AQRP Monthly Technical Report

PROJECT TITLE	High Background Ozone Events in the Houston-Galveston-Brazoria Area: Causes, Effects, and Case Studies of Central American Fires	**PROJECT #**	16-008
PROJECT PARTICIPANTS	University of Houston	**DATE SUBMITTED**	11/7/2016
REPORTING PERIOD	**From:** 09/22/2016 **To:** 10/31/2016	**REPORT #**	1

A Financial Status Report (FSR) and Invoice will be submitted separately from each of the Project Participants reflecting charges for this Reporting Period. I understand that the FSR and Invoice are due to the AQRP by the 15th of the month following the reporting period shown above.

Detailed Accomplishments by Task

Task 1: We collected the daily maximum 8 h average (MDA8) ozone concentrations during the ozone season (April through October) measured at Continuous Ambient Monitoring Stations (CAMS) and regional background ozone over the Houston−Galveston−Brazoria (HGB) area during the study period (2000-2015). The background ozone data were provided by Mark Estes at Texas Commission on Environmental Quality (TCEQ) using the method described by Berlin et al. (2013). We downloaded the whole set of the National Centers for Environmental Prediction (NCEP) North American Regional Reanalysis (NARR) from 1979 to 2015. We are in the process of writing programs to extract meteorological parameters and calculate extreme weather events (heat wave and stagnation) over the HGB region from the NARR data.

Task 2: Not started.

Task 3: We collected Fire Inventory from NCAR (FINN) v1.5 fire burning area and emissions from NCAR website. We selected Apr and May 2011 as the first case study of Central America fire events, which were reported by Saide et al. (2015). Emissions of Central American fires and HGB background ozone variability for this case study were analyzed. We calculated 3-day back trajectories and conducted the cluster analysis to characterize transport patterns of fire emissions during the case study months.

Task 4: Not started.

Preliminary Analysis

Task 1

Figure 1 shows the study area (HGB) overlaid with the NARR grid points (32 km × 32 km). The HGB region is delineated by longitude from 94.5°W to 96.0°W and by latitude from 28.5°N to 30.5°N (red box in Figure 1). Locations of NARR data points are marked as "*". Only those NARR data on land and inside the red box (i.e., HGB) are analyzed in this task.

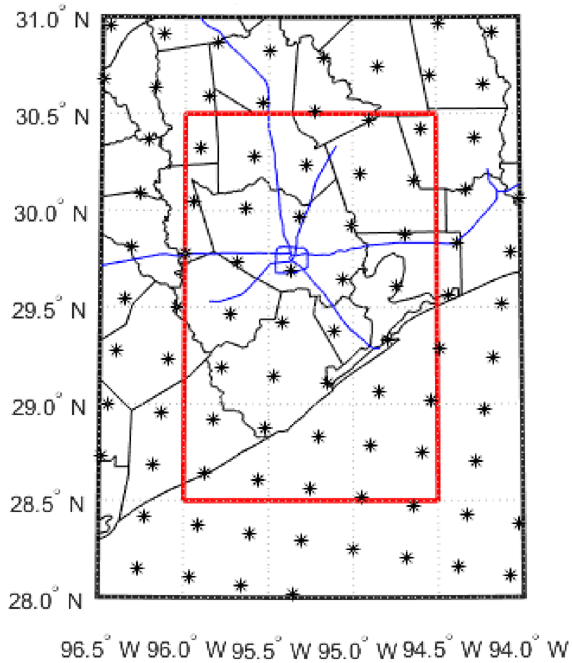

Figure 1. NARR reanalysis data points (*) over the HGB region (red box).

The ozone season (April to October) mean MDA8 and background ozone time series over the HGB region are shown in Figure 2. Both show a declining trend in 2000-2015. MDA8 ozone decreases faster than background ozone with a more significant trend, indicating the key role of in-state emissions control in reducing ozone.

