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**	04/10/2017
REPORTING PERIOD	**From:** 03/01/2017 **To:** 03/31/2017	**REPORT #**	6

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 compiled the cold front and thunderstorm data for HGB and presented their time series.

Task 2: We analyzed probability density distribution of MDA8 and background ozone mixing ratio during different types of event days. We also investigated the overlapping of stagnation and high ozone events.

Task 3: Analysis of model biases and methods of selecting fire cases.

Task 4: None this period.

Preliminary Analysis

Task 1:

We extracted cold fronts from Northern Hemisphere Cyclone Locations and Characteristics from NCEP/NCAR Reanalysis Data (https://nsidc.org/data/docs/daac/nsidc0423_cyclone/). We chose cyclones with life cycle greater than 1 day whose centers appeared in east-south of Texas (delineated by longitude from 70°W to 120°W and by latitude from 15°N to 50°N). One cold front event is defined as the period from the first day when cyclones appeared to the day before the first day when no cyclones showed in this region. The days during cold front events are defined as cold front days.

Figure 1 shows the annual and monthly time series of cold front events. For annual time series, the average cold front event occurrence was 23.3 times per year. The maximum 30 was in 2014 while the minimum 18 was in 2012. No clear trend was found in past 16 years but the fluctuation range became larger in the second half of research period. For monthly series, the average cold front event occurrence was 3.33 times per month. The maximum 4 was in May while the minimum 2.75 was in June.

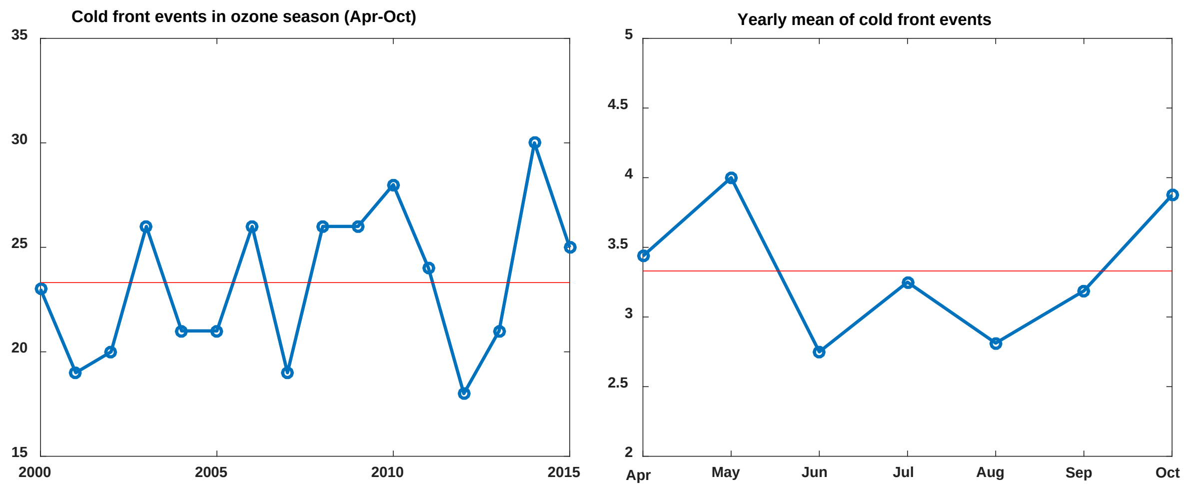

Figure 1. Annual (left) and monthly (right) time series of cold front events during the ozone season (April - October). Red line shows the average.

We extracted thunderstorms from historic weather records of Weather Underground (https://www.wunderground.com). We selected thunderstorm records from 9 airports in the HGB area (delineated by longitude from 94.5°W to 96.0°W and by latitude from 28.5°N to 30.5°N). A thunderstorm day is defined as the day when more than one airports reported thunderstorms.

