THE THREAT OF WILDLAND AND AGRICULTURAL FIRES TO OZONE NAAQS ATTAINMENT IN SOUTHEAST TEXAS

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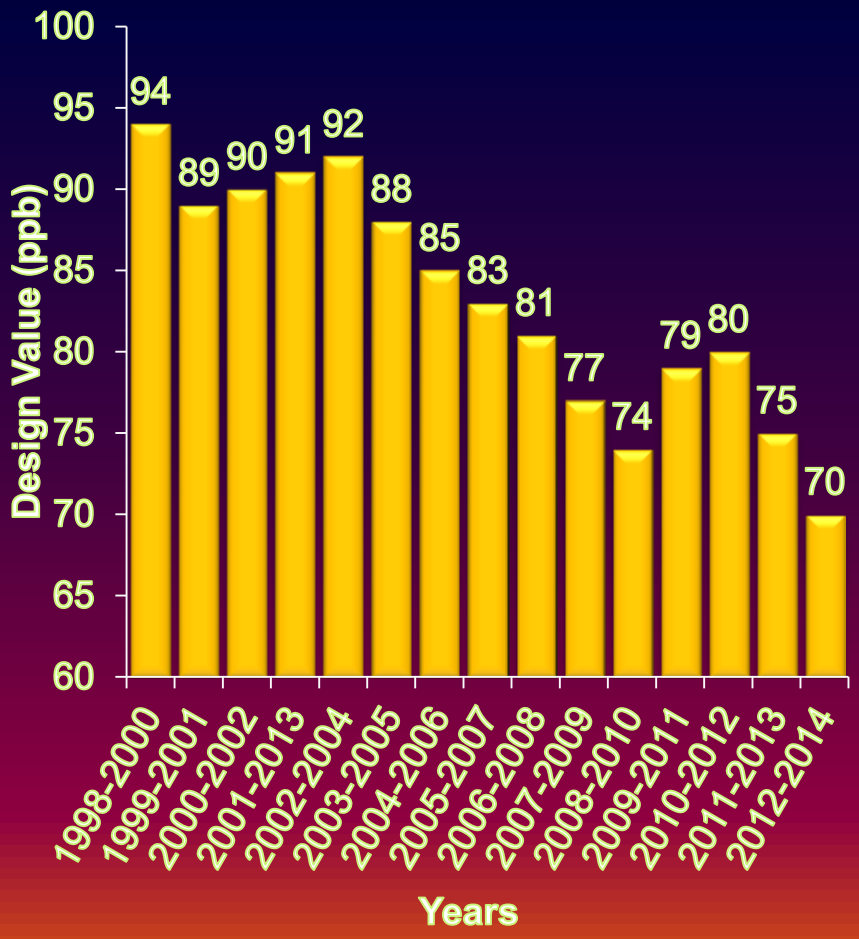
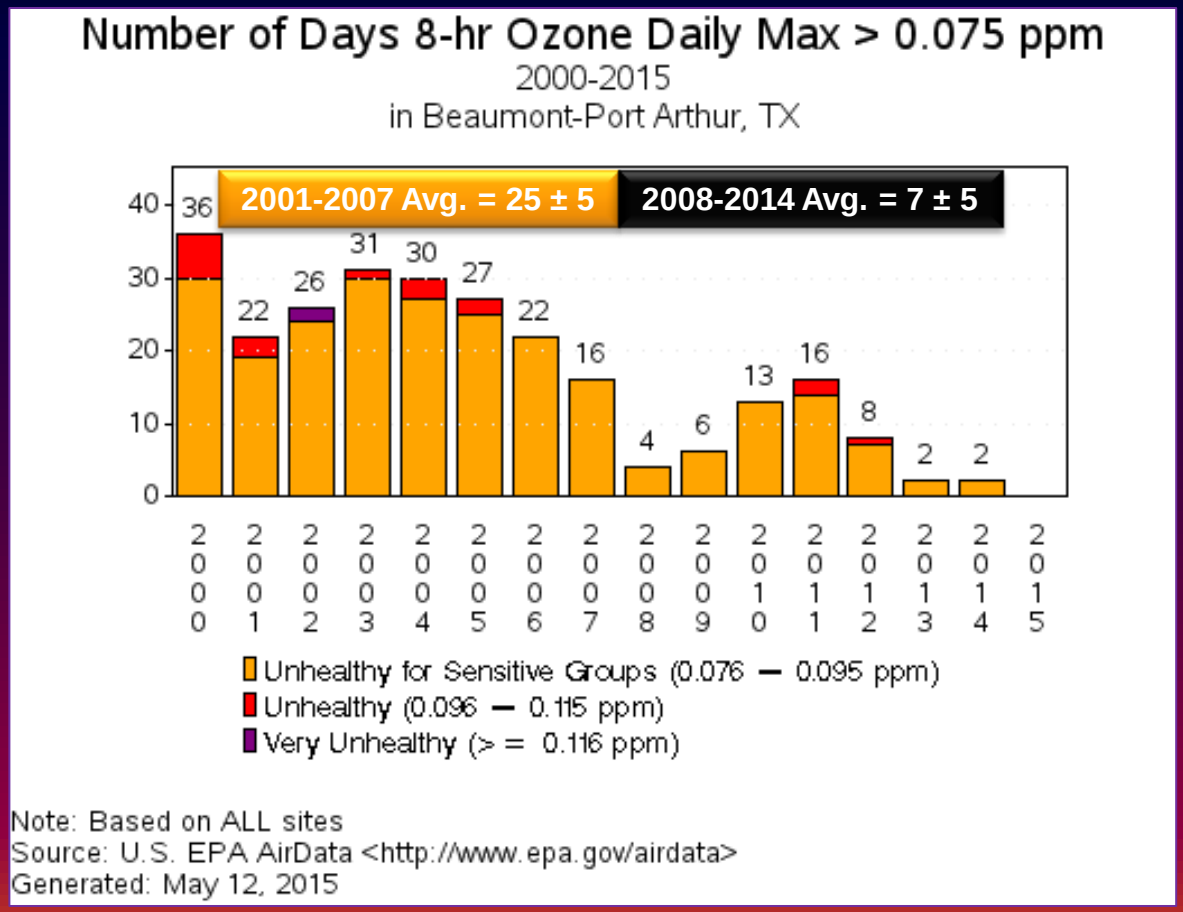
OZONE DESIGN VALUE TREND IN THE BEAUMONT – PORT ARTHUR (BPA) AREA



- The BPA O3 design value decreased an average of 3 ppb/year from 2004 to 2010; a total decrease of 18 ppb in six years
- After reaching attainment with the 2008 NAAQS in 2010, BPA flipped out of attainment for the following two years as ozone levels in 2011-2012 were out of synch with the previous 6 year's trend
- Air quality began to improve again in mid 2012 as record heat, extreme drought, and historic wildfire activity that prevailed for two years began to moderate; BPA completed the flip-flop back to attainment at the end of 2013
- BPA's Air quality continued to improve through 2014 and the area finished the year with the best 3-year air quality ever recorded