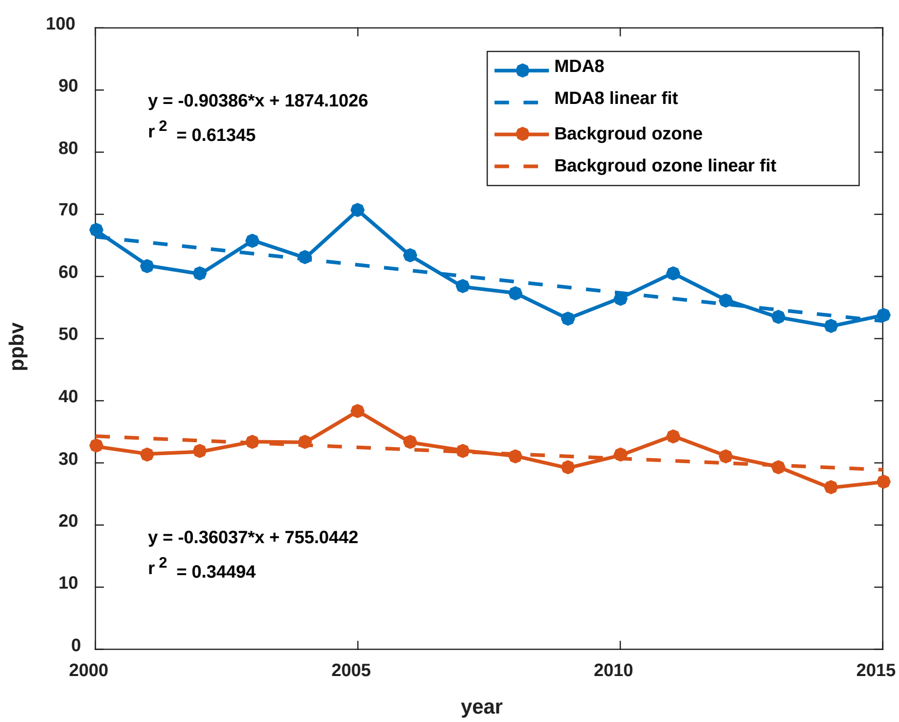

Figure 2. The ozone season mean MDA8 and background ozone during 2000-2015 for the HGB region

The ozone season mean daily maximum temperature over the HGB region is shown in Figure 3, which were extracted from the NARR data. High temperatures and high ozone seem to appear simultaneously (e.g. 2005 and 2011). This provides initial evidence for the connection between high ozone and extreme weather events. Note 2005 and 2011 were drought years.

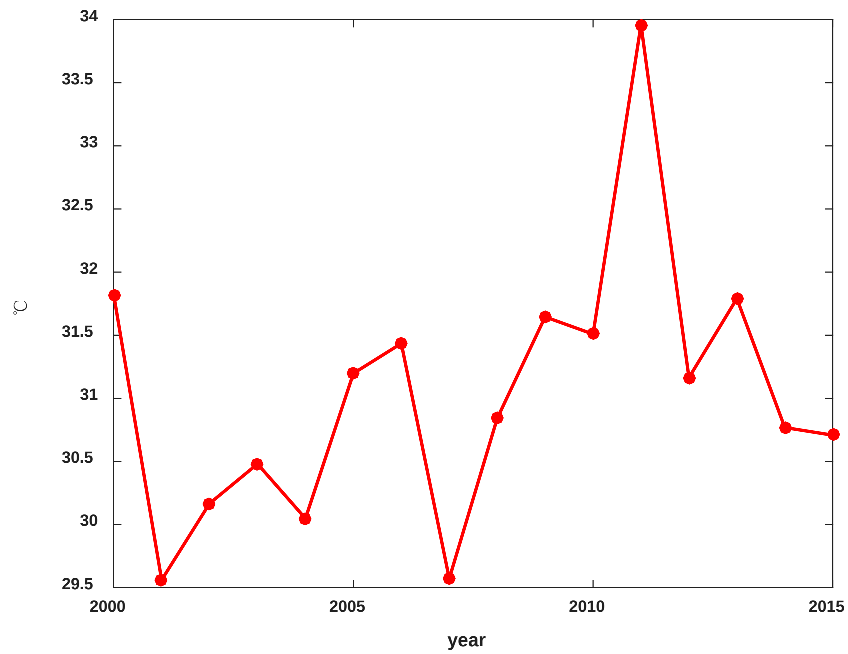

Figure 3 Time series of ozone season mean daily maximum temperature during 2000-2015 over the HGB region.

We are in the process of writing programs to extract meteorological parameters and calculate extreme weather events (heat wave and stagnation) over the HGB region from the NARR data. We adopted the following definitions for selected extreme events from the study of Hou et al. (2016):

- Heat wave day: A heat wave is defined when the daily maximum temperature at a given location exceeds the "climatological" daily maximum temperature by at least 5 K for more than two consecutive days.
- Stagnation day: A stagnation episode is defined when the 10 m wind speed, 500 hPa wind speed, and precipitation at a given location are all less than their climatological values for the reference by at least 20%. If a stagnation episode appeared at any time point in a day, we call it a stagnation day.

