterly wind flow (about 2/3 of the time). Total southerly wind flow on 8-hour ozone exceedance days from 0500-1900 LST was 87% at Burneyville and 95% at Fort Worth Meacham Field.

3.3 Interpretation of Ozone Diurnal Profiles

Hourly ozone diurnal profiles were constructed for the three ozone sites at Burneyville (Figure 4), Walters (Figure 5) and Healdton (Figure 6). Each diurnal profile figure covers June-August for the six years of operation at each site and also plots the average ozone diurnal profile for all 8-hour ozone exceedance days during May-September for the six years of operation at each site. The ozone exceedance day profiles at all three sites track the profiles for the other six annual June-August averages through hour 0700 LST. Then over the next three hours, from 0800 LST to 1100 LST, the hourly ozone concentrations increase at a higher rate compared to the annual average June-August traces, resulting in a clear separation for the rest of the day for the trace for the 8-hour ozone exceedance days compared to the annual summer average curves. The higher ozone production rate from 0800-1100 LST on ozone exceedance days probably results from the arrival of air containing higher concentrations of NO_x and VOC precursors which are undergoing photochemical conversion to ozone. This photochemically active air originates about 20 miles away from the monitoring sites (usually from the south), based on the average morning wind speeds observed at both the Burneyville Mesonet and Fort Worth Meacham Field sites. For the next eight hours from 1100-1900 LST the air arriving at the Red River ozone sites is probably dominated by higher concentrations of previously photochemically formed ozone which, based on the average afternoon wind speeds of 7-8 mph from the Burneyville Mesonet and Fort Worth Meacham Field sites, traces back another 60 miles to the core of the Dallas-Fort Worth area where elevated NO_x and VOC precursors had collected during the morning rush hours. Examining the individual year average traces at the Walters and Healdton sites (Figures 5 and 6) shows that the last two years, 2011 and 2012, recorded the highest hourly average ozone concentrations, coinciding with the highest ambient temperatures recorded in the south central Oklahoma area during the six years of monitoring site operations at Walters and Healdton.

3.4 8-hour Ozone Monitoring Data Trends at Red River Ozone Sites

Ozone monitoring data trends were analyzed at the Burneyville, Walters and Healdton sites. Each of those three sites had six years of ozone monitoring data recorded during the period 1999-2012 as seen in Figure 7. The left axis of Figure 7 plots the percentage of time at each monitor during June-August for the 8-hour periods ending at 1600-1900 LST where 8-hour ozone concentrations were greater than the 2008 National Ambient Air Quality Standard threshold of 75 ppb. The right axis of Figure 7 plots the mean ambient temperature for the hours 0500-1900 LST during June-August at the Burneyville Mesonet site. Ozone concentrations decreased at the Burneyville site from 1999-2000 to 2005-2006 to 2009-2010. The 2010 mean June-August ambient temperature was the second highest for the six years examined at Burneyville yet encouragingly there were no 8-hour ozone exceedances of the 75 ppb standard recorded at the Burneyville ozone site. Note in Figure 4 that the 2010 average summer day ozone diurnal profile had the lowest afternoon ozone concentrations displayed compared to the other five years of ozone monitoring data. The Walters and Healdton ozone sites generally recorded lower ozone concentrations in 2007-2008 compared to 2003-2004, but the high temperature years of 2011-2012 resulted in increased ozone concentrations. Note how the average summer day time temperatures at the Burneyville Mesonet site for 2011-2012 were higher than all four years 2003-2004 and 2007-2008. The year 2011 was especially hot (93.2 degrees Fahrenheit mean for June-August, 0500-1900 LST). Indeed, the average summer temperature in Oklahoma for 2011 was 86.9 degrees Fahrenheit, the hottest three month period for any State on record.[4]