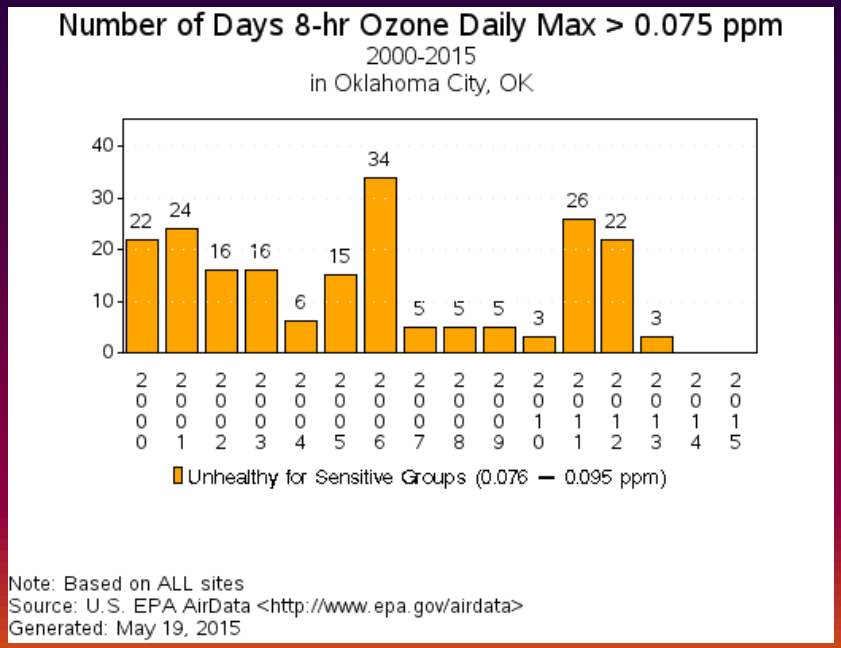
OZONE EXCEEDANCE DAY TREND IN THE BEAUMONT – PORT ARTHUR AREA

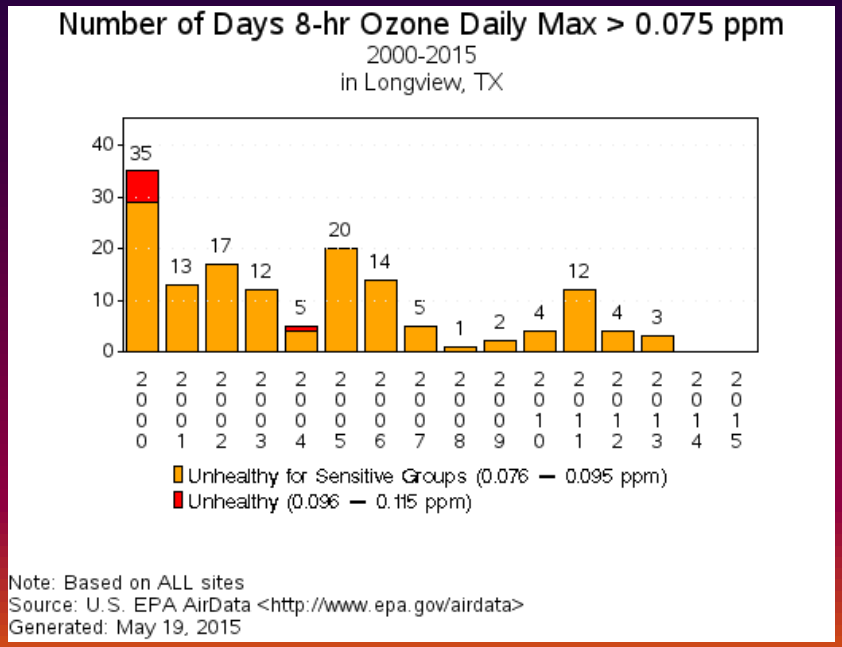


- A step-down in the annual number of high O3 days from 2007 to 2008 is statistically significant at the 95th percent confidence level and consistent with decreasing NOx emissions at the local, state, and national levels
- In contrast, no changes in manmade emissions are known or believed to explain the increase in the frequency of high O3 days from 2008 to 2011 or the subsequent decrease from 2011 to 2014

OZONE EXCEEDANCE DAY TRENDS IN LONGVIEW, TX AND OKLAHOMA CITY, OK

- The BPA O3 trends are not unique to Southeast Texas
- Similar trends were observed in many other central and eastern U.S. cities (for example, Longview, TX, and Oklahoma City)





THE 2010-2014 CENTRAL AND EASTERN U.S. OZONE ATTAINMENT FLIP-FLOP

- Approximately 50 officially designated attainment areas, composed of approximately100 counties, flip-flopped out of attainment with the 2008 O3 standard in 2010-2012 and back into attainment by 2012-2014

- Explanations may include:

1) Weather anomalies in 2011-2012 (e.g., record heat and extreme drought)

2) Wildland fire anomalies in 2011-2012 (i.e., an historically high number of incidents and acreage burned in parts of the U.S.)

3) Global climate change (apparent weather and fire anomalies are actually the new norms)

4) La Nina (the extreme weather and fire conditions of 2011-2012 were caused by cyclical patterns in the global atmospheric and oceanic circulations; they are anticipated to recur every few years)

5) The economy (ozone levels were not atypically high in 2011-2012, they were atypically low in previous years due to a struggling economy

HOW WELL CAN THE 2010-2014 OZONE NAAQS ATTAINMENT FLIP-FLOP BE EXPLAINED BY THE HISTORIC WILDLAND FIRE ACTIVITY OF 2011 AND 2012?

Judging Quality of Explanation

When we seek explanations for air pollution atmospheric chemical phenomena, there is a need to categorize them so that one might better understand the choices being made in creating mechanisms. One useful hierarchy used by Schopf[8] is:

Compelling: This explanation is so well supported that it is likely the only one. Other competing explanations are seen as being very unlikely in view of this one.

Preponderant: This explanation is "more likely than not" a correct one. Other competing explanations are seen as somewhat likely, but less so than this one.

Permissive: This explanation is not ruled out by any evidence. Other competing explanations are also not ruled out by any evidence. Several different explanations remain possible.

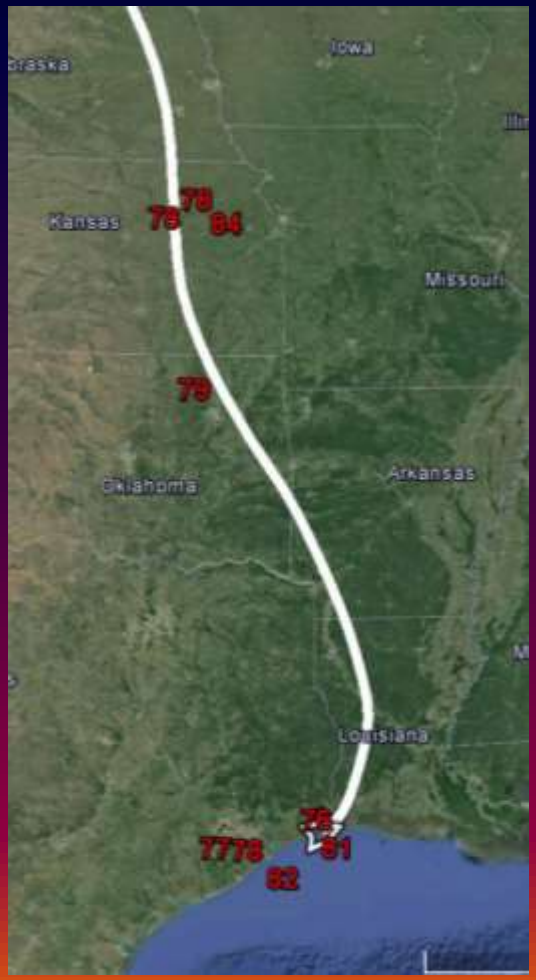
Missing: No explanations have been identified.

Harvey Jeffries — Atmospheric Chemical Mechanisms Status and Issues

APRIL 12, 2011

4/12/2011 MONITORED DAILY MAX OZONE LEVELS OVER 75 PPB 8-HOUR AVERAGE

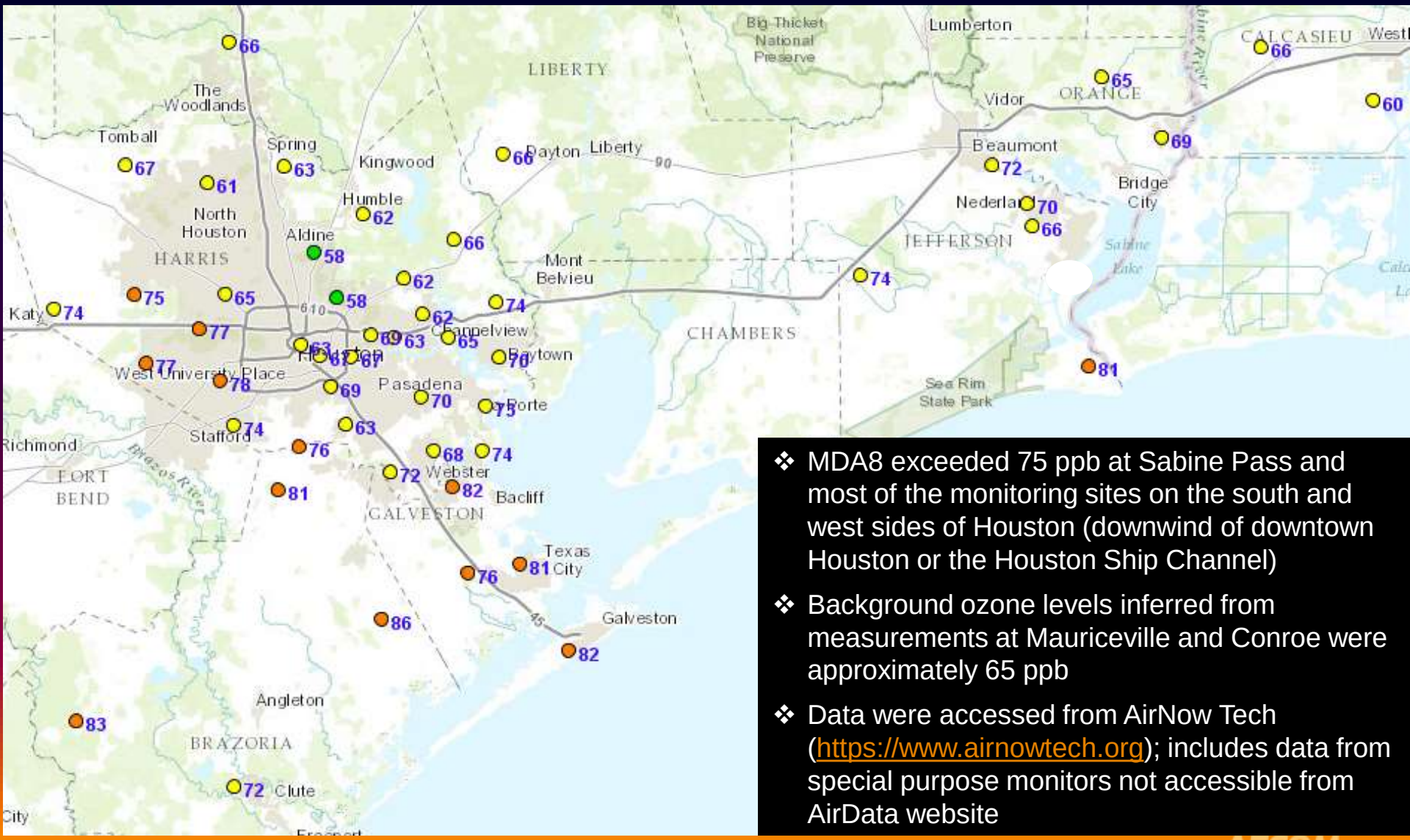
AQS Site ID	Latitude	Longitude	State Name	CBSA Name	Max 8-Hour O3 (ppb)
480430101	29.3025	-103.1678	Texas	Not in a CBSA (Big Bend National Park)	84
201770013	39.0243	-95.7113	Kansas	Topeka, KS	84
481671034	29.2545	-94.8613	Texas	Houston-Sugar Land-Baytown, TX	82
480391004	29.5204	-95.3925	Texas	Houston-Sugar Land-Baytown, TX	81
482450101	29.7280	-93.8940	Texas	Beaumont-Port Arthur, TX	81
401431127	36.2049	-95.9765	Oklahoma	Tulsa, OK	79
201619991	39.1021	-96.6096	Kansas	Manhattan, KS	78
482010055	29.6957	-95.4993	Texas	Houston-Sugar Land-Baytown, TX	78
201619991	39.1021	-96.6096	Kansas	Manhattan, KS	78
482010066	29.7247	-95.5036	Texas	Houston-Sugar Land-Baytown, TX	77
482450011	29.8975	-93.9911	Texas	Beaumont-Port Arthur, TX	76