The study of Hou et al. (2016) is a global analysis using the coarse-resolution (2.5° latitude by 2.5° longitude) NCEP reanalysis data which cannot resolve the HGB region. They used 1961-1990 as the reference period to calculate the 'climatological' conditions for stagnation and heat wave. Since the NARR data is available 1979 - present, we chose a 20-year period 1979-1998 as the climatological reference. We first calculated the extreme event by grids. For a certain day, if more than half of the NARR grids in the HGB region show an event day, we call it an HGB event day.

Task 3

Saide et al. (2015) investigated the Central American fire events in April 2011 and suggested that they not only led to increasing $PM_{2.5}$ concentrations in southeastern U.S. but also were responsible for the outbreak of tornadoes on 27 April 2011. Therefore, we chose April 2011 as a sample month to test the possible associations between the Central American fires and HGB ozone. Figure 4 shows the time series of the daily burning area over Central America in April and May 2011; the data was collected from FINN for the Central America domain (10^{o}N-26^{o}N; 83.33^{o}W-110^{o}W) shown in Figure 5. Figure 4 shows large day-to-day variations in burning areas over Central America in 2011. The largest burning area occurred on April 27, 2011. Figure 6 shows the daily time series of peak MDA8 ozone and background ozone in HGB. Both MDA8 and background ozone show a distinct peak on April 27, coincident with the peak in burning area in Central America on the same day.

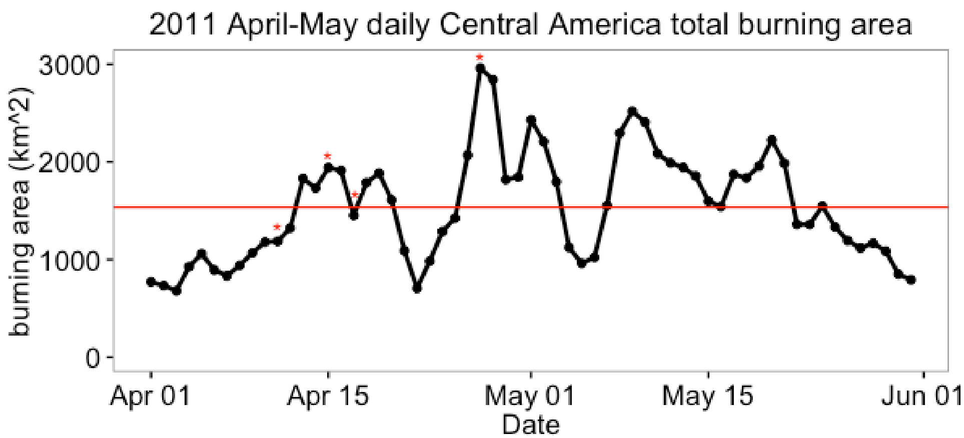

Figure 4. Time series of the total burning area (black line) in Central America from April to May in 2011. The red line indicates the mean burning area of the time period. The red dots indicate the four days when back trajectories passed through Central America and HGB background ozone shows enhancements.

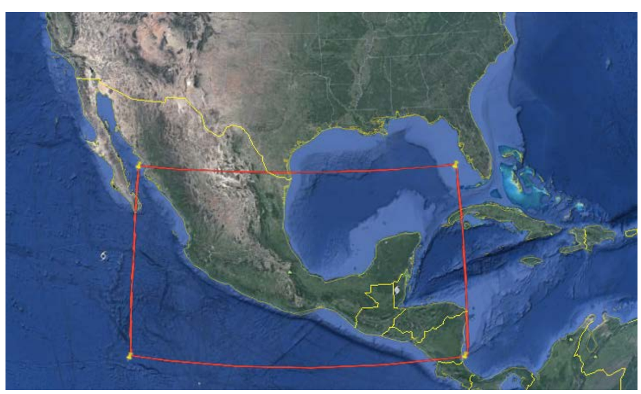

Figure 5. The Central America domain (10^{o}N-26^{o}N; 83.33^{o}W-110^{o}W) used to obtain burning area and emission information in FINN.