Figure 2 shows the annual and monthly time series of thunderstorm days. For annual time series, the average thunderstorm day occurrence was 76 days per year which is the most frequent weather event in this study. The maximum 100 was in 2007 while the minimum 39 was in 2011. The co-occurrences of thunderstorm trough and heatwave peak in 2011 may explain the exceedance peak in that year. The monthly series showed a single peak in July.

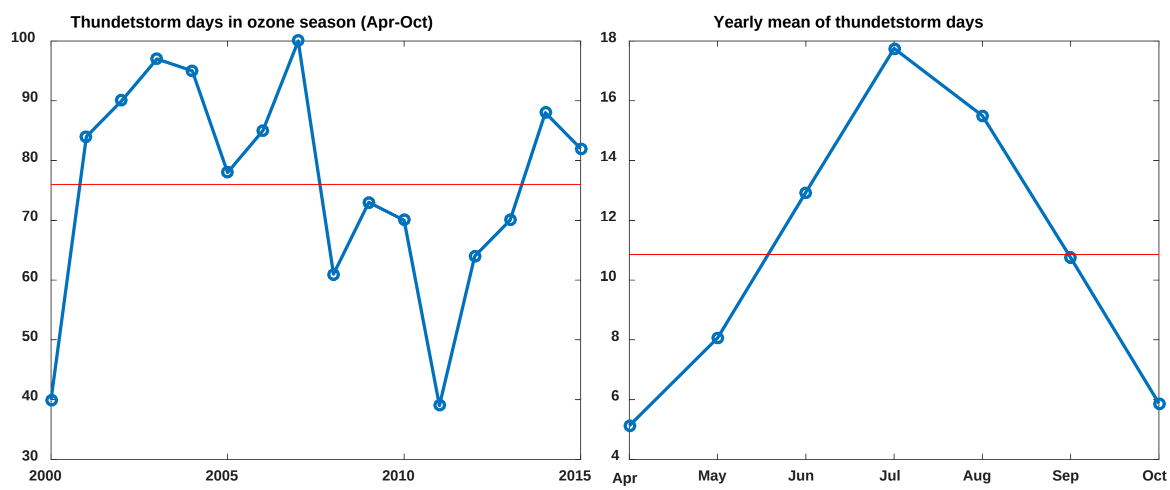

Figure 2. Annual (left) and monthly (right) time series of thunderstorm days during the ozone season (April - October). Red line shows the average.

Task 2:

We examined the effects of meteorological 'event days' identified in Task 1 on HGB ozone distribution during the whole study period (2000-2015). Since the majority of heatwave days appeared in a single year (2011), it is excluded from the long-term analysis.

Figure 3 shows the probability distribution of MDA8 ozone mixing ratio during each type of events by season. The ozone distribution during top 15% MDA8 ozone days and top 15% background ozone days is also shown for comparison. Compared with the distribution of all data (black curve), stagnation shows a clear effect of increasing MDA8 ozone as it shifts the mode of the distribution toward higher concentrations by about 40 ppbv in each season. The ozone distribution during stagnation is close to that of the top 15% background ozone days. By contrast, thunderstorm has a clear effect of decreasing MDA8 ozone as it reduces the right tail of the ozone distribution as well as a slight decrease of the mode. The effect of cold front is less clear. This is because cold front is a regional event and ozone response to cold front may differ from pre-front to post-front. The front statistics compiled so far do not label different stages of the front.