4. CONCLUSIONS

Detailed evaluation of the Dallas-Fort Worth ozone pollution plume far downwind in rural southern Oklahoma was conducted using ambient ozone and meteorological data from 1999-2012. Over 90% of the 8-hour ozone exceedance days (based on the most recent 2008 8-hour NAAQS of 75 ppb) recorded at the southern Oklahoma Red River ozone monitoring sites showed air flow coming from the south, especially from the southeast, where the Dallas-Fort Worth metropolitan area and its ozone precursor concentrations reside. It is encouraging that 8-hour ozone concentrations decreased at the Burneyville site from 1999-2000 to 2005-2006 to 2009-2010, a time frame in which ozone precursors significantly decreased in the Dallas-Fort Worth area.[5] The very hot summers of 2011 and 2012, including the record hot summer of 2011 in Oklahoma, resulted in ozone concentration increases at the Red River ozone monitors Walters and Healdton after ozone concentrations decreased from the 2003-2004 to the 2007-2008 time period at those two sites. Future ozone concentrations at all Red River ozone sites will be analyzed against 2011-2012 and the other years to assess the effectiveness of continuing expected ozone precursor emission reductions in the Dallas-Fort Worth area.

REFERENCES

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3. *Rethinking the Ozone Problem in Urban and Regional Air Pollution*, National Research Council of the National Academies, The National Academies Press, Washington, D.C., 1992, pp 50-51, 56-57, 93.

4. S*tate of the Climate in 2011*, Special Supplement to the Bulletin of the American Meteorological Society, Vol. 93, No. 7, July 2012, pp 165-166.