Daily ozone data from the EPA Air Quality System (AQS) were accessed fohttp://aqsdr1.epa.gov/aqsweb/aqstmp/airdata/download_files.html#Daily

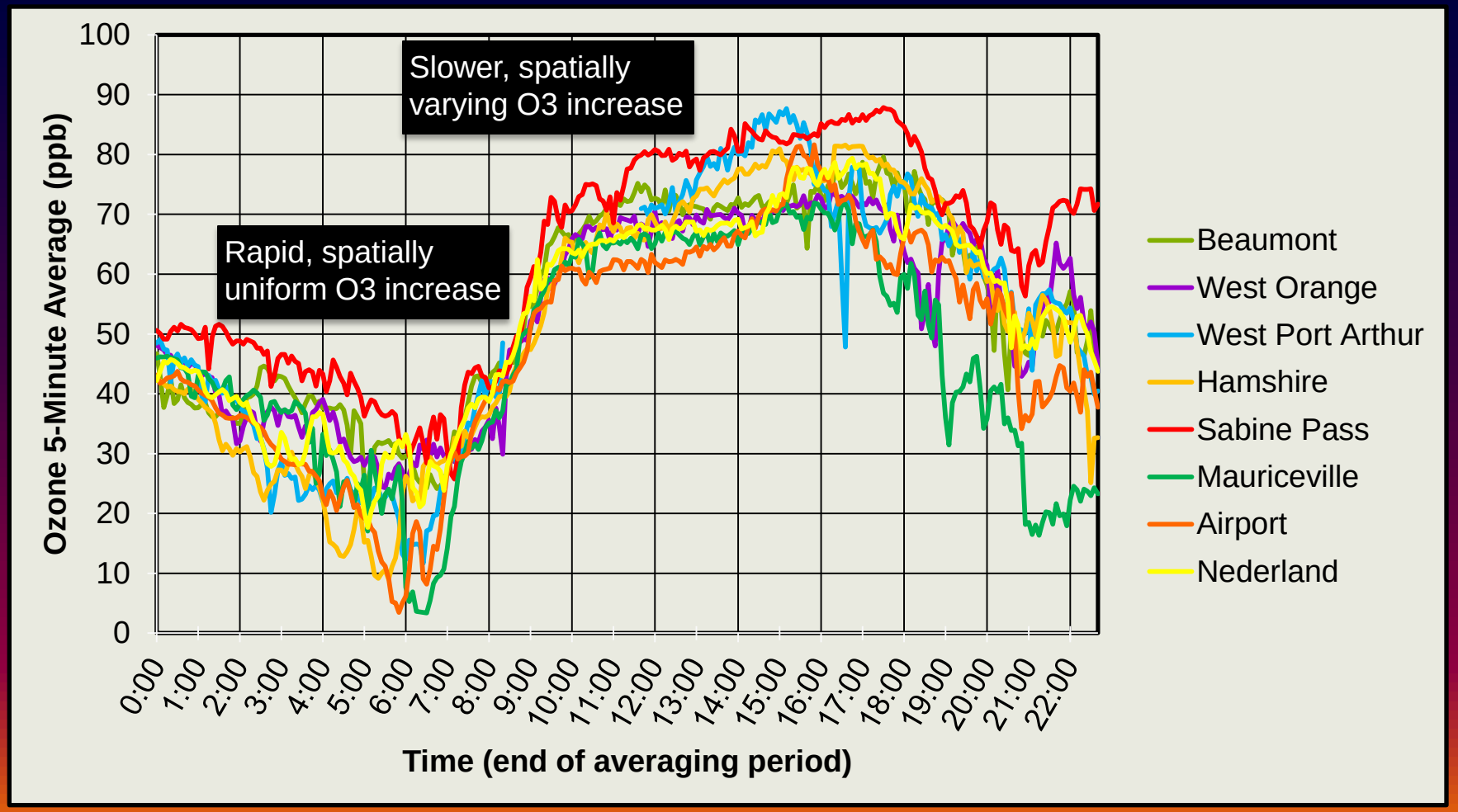
Monitors in Oklahoma and Kansas that recorded MDA8 over 75 ppb were near the 24-hour trajectory drawn backward from Sabine Pass

4/12/2011 MAX 8-HR O3 IN THE HOUSTON AND BEAUMONT-PORT ARTHUR AREAS

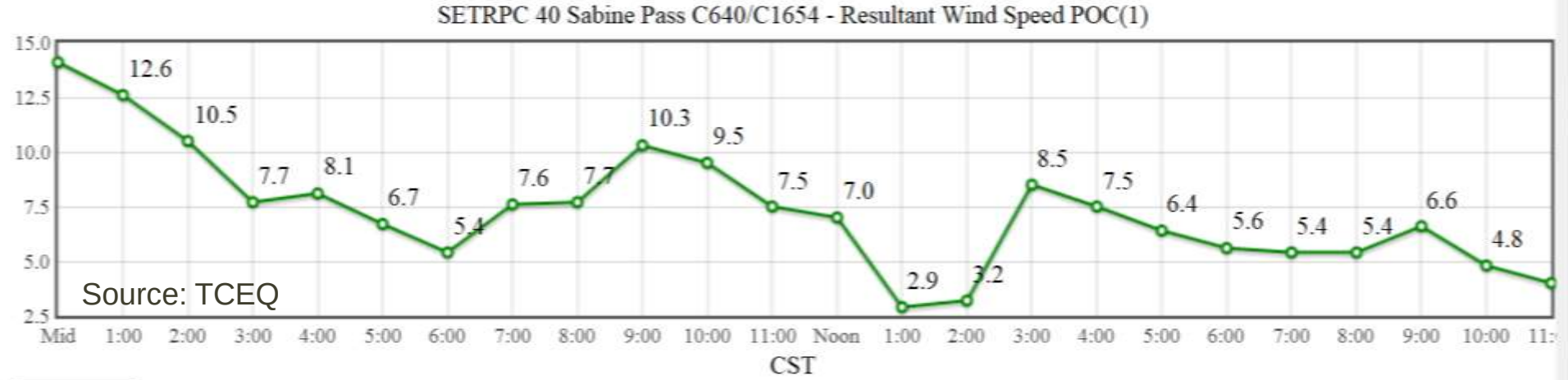


- MDA8 exceeded 75 ppb at Sabine Pass and most of the monitoring sites on the south and west sides of Houston (downwind of downtown Houston or the Houston Ship Channel)
- Background ozone levels inferred from measurements at Mauriceville and Conroe were approximately 65 ppb
- Data were accessed from AirNow Tech (https://www.airnowtech.org); includes data from special purpose monitors not accessible from AirData website

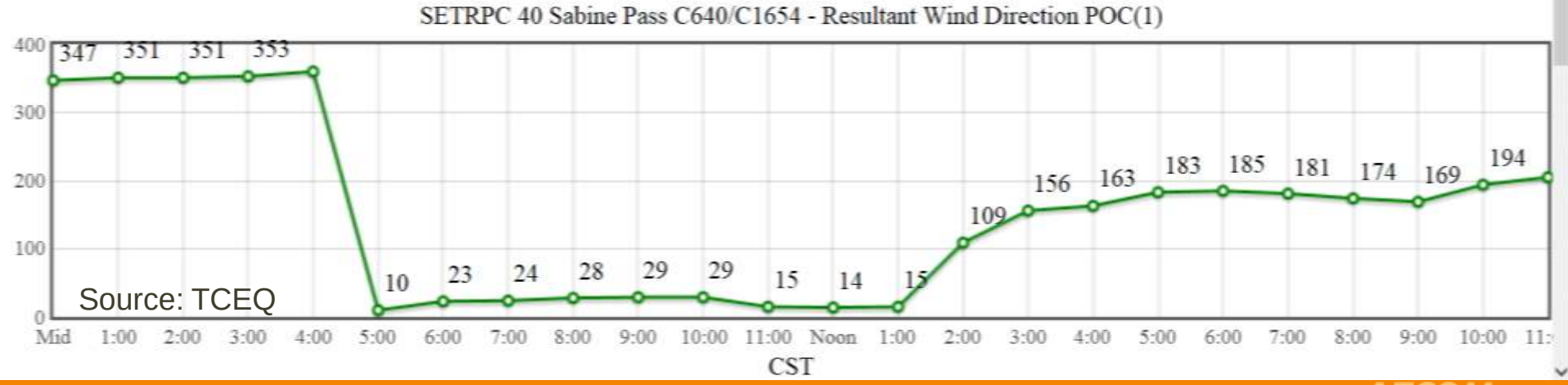
DIURNAL PATERN OF 5-MINUTE AVERAGE O3 LEVELS AT BPA MONITORING SITES ON 4/12/2011