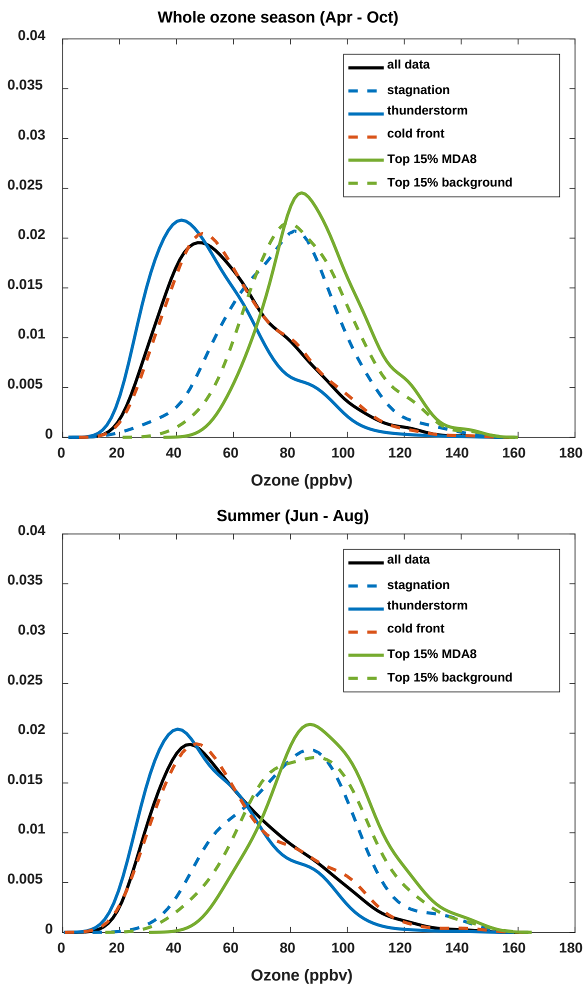

Figure 3. Probability density curves of seasonal MDA8 ozone mixing ratio

Figure 4 is the same as Figure 3 but for background ozone distributions. As for MDA8 ozone, stagnation increases background ozone for both its mode and right tail while thunderstorm has the opposite effect. Similarly, cold front does not show a clear effect on background ozone, but that's because the cold front days selected include the whole lifecycle of cold fronts whose effects on ozone may vary.

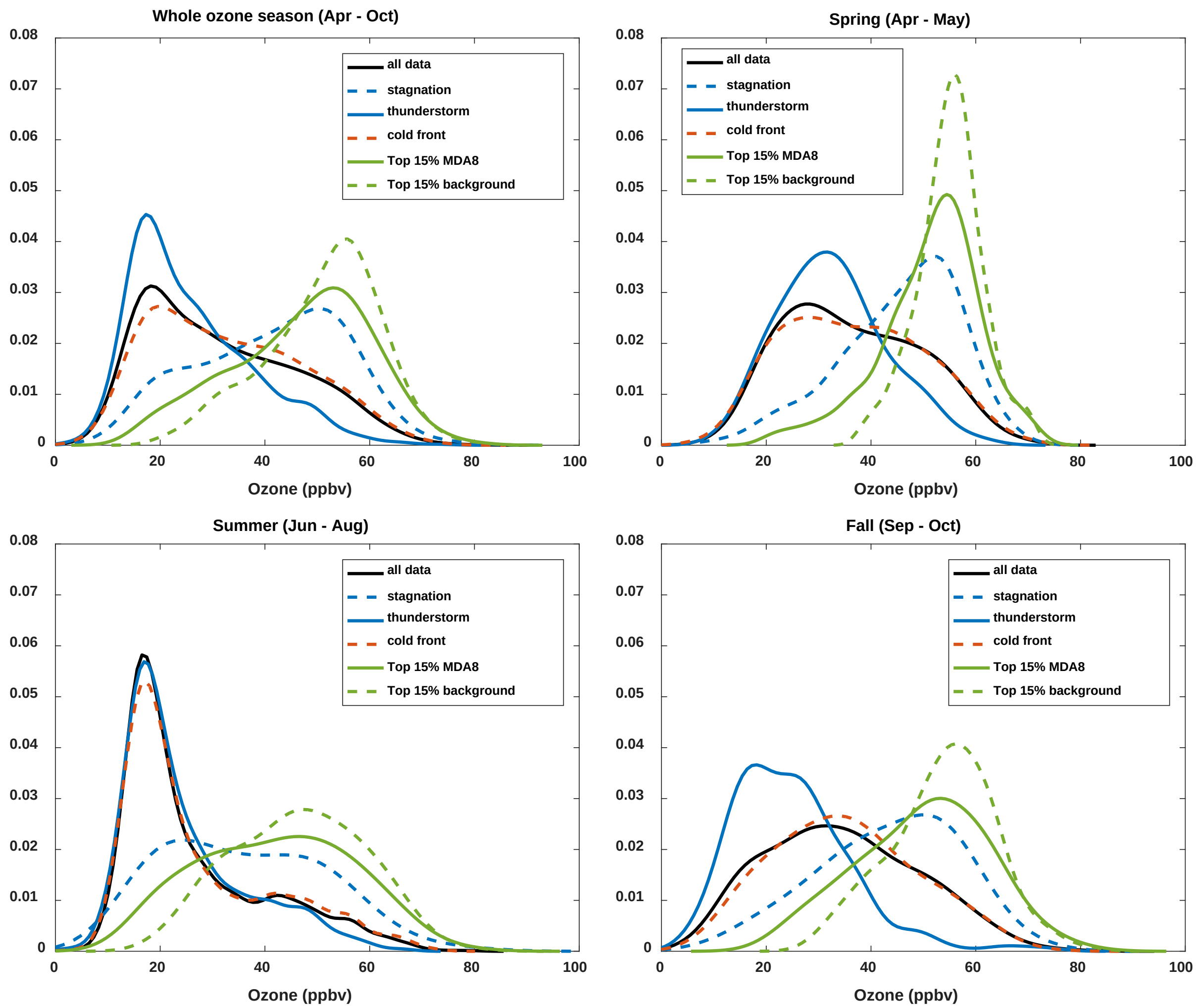

Figure 4. Probability density curves of seasonal background ozone mixing ratio

Since only stagnation showed clear increasing effects on ozone, we then focused on the overlapping patterns of stagnation with high ozone days. Figure 5 shows the overlapping patterns by month; the Y-axis shows the total number of days during the study period (2000-2015) summed up by month. For the top 15% MDA8 and top 15% background ozone days (5a and 5b respectively), since their count is always 5 days per month by definition, the total count is 90 days. Within those 90 days, stagnation contributes 20%~55% and the fraction is highest in April, June, and October. For the same month, stagnation accounts for a higher fraction of high MDA8 ozone days than high background ozone days, indicating its effects on local ozone production. For exceedance days (5c), the total number of days varied by month with the typical bimodal distribution. Despite of this, the overlapping pattern of exceedance days with stagnation has a similar month-to-month variability to that of top 15% MDA8 ozone days, but with a slightly higher overlapping ratio.

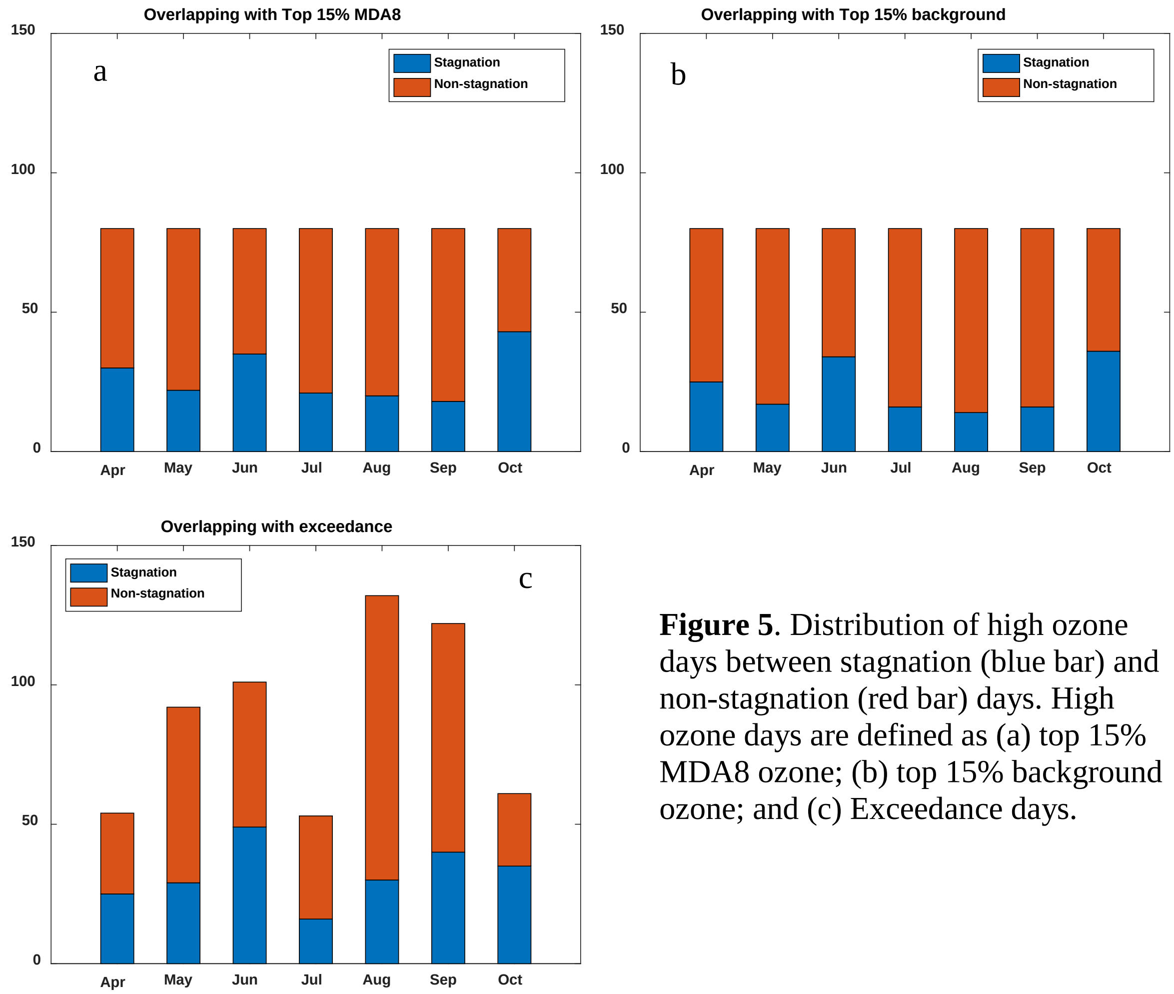

Figure 5. Distribution of high ozone days between stagnation (blue bar) and non-stagnation (red bar) days. High ozone days are defined as (a) top 15% MDA8 ozone; (b) top 15% background ozone; and (c) Exceedance days.

Task 3:

In previous report, model simulation of surface ozone in HGB for two selected cases was shown to have large positive bias (mean bias 6.98 and 15.6 ppbv for April 2011 and May 2008 respectively). While such high bias is a known problem for photochemical grid models, it is necessary to evaluate the extent to which it affects the simulated impact of fires on HGB ozone, therefore in this report we first examine the correlation between model bias and fires. CO has been known to be a good tracer of biomass burning, so CO enhancement at HGB due to Central American fires (referred to as ΔCO) is used as an indicator to show whether the fire plumes reached HGB or not. ΔCO was calculated as the difference between the control run and fire-off run. Figure 6 shows the scatter plots of ΔCO and model bias of ozone for the May 2008 and April 2011 case. There is no apparent correlation between ΔCO and model bias of ozone, which suggests that the model bias is not related to Central American fires but rather a systematic one. Therefore, we argue that simulated ΔO_3 due to Central American fires, since it is derived as the difference between the control run and the fire-off run, is not subject to the model's systematic high ozone bias.

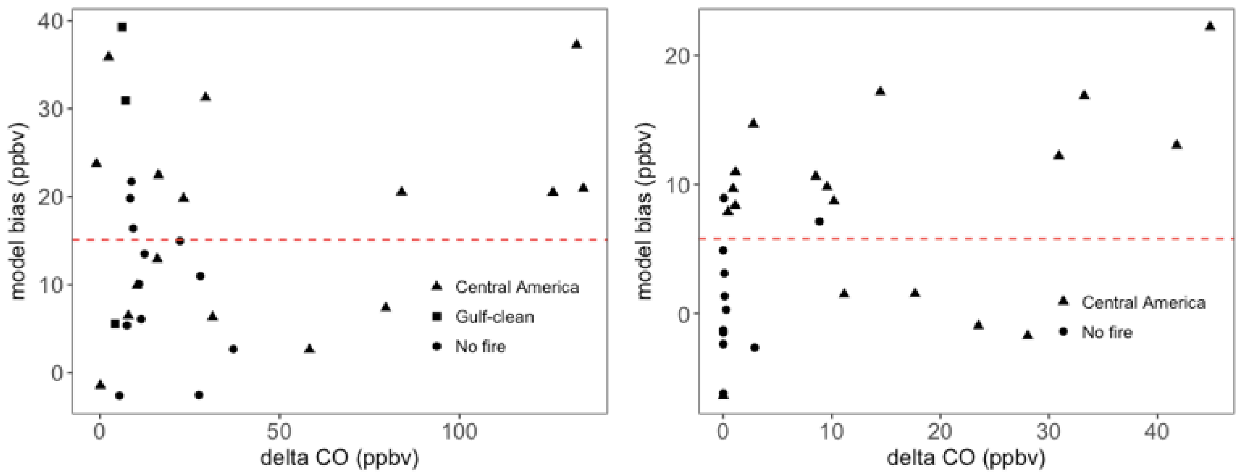

Figure 6. Scatterplot of model bias of ozone vs. ΔCO in May 2008 (left) and April 2011 (right) and the red line indicates the mean bias.

Recognizing both back trajectory and GEOS-Chem model have their uncertainties to determine the fire-impact days, we then investigated the difference between the two methods and the factors causing this difference. Figure 7. shows the mean AOD from MODIS for fire-impact days and non-fire-impact days categorized by back trajectory. The mean AOD during fire-impact days clearly illustrates the transport of fire plumes from Central America to the US Gulf coast, while during the non-fire-impact days fire plumes stayed in Mexico coastal regions instead of reaching to the US. AOD over the US Gulf coast is significantly higher during fire-impact days as compared to the non-fire-impact days, suggesting fire plumes did reach there during the fire-impact days which are determined by back trajectory.

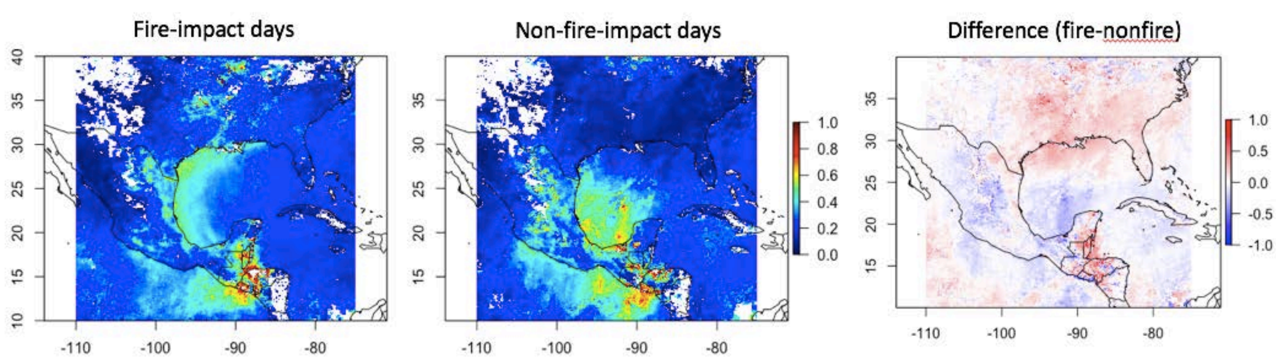

Figure 7. MODIS AOD Daily plot (Terra and Aqua average) in 2011 April and the categorization of fire-impact days is based on back trajectory.