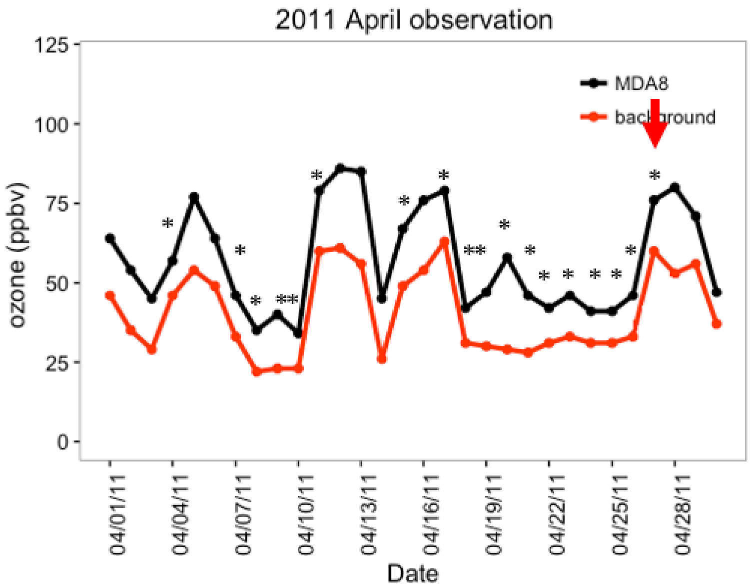

Figure 6. The time series of MDA8 ozone (black line) and background ozone (red line) in April 2011. Black stars indicate the days with back trajectories passing through Yucatan or Mexico. The red arrow indicates April 27, 2011 with the largest burning area in Central America.

In order to find other days likely influenced by Central American fires, we conducted 72-hour back trajectory analysis using the NOAA HYSPLIT model for the whole month of April 2011. The trajectories were initiated at 1000 m above the surface over HGB for every 3 hours and were driven by the National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) Reanalysis metrological data. The trajectories are clustered into two groups: the first one represents air masses coming from the south across the Gulf of Mexico and the other indicates air masses from the north. Figure 7 presents the mean trajectory of the two clusters in April 2011 and their corresponding percentages. About 65% of the air masses came from the south, but not all of them passed through Yucatan or central Mexico.

We defined two sub-domains (box 1 and 2 in Figure 8) to select the trajectories passing through Yucatan and central Mexico, respectively. Within Cluster 2 (i.e. the southern cluster), 51.7% of trajectories passed through Yucatan and 21.5% through central Mexico. Corresponding with those trajectories, 18 days were identified when at least two back trajectories for each day passed through either of the two sub-domains, representing potential influences by the fires. These days are marked with black stars in Figure 6. Note not all the marked days are associated with higher MDA8 or background ozone in HGB. This is expected because those days were selected solely by back trajectories, without considering other factors such as emission intensity over the source region, chemistry and dynamic processes during the transport. However, four marked days are associated with distinct peaks of background ozone all higher than 50 ppbv; these days are 11, 15, 17 and 27 April 2011.Two of them have relatively large burning areas which are above the monthly mean (c.f. Figure 4) and hence larger fire intensity and higher emissions. Note the fourth day (27 April 2011) is the fire event reported by Saide et al. (2015), but their study did not investigate the impact on ozone. Our analysis here provides initial evidence that the Central American fires can result in significant enhancement on background ozone and hence MDA8 ozone over the HGB. Our next steps are to identify other fire cases, analyze the conditions conducive for the transport, and quantify the resulting ozone enhancement.

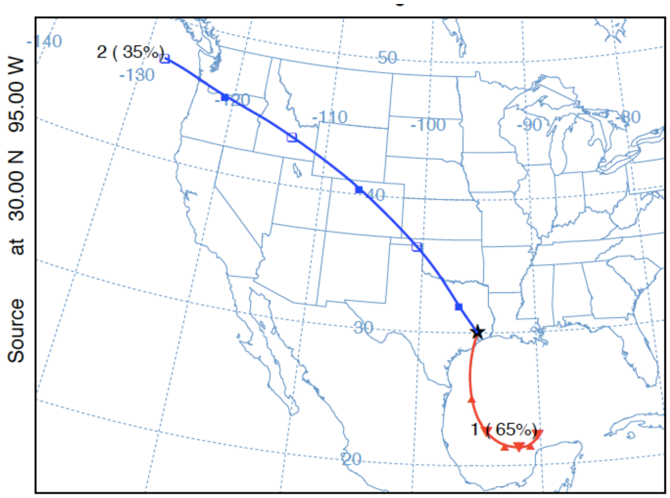

Figure 7. The mean background trajectory of the two clusters identified for April 2011.