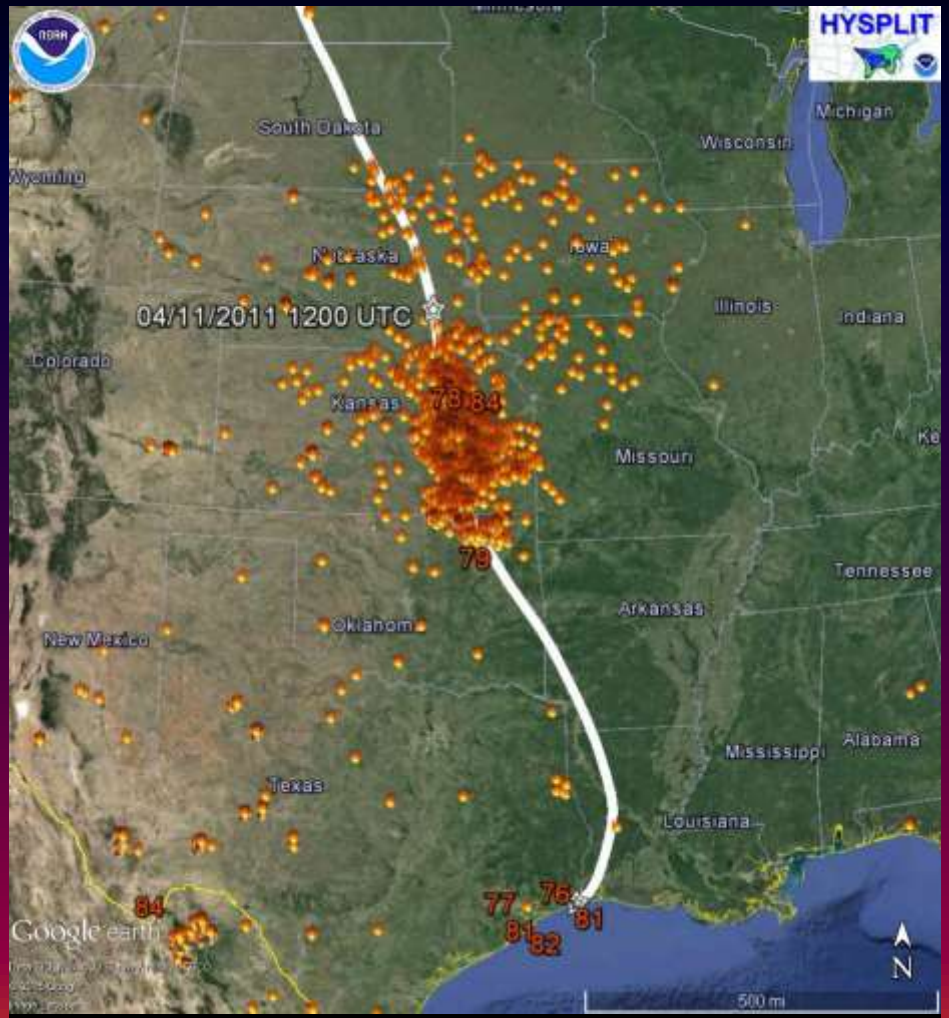
APRIL 12, 2011 WIND SPEED AND DIRECTION



- The wind speed was unusually high for a high ozone day, until 1:00 p.m.
- The veering of wind direction was typical of Sabine Pass high ozone days but the clockwise rotation began later than usual (1:00 p.m.), after a relatively long period of steady northerly to north-northeasterly winds
- The unusually strong and steady northerly to north-northeasterly winds until 1:00 p.m. were favorable for transport from the north



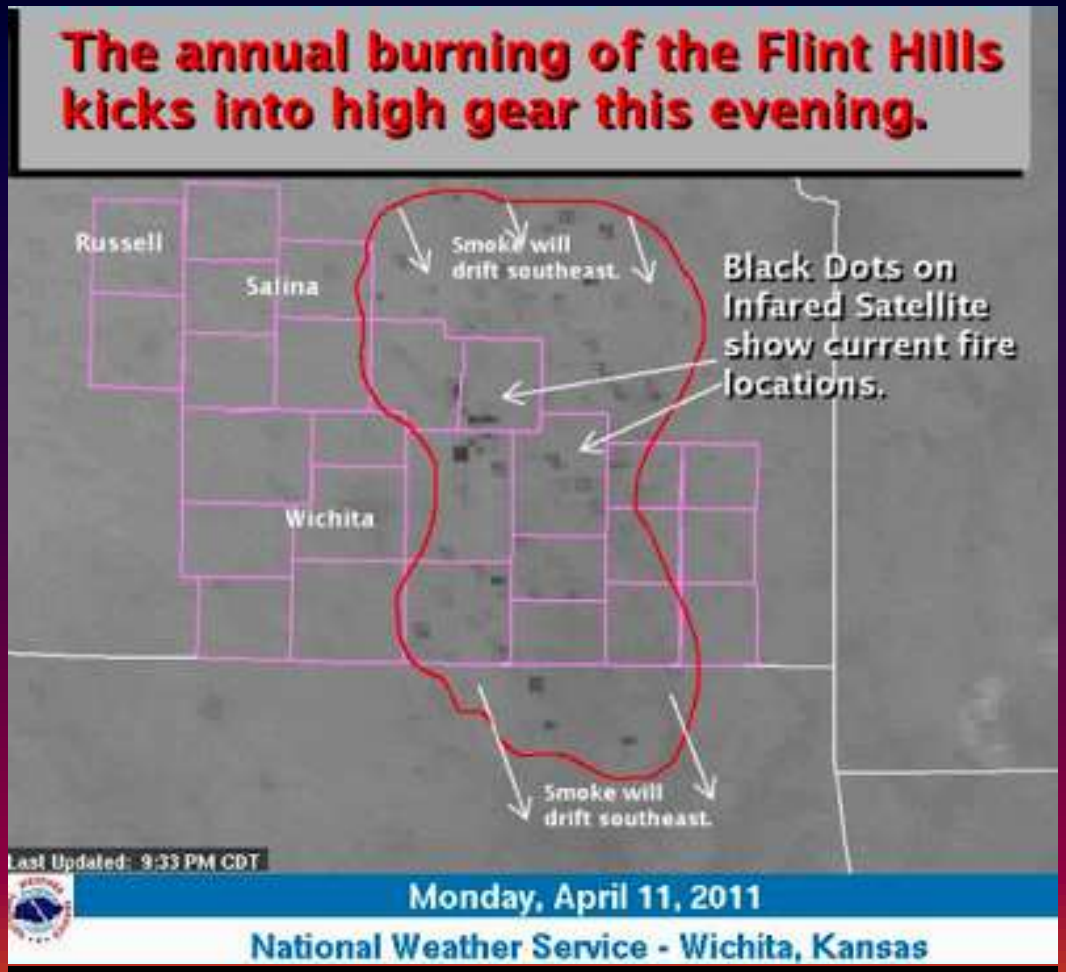
NOAA HYSPLIT BACKWARD AIR TRAJECTORY TERMINATING AT 300M ABOVE SABINE PASS AT 3:00 P.M. ON 4/12/2011



Orange markers represent NOAA Hazard Mapping System (HMS) fire detections for 4/11/2011, accessed from the NOAA Air Resources Laboratory (ARL) FTP archive; Red numbers represent monitoring sites and MDA8 where the peak 8-hour average exceeded 75 ppb, accessed from the EPA AirData website

- Air trajectories projected backward from several heights within the mixed layer above Sabine Pass, from 11 a.m. through 5:00 p.m., indicate transport from the north
- The trajectories passed over an area of intense fire activity in the eastern Kansas and northeastern Oklahoma grasslands 24 hours earlier
- MDA8 exceeded 75 ppb in Topeka, KS; Tulsa, OK; Port Arthur; Houston; and El Paso
- All the sites with MDA8 > 75 ppb on 4/12/2011 except El Paso were on or near the same trajectory path

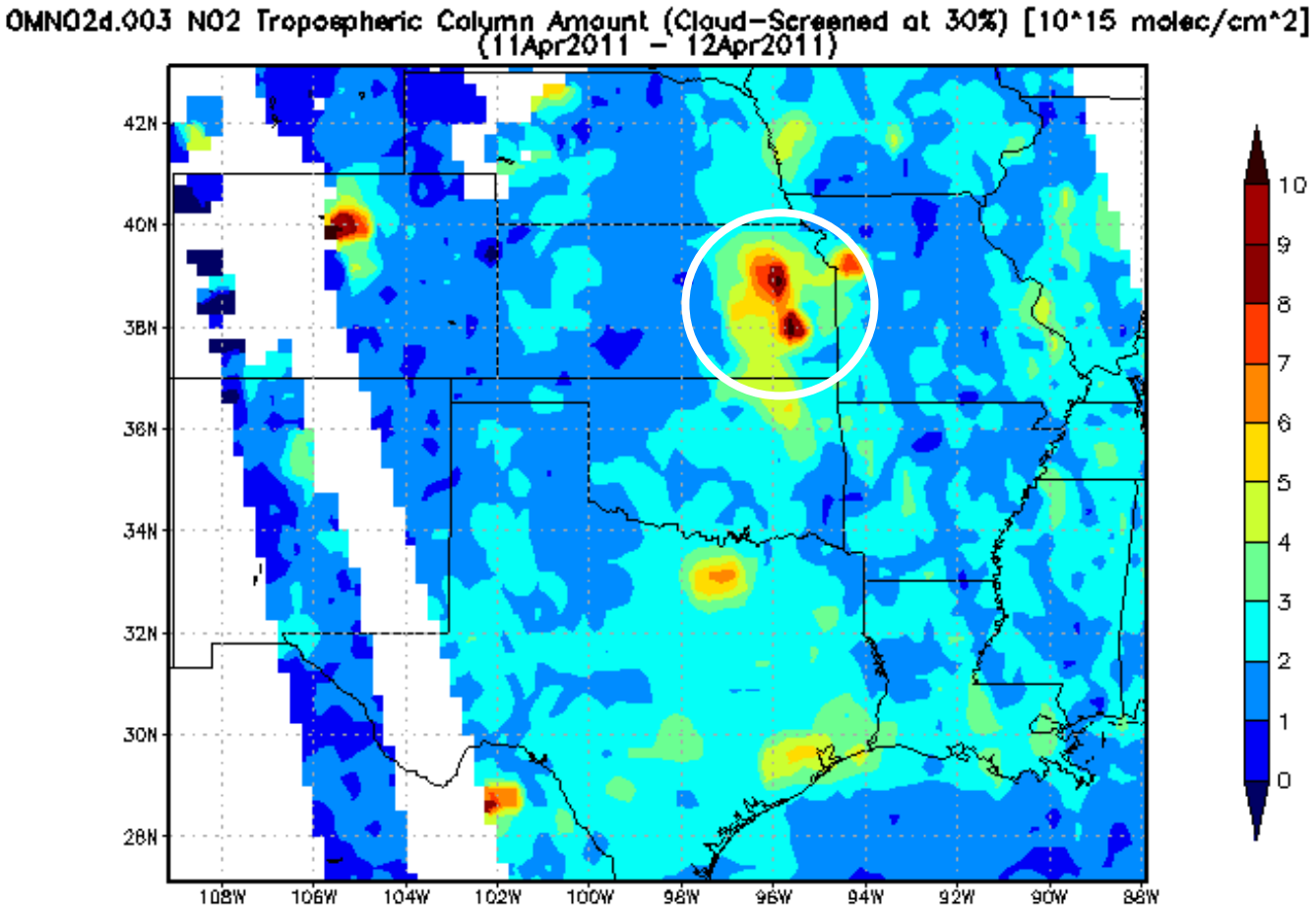
KANSAS GRASSLAND FIRES



Smoke Alert Issued by the Wichita National Weather Service Office on 4/11/2011

- Grasslands in eastern Kansas are burned every year according to a state-approved Smoke Management Plan as part of a program to preserve the native ecosystem
- An alert issued by the Wichita National Weather Service Office on 4/11/2011 warned of intensifying smoke with transport toward the southeast
- The Kansas Department of Health and Environment (KDHE) determined that ozone levels measured at 2 nearby O3 monitoring sites on 4/12/2011, which exceeded 75 ppb, were caused by the grassland fires and flagged the NAAQS exceedances as "exceptional events"

OMI TROPOSPHERIC COLUMN NO2 TIME AVERAGED FOR APRIL 11 – APRIL 12, 2011



NO2 emissions from the grassland fires on 4/11/2011 and 4/12/2011 were detected by remote sensing from satellites

Time-averaged tropospheric column NO2 on April 11-12, 2011, measured by OMI Aura and accessed using the Giovanni OMI/Aura Online Visualization Website
http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=omi

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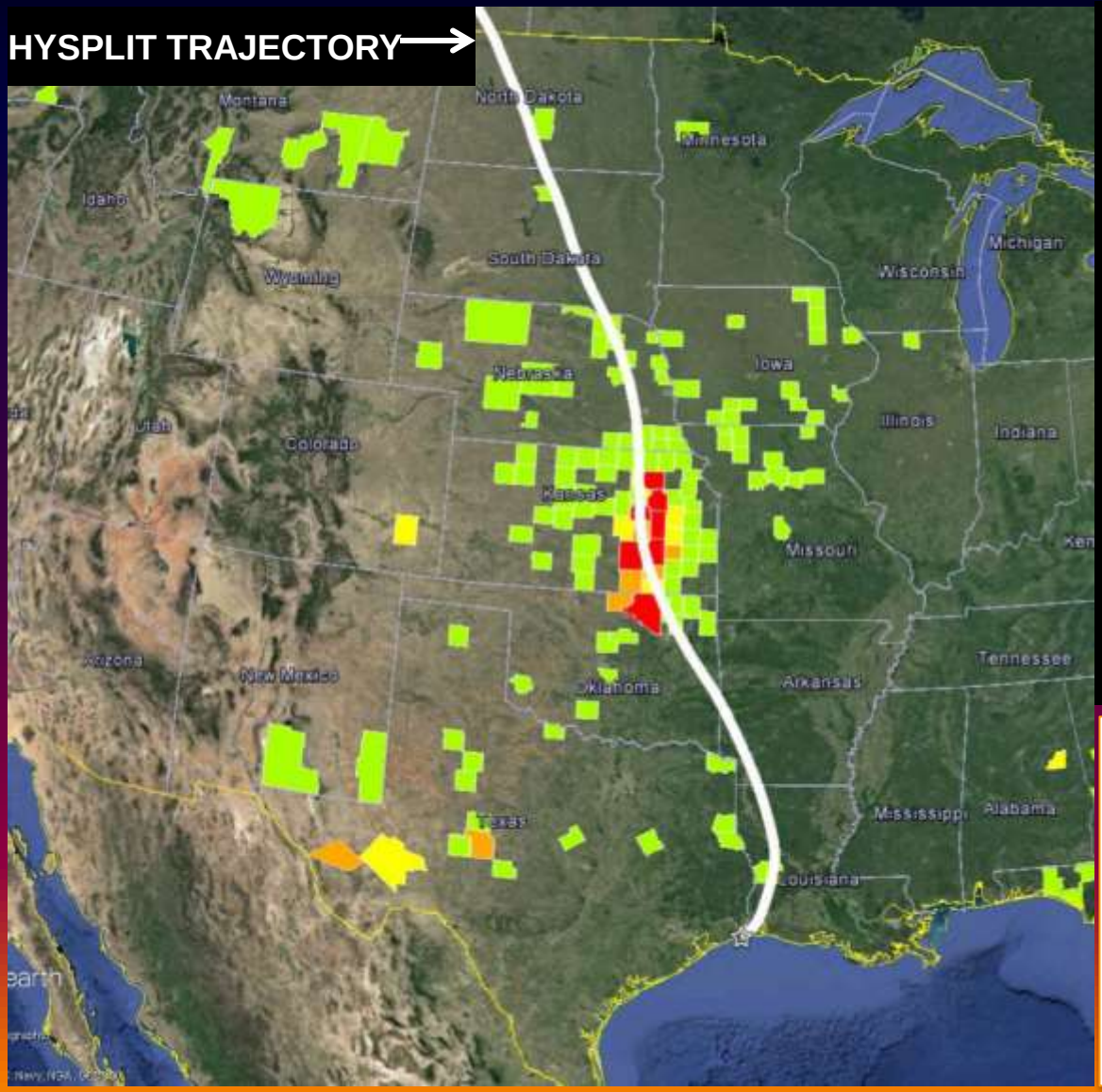
NEI COUNTY-LEVEL WILDLAND AND AGRICULTURAL FIRE NOX EMISSIONS FOR APRIL 11, 2011

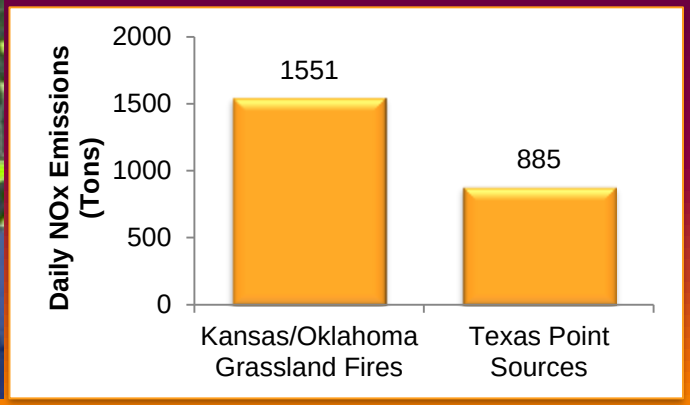


More NOx was emitted from the Kansas grassland fires on 4/11/2011 than in the entire Texas industrial point source average daily emissions inventory for 2011

Sources:

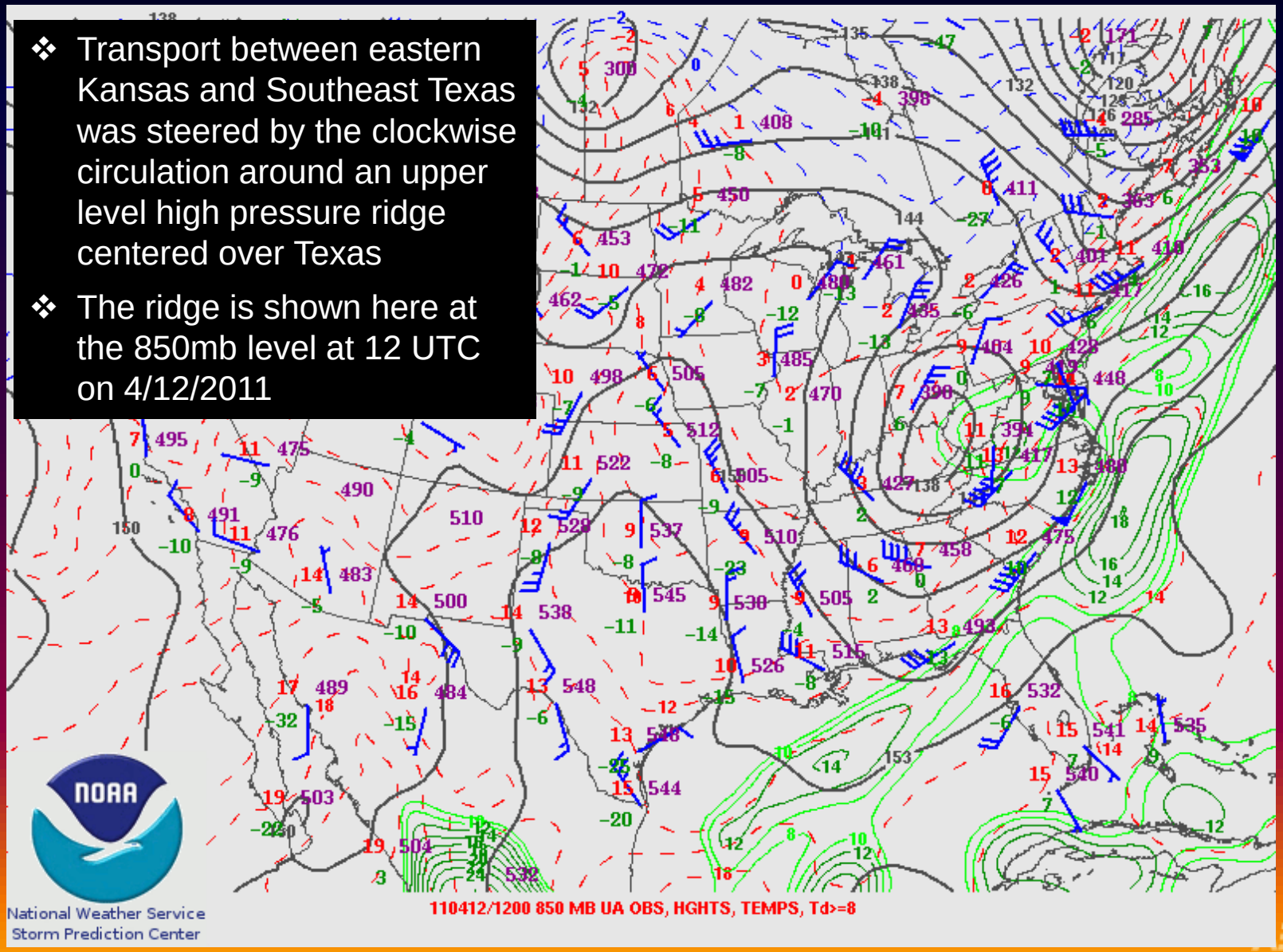
(1) EPA 2011 National Emissions Inventory (http://www.epa.gov/ttnchie1/net/2011inventory.html); and

(2) Texas Point Source Emissions Inventory (https://www.tceq.texas.gov/airquality/point-source-ei/psei.html)



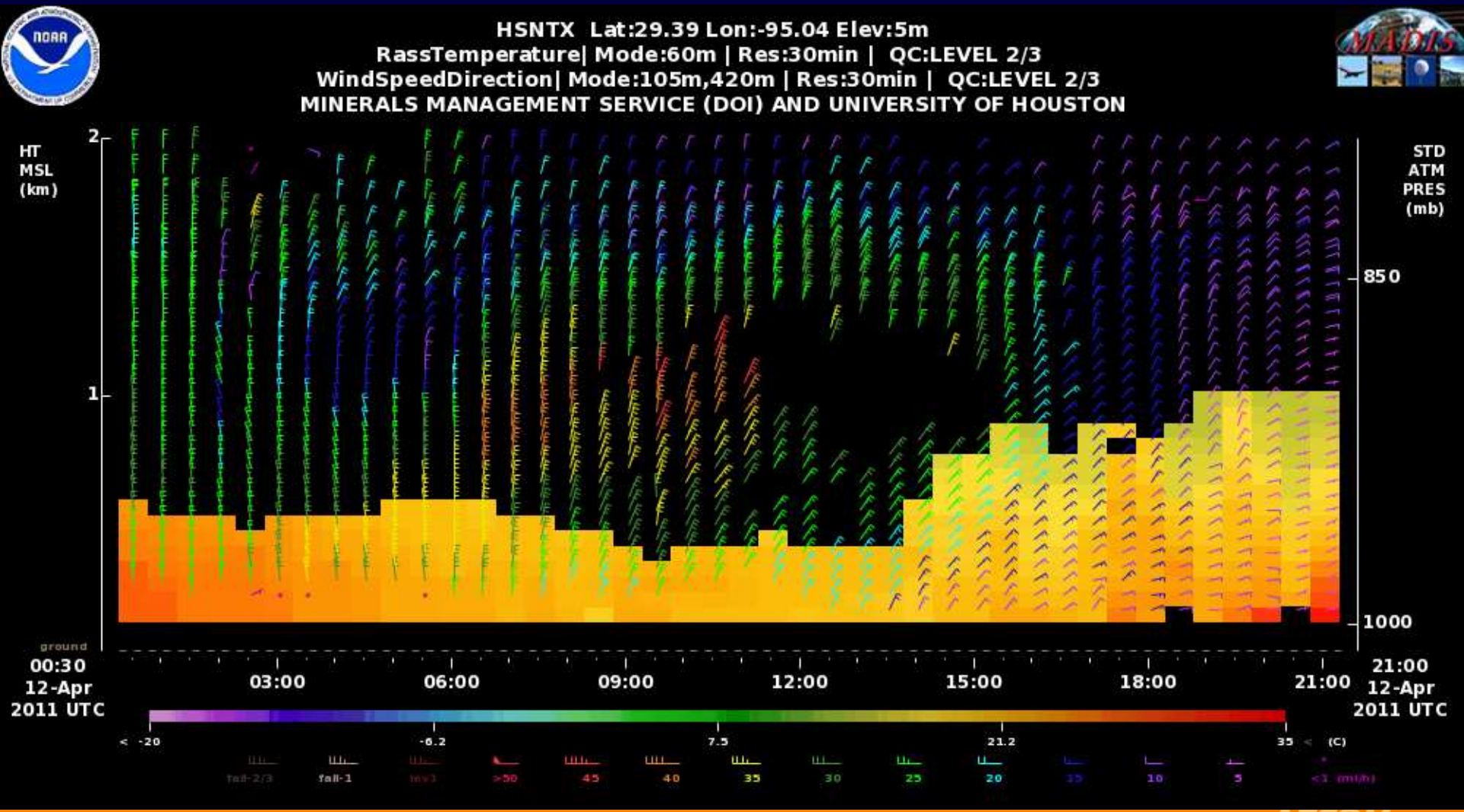
850-MB WINDS ON 4/12/2011

- Transport between eastern Kansas and Southeast Texas was steered by the clockwise circulation around an upper level high pressure ridge centered over Texas
- The ridge is shown here at the 850mb level at 12 UTC on 4/12/2011

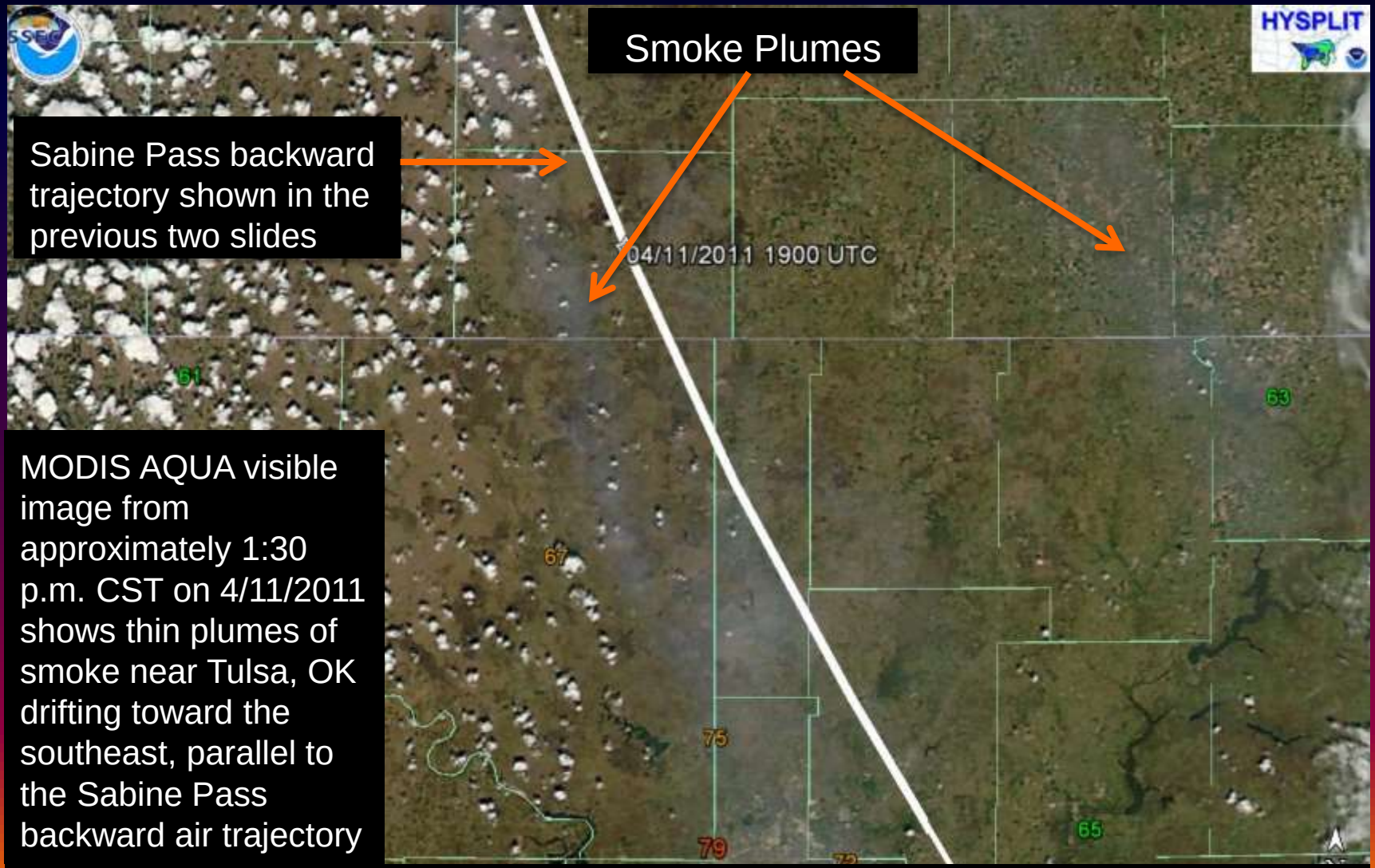


LOW LEVEL JET WINDS OVER SOUTHEAST TEXAS

A low level jet of 40-50 mph north-northeasterly winds at approximately 1000m above ground promoted rapid transport from eastern Kansas to Southeast Texas



MODIS AQUA IMAGE OF SMOKE PLUMES NEAR TULSA, OK DRIFTING SOUTHEASTWARD ON APRIL 11, 2011



kml file generated by MODIS Today (http://ge.ssec.wisc.edu/modis-today/) and plotted in Google Earth

PM2.5 24-HOUR AVERAGE AND MAXIMUM 1-HOUR LEVELS WERE ELEVATED NEAR THE TRAJECTORY PATH ON APRIL 12, 2011

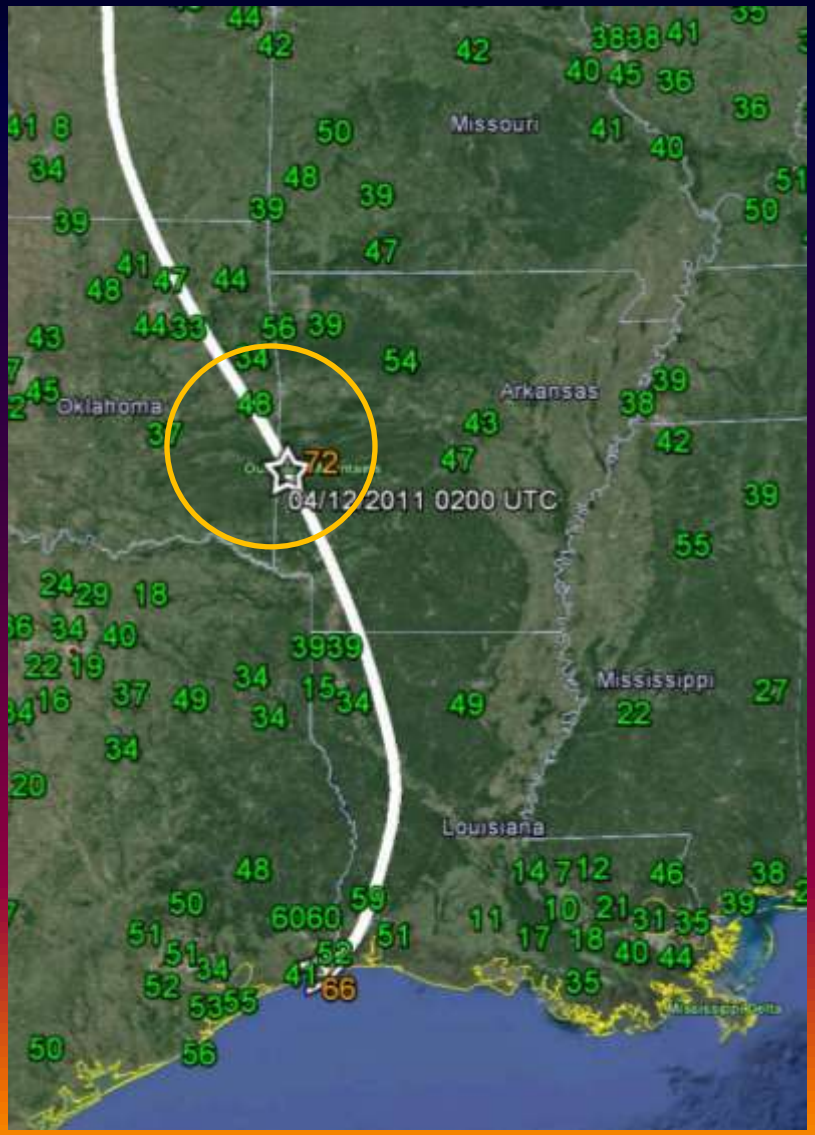
24-Hour Average

1-Hour Maximum

PM2.5 CHEMICAL SPECIATION RESULTS FOR ORGANIC CARBON AND SULFATE

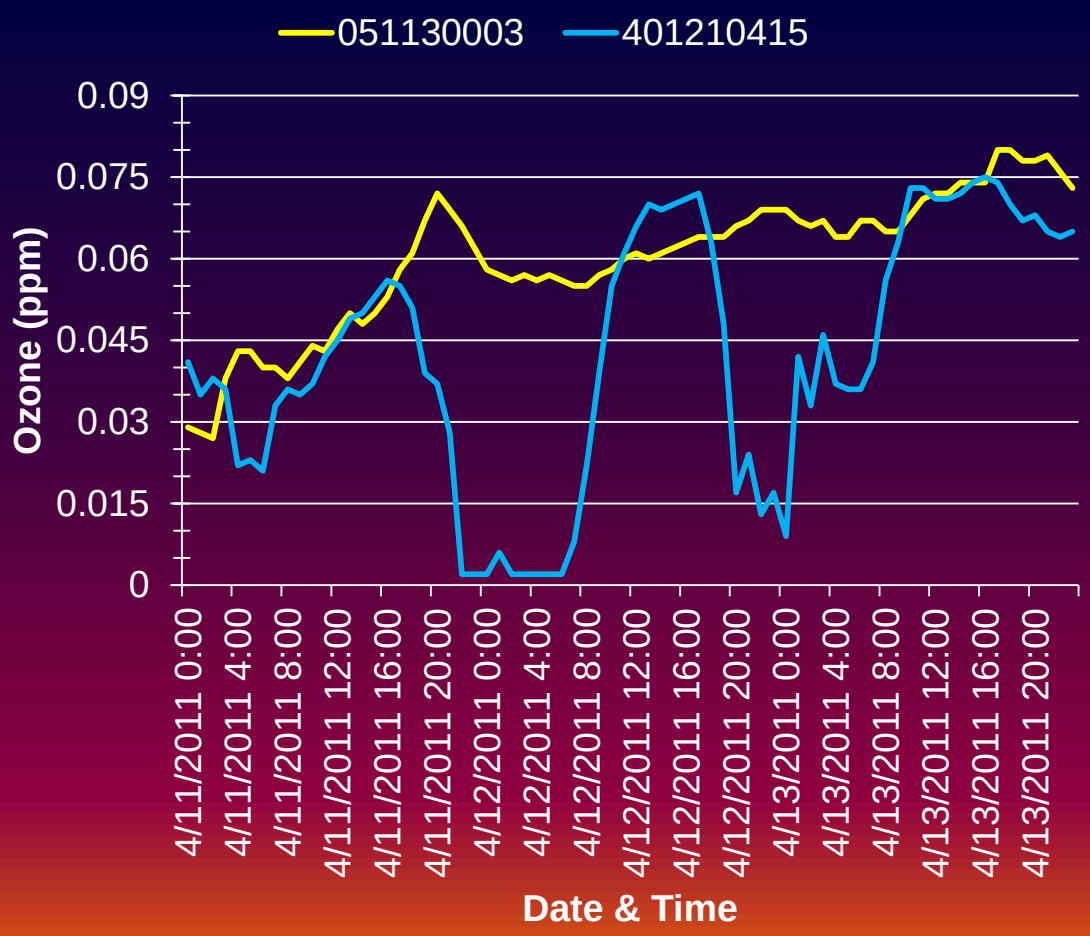
- Elevated levels of organic carbon, but not sulfate, were measured in PM2.5 Chemical Speciation Network (CSN) samples collected near the trajectory path on April 12, 2011
- Organic carbon aerosol is produced by biomass combustion while particulate sulfate is more commonly attributed to combustion of fossil fuels
- The chemical speciation results indicate that the elevated levels of PM2.5 mass shown near the trajectory path on the previous slide was more likely produced by the Kansas grassfires than by any urban-industrial PM source

1-HOUR O3 LEVELS AT EAGLE MT., AR SHOW TRANSPORT OF OZONE ABOVE THE NOCTURNAL BOUNDARY LAYER ON 4/11/2011



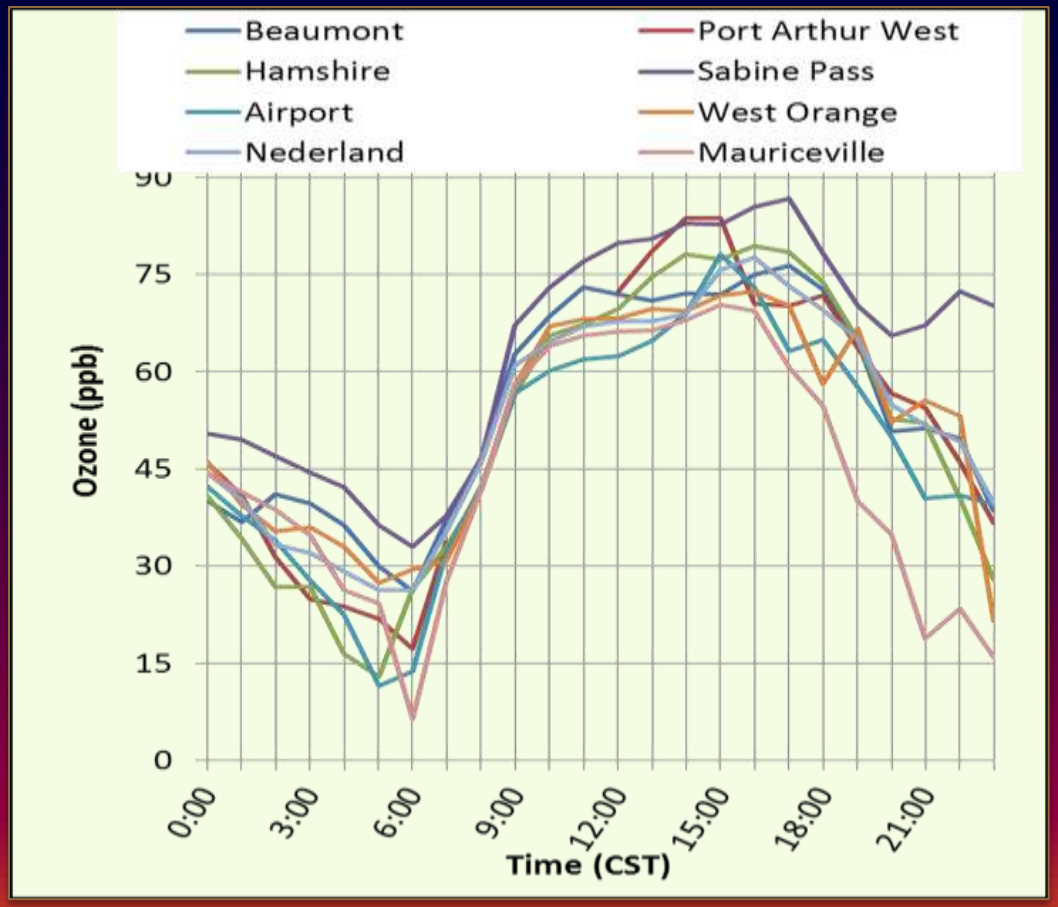
- The ADEQ Eagle Mountain Monitoring Site in the Arkansas Ouachita Mountains (AQS# 051130003) has an elevation of approximately 690m above sea level
- The 1-hour average ozone level at the Arkansas, Eagle Mountain monitoring site peaked at 72 ppb on 4/11/2011 at 8:00 p.m. CST (0200 UTC on April 12) and stayed between 55-60 ppb through the night
- The elevation of the Eagle Mountain Ozone Monitoring Site is approximately 690 m above sea level, placing it above the nocturnal boundary layer and in good position for monitoring ozone in the free troposphere
- The trajectory projected back from 300m above Sabine Pass at 3:00 p.m. CST on 4/12/2011 passed almost directly over the Eagle Mountain monitoring site at 8:00 p.m. on 4/11/2011

1-HOUR AVERAGE OZONE LEVELS AT EAGLE MT., AR AND OKLAHOMA



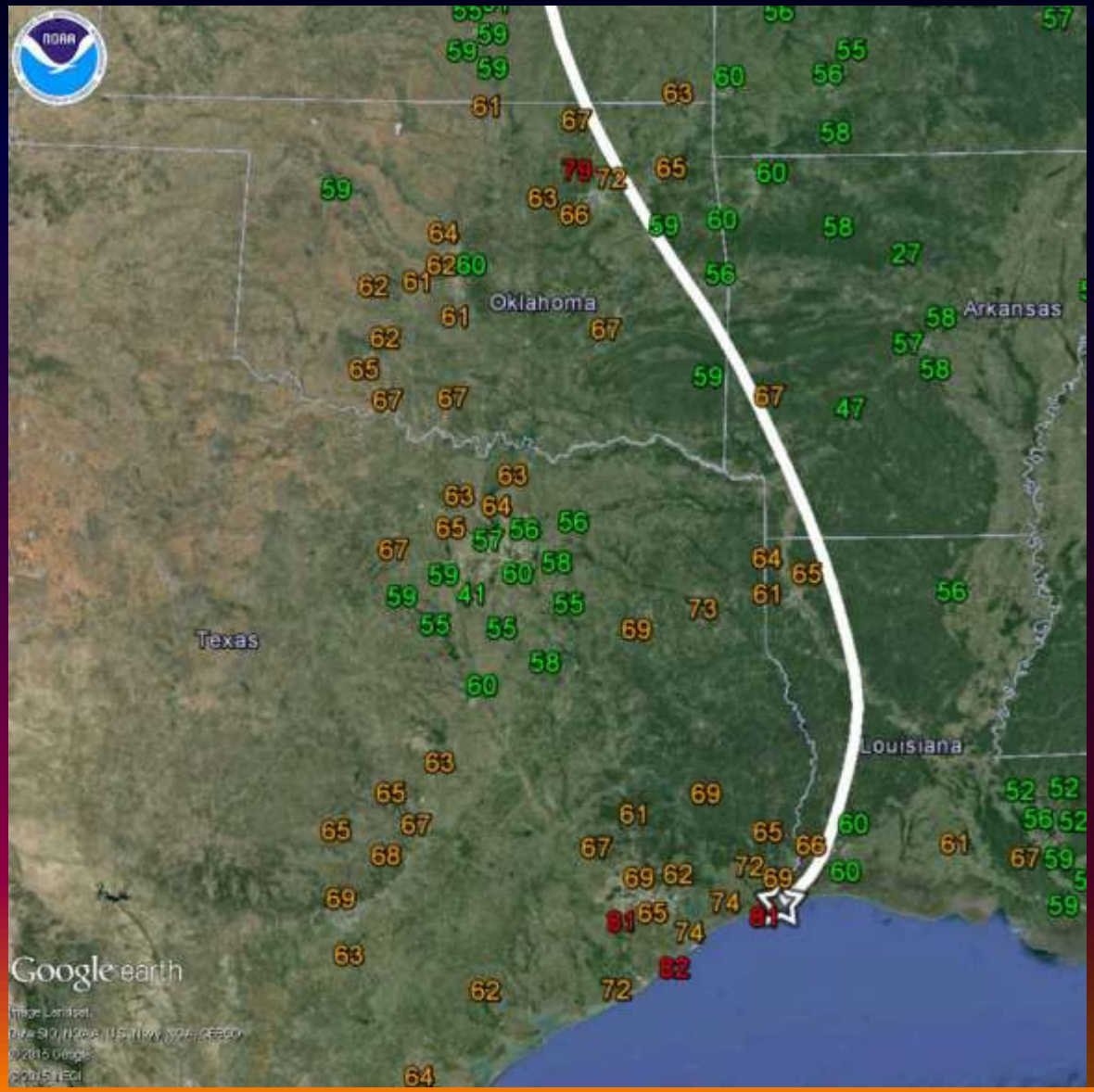
Ozone levels at Eagle Mountain stay elevated overnight as the air monitored at this station is layered above the nocturnal boundary layer and isolated from surface sinks

OZONE DIURNAL PROFILES MEASURED BY BPA MONITORS ON 4/12/2011



- Ozone levels increased rapidly and uniformly across southeast Texas between approximately 6:00 a.m. and 10:00 as the mixed layer grew by entraining the ozone-rich air aloft

APRIL 12, 2011 CONCLUSIONS



Evidence strongly supports the following conclusions:

- Fires in eastern KS and northeastern OK produced a substantial amount of NOx and possibly VOC emissions, which contributed to high ozone locally
- Ozone produced from the fire emissions was transported above the nocturnal boundary layer to southeast Texas on 4/11/2012 – 4/12/2012, where it contributed to regionally elevated ozone levels including NAAQS exceedances at Sabine Pass, West Port Arthur and on the south side of Houston