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5. ILLUSTRATIONS AND TABLES

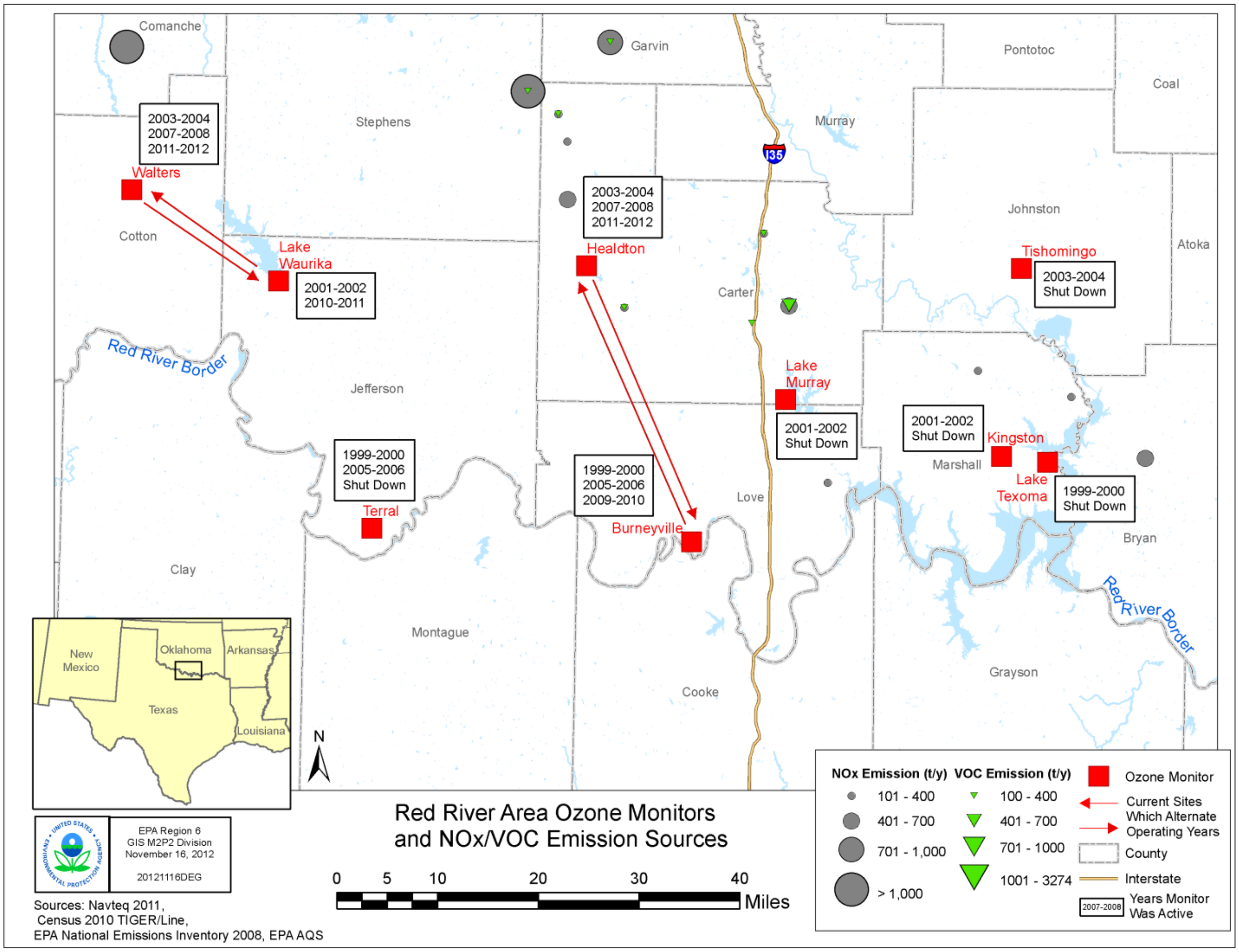


Figure 1. Red River area ozone monitors and stationary source NO_x/VOC emission sources in southern Oklahoma.

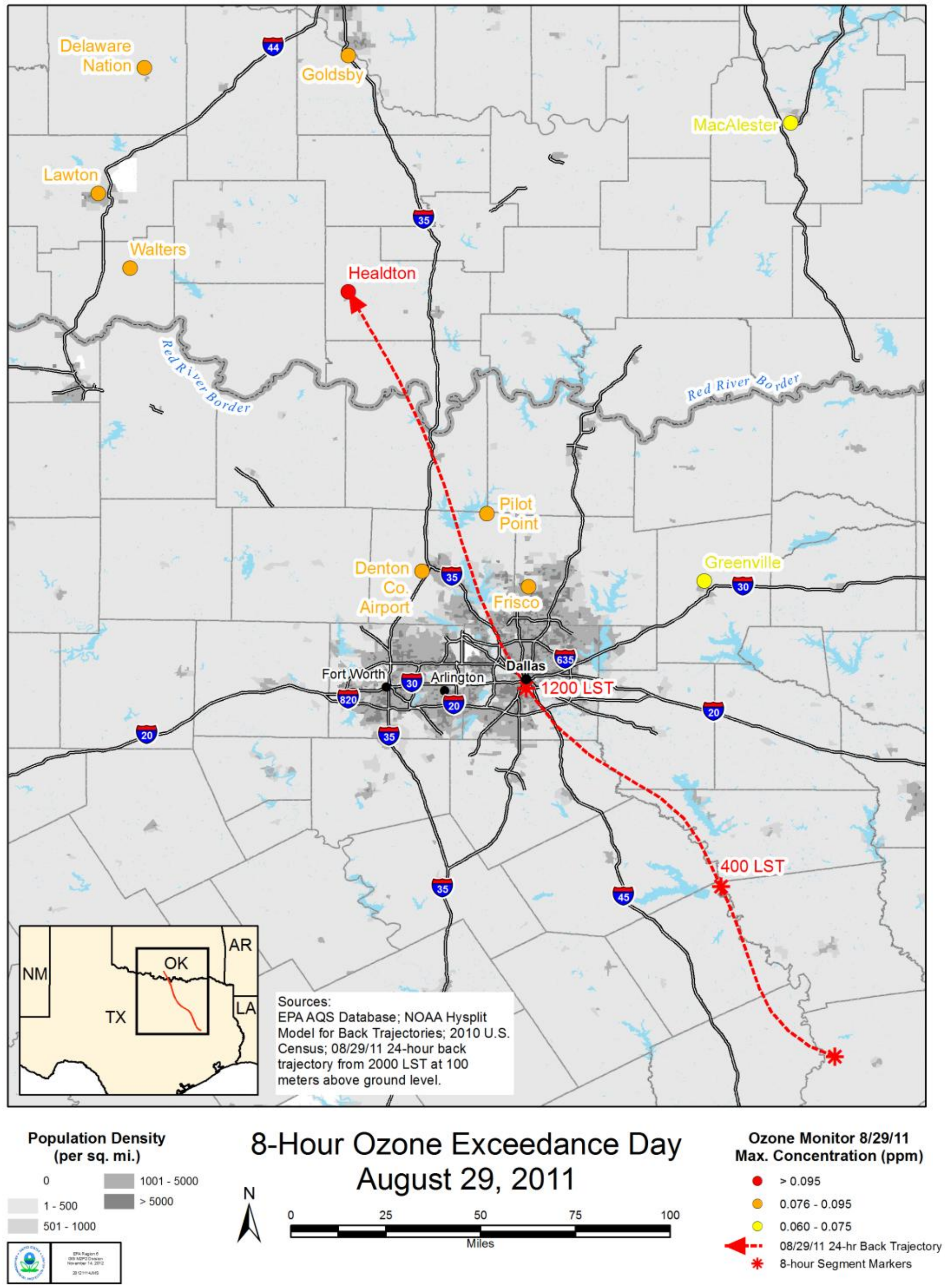


Figure 2. August 29, 2011 8-hour ozone exceedance day in southern Oklahoma and north Texas with southeasterly back trajectory.

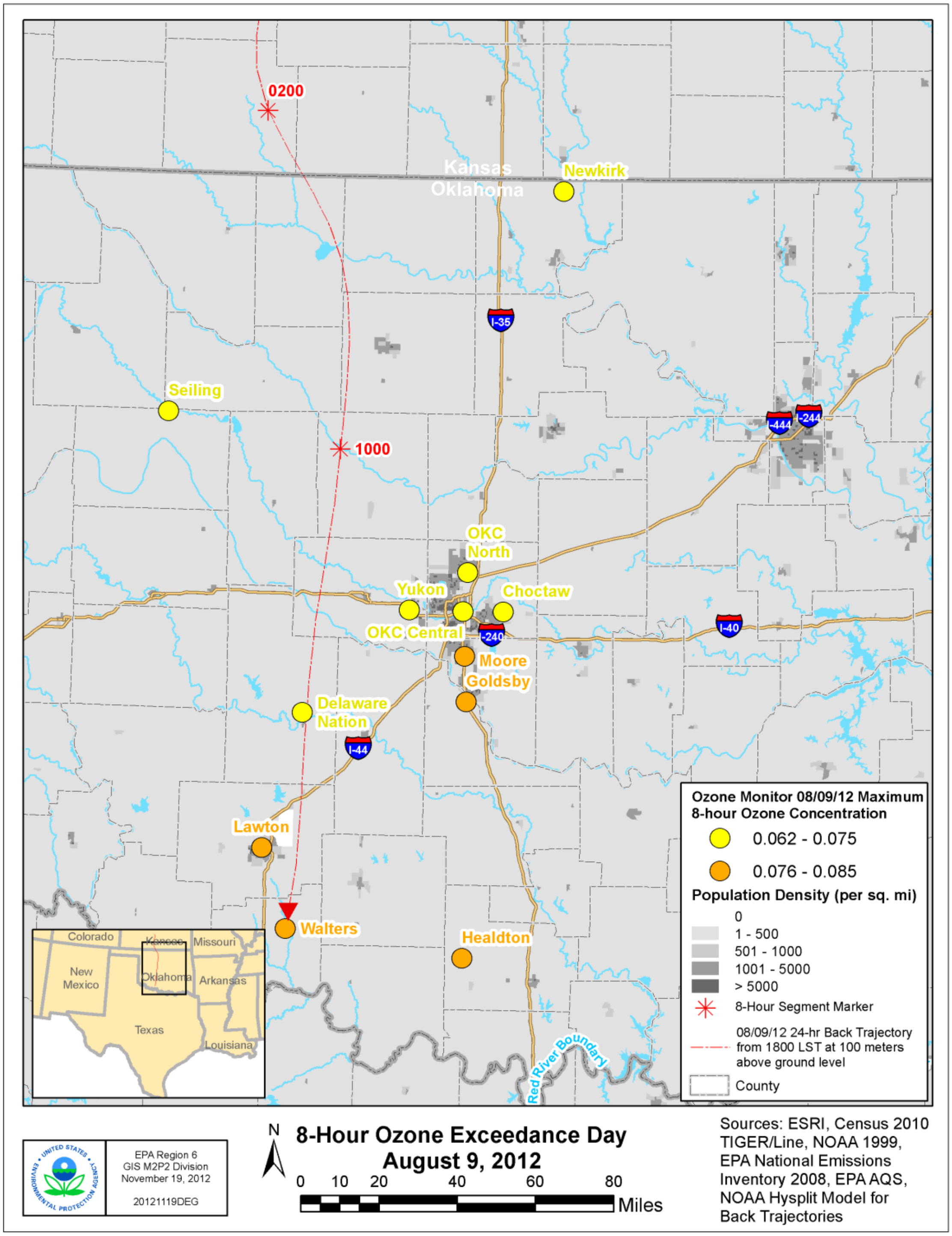


Figure 3. August 9, 2012 8-hour ozone exceedance day in Oklahoma with northerly back trajectory.

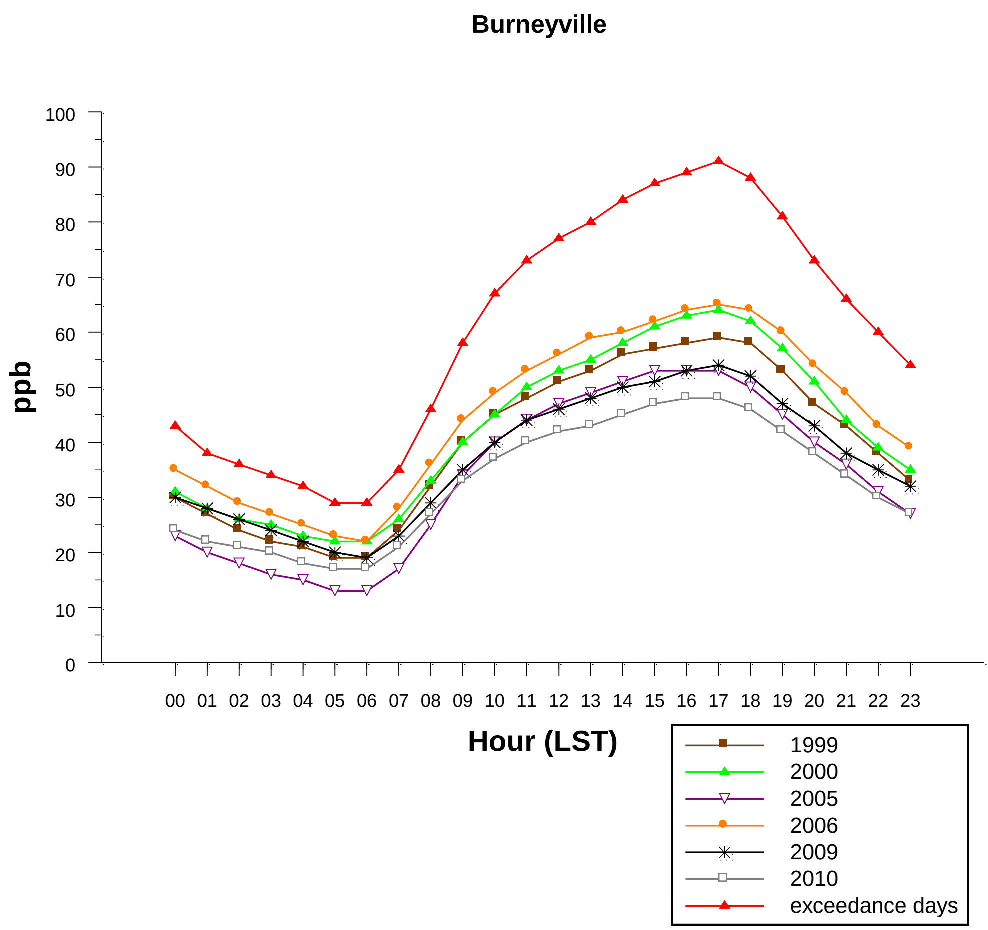


Figure 4. June-August hourly ozone concentration diurnal profiles at the Burneyville site; 8-hour ozone exceedance days for May-September.

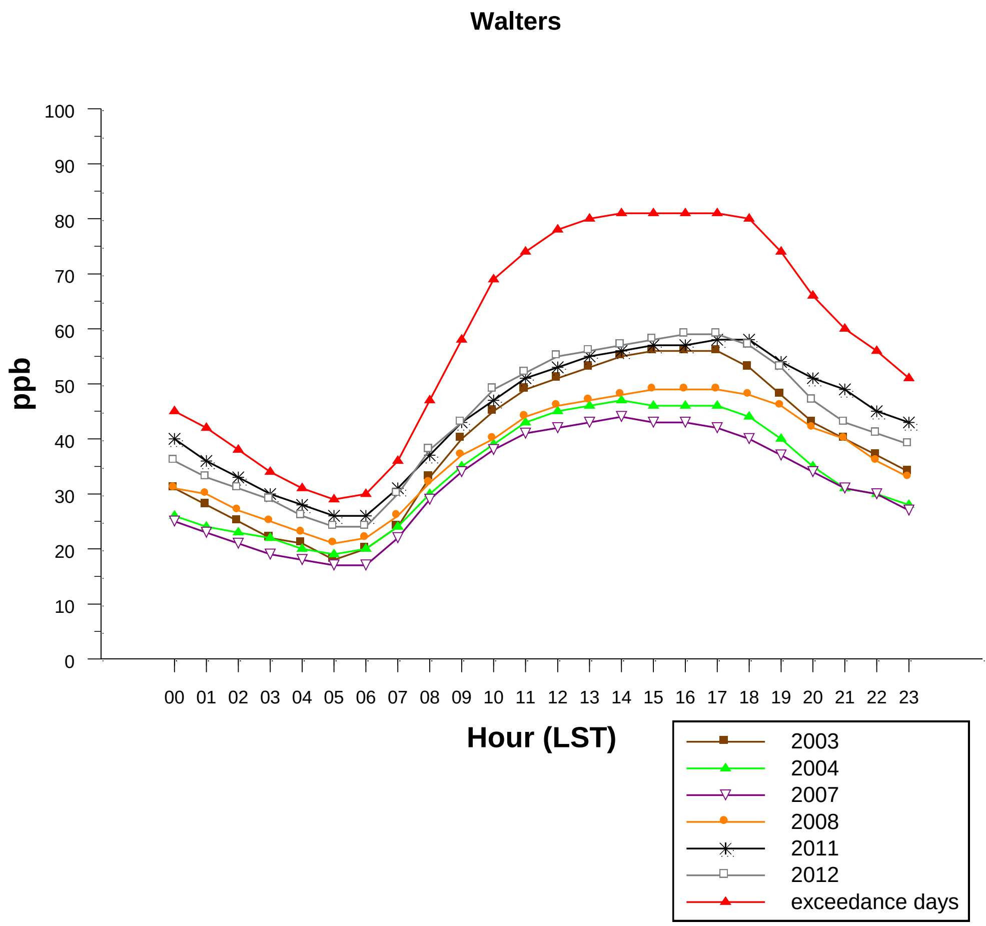


Figure 5. June-August hourly ozone concentration diurnal profiles at the Walters site; 8-hour ozone exceedance days for May-September.

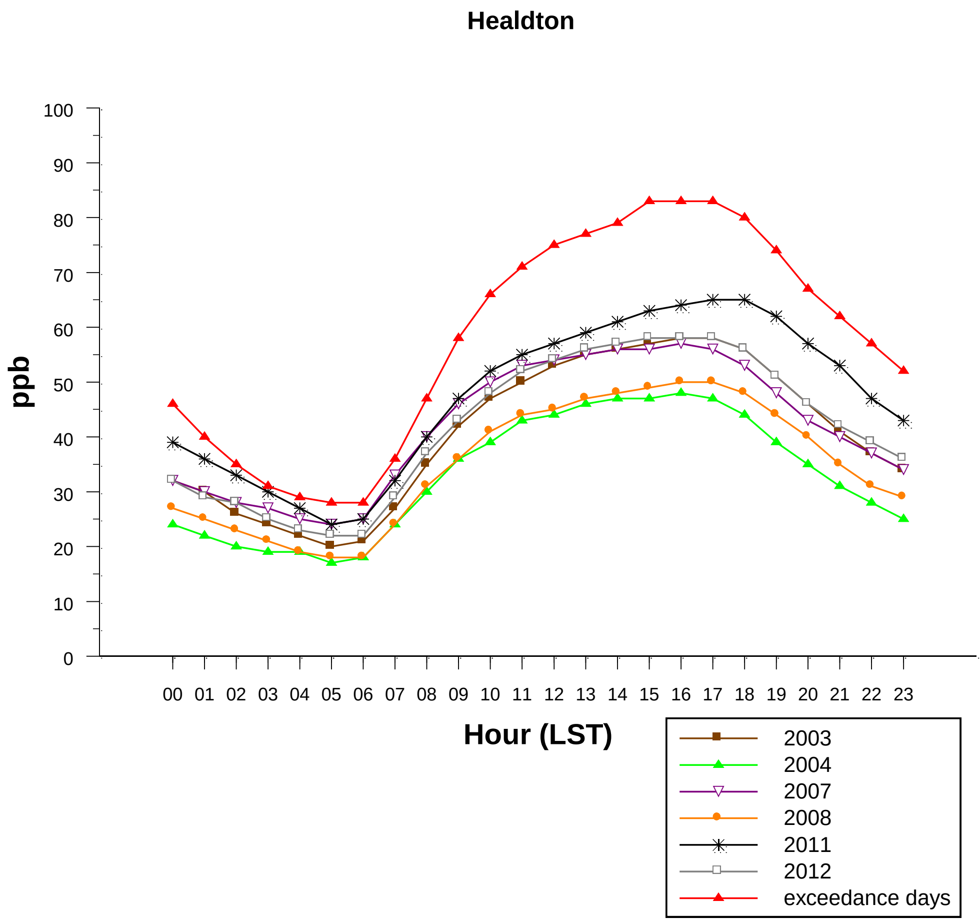
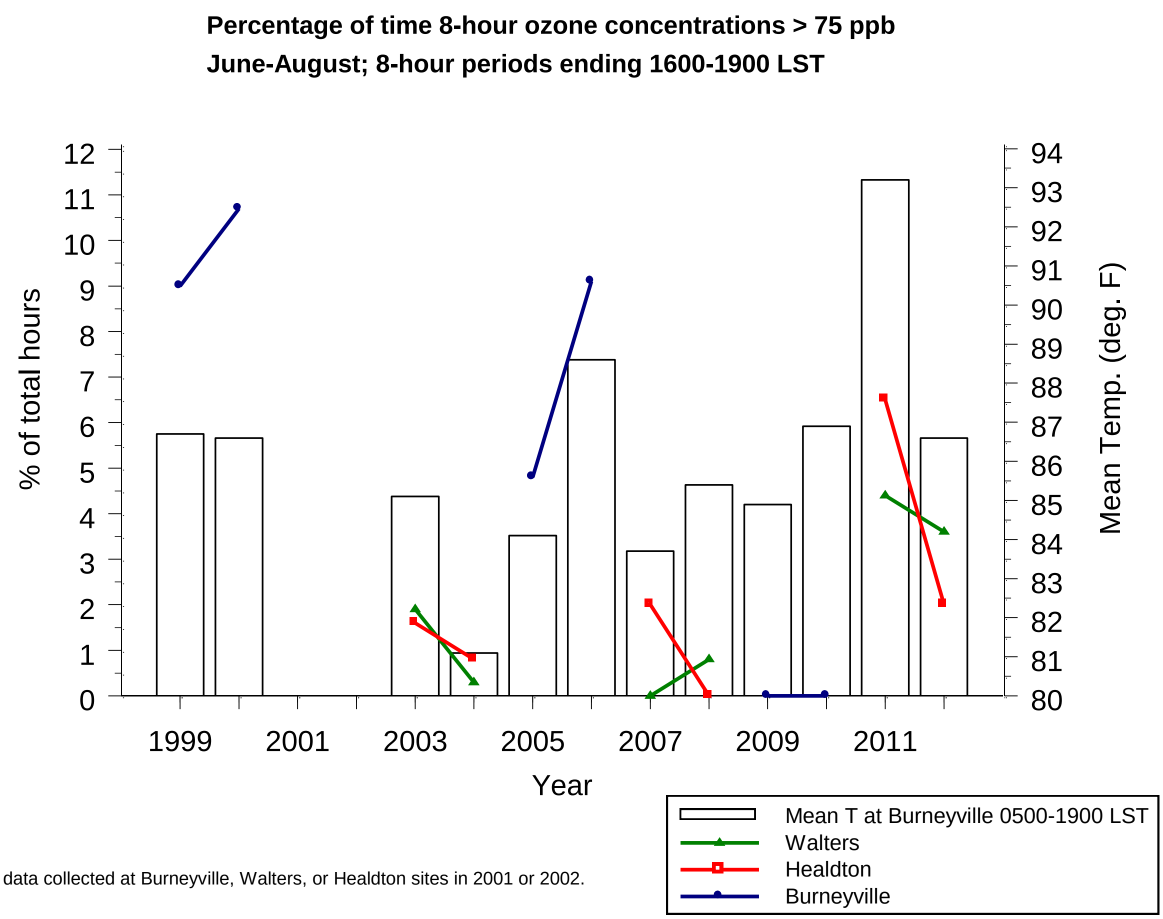


Figure 6. June-August hourly ozone concentration diurnal profiles at the Healdton site; 8-hour ozone exceedance days for May-September.



no ozone data collected at Burneyville, Walters, or Healdton sites in 2001 or 2002.

Figure 7. 8-hour ozone trends at red river ozone sites.

	Burneyville; average summer day (1999-2012 average)	Burneyville; 8-hour ozone exceedance day (average of 69 exceedance days in 1999, 2000, 2005, 2006)		Fort Worth Meacham; average summer day (1976-2011 average)	Fort Worth Meacham; 8-hour ozone exceedance days at Burneyville (1999, 2000, 2005, 2006)
% hours t >= 90 deg. F	39.5	47.9		39	45.3
mean t (deg. F)	85.9	86.6		86.2	86.8
% hours rws = 0-4 mph	24.6	22		23.7	27.7
% hours rws = 5-9 mph	49.5	54.9		56.1	62.5
% hours rws >= 10 mph	26	23.1		20.3	9.7
mean rws (mph)	7.2	7.0		6.9	6
mean rws (mph; 0500-0800 LST)	4.9	4.1		5.1	3.8
mean rws (mph; 0800-1900 LST)	7.9	7.9		7.4	6.6
% hours rwd from NE	17	10		13.1	2.5
% hours rwd from SE	48.3	66.4		43.6	67.1
% hours rwd from SW	27.6	20.9		35.7	28
% hours rwd from NW	7.2	2.7		7.6	2.5
TNMOC 0500-0800 LST (ppbC); 2003-2011				112	144
NOx 0500-0800 LST (ppb); 1999-2011				24	43

Table 1. Comparison of meteorological data at the Burneyville Mesonet and Fort Worth Meacham Field sites for June-August average summer days and for 8-hour ozone exceedance days (i.e. where the daily maximum 8-hour ozone concentrations were greater than 75 ppb) at the Burneyville ozone site. Average summer day = 0500-1900 LST except as noted; t = ambient temperature, rws = resultant wind speed, rwd = resultant wind direction, TNMOC = total non-methane organic compounds and NO_x = nitrogen oxides.