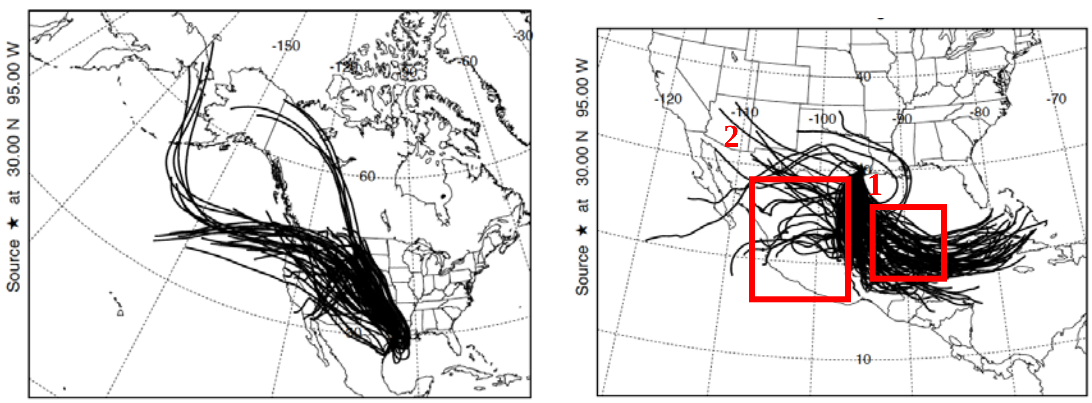

Figure 8. The two groups of trajectories from the cluster analysis: the northern group (left) and the southern group (right). The red boxes in the right panel show the sub-domain of Yutacan (box 1, 17.23°N-21.65°N; 85.45°W-91.79°W) and Central Mexico (box 2; 16.35°N-25.97°N; 97.59°W-105.72°W).

Data Collected

<u>Task 1</u>

1) Observational data:

MDA8 ozone concentrations during the high ozone season (May through October) at the CAMS over the HGB region during the study period 2000-2015.

Daily background ozone concentrations in HGB during 2000-2015 provided by Mark Estes at TCEQ.

2) Reanalysis data:

The NCEP North American Regional Reanalysis (NARR) products are outputs of 32×32 km model with 45 vertical layers every 3 hours based on observations used in NCEP/NCAR Global Reanalysis project (http://rda.ucar.edu/datasets/ds608.0/).

This data set is zipped by date. As there is no easy way to just download data for the HGB region, we downloaded the whole data set (about 13 TB for 1979-2015) and then extracted the HGB region on our server. Although the data before 2000 is outside our research period, they are necessary to calculate the climatological reference conditions used for identifying the extreme weather events.

Task 3

Fire Inventory from NCAR (FINN):

FINN emission estimation is based on the work by Wiedinmyer et al (2011). FINN provides daily fire emissions product from open burning at a horizontal resolution of 1 km^2. FINN uses fires and land type observation from satellite to estimate burning area and emissions of different tracers. We collected FINN v1.5 fire burning area and emissions from NCAR website (http://bai.acom.ucar.edu/Data/fire/), which is the latest version of FINN available publicly. We used this dataset to obtain the variability of fire intensity in the study period from 2000 to 2015.

Identify Problems or Issues Encountered and Proposed Solutions or Adjustments

None this period.

Goals and Anticipated Issues for the Succeeding Reporting Period

Task 1: We will identify extreme weather events during 2000-2015 and analyze the difference of MDA8 and background ozone between the event and non-event days.

Task 3: We will apply the same method to identify all the Central American fire events in April and May from 2000 to 2015 that will potentially influence the HGB ozone and set up the GEOS-Chem run.

Detailed Analysis of the Progress of the Task Order to Date

Progress on the project is ongoing.

Do you have any publications related to this project currently under development? If so, please provide a working title, and the journals you plan to submit to.

___Yes √ No

Do you have any publications related to this project currently under review by a journal? If so, what is the working title and the journal name? Have you sent a copy of the article to your AQRP Project Manager and your TCEQ Liaison?

___Yes √ No

Do you have any bibliographic publications related to this project that have been published? If so, please list the reference information. List all items for the lifetime of the project.

___Yes √ No

Do you have any presentations related to this project currently under development? If so, please provide working title, and the conference you plan to present it (this does not include presentations for the AQRP Workshop).
___Yes √ No

Do you have any presentations related to this project that have been published? If so, please list reference information. List all items for the lifetime of the project.

___Yes √ No

Submitted to AQRP by

Principal Investigators: Yuxuan Wang and Robert Talbot

References
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Hou P, Wu S. Long-term Changes in Extreme Air Pollution Meteorology and the Implications for Air Quality[J]. Scientific reports, 2016, 6.

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Wang J, Van den Heever S C, Reid J S. A conceptual model for the link between Central American biomass burning aerosols and severe weather over the south central United States[J]. Environmental Research Letters, 2009, 4(1): 015003.

Wiedinmyer C, Akagi S K, Yokelson R J, et al. The Fire INventory from NCAR (FINN): a high resolution global model to estimate the emissions from open burning[J]. Geoscientific Model Development, 2011, 4: 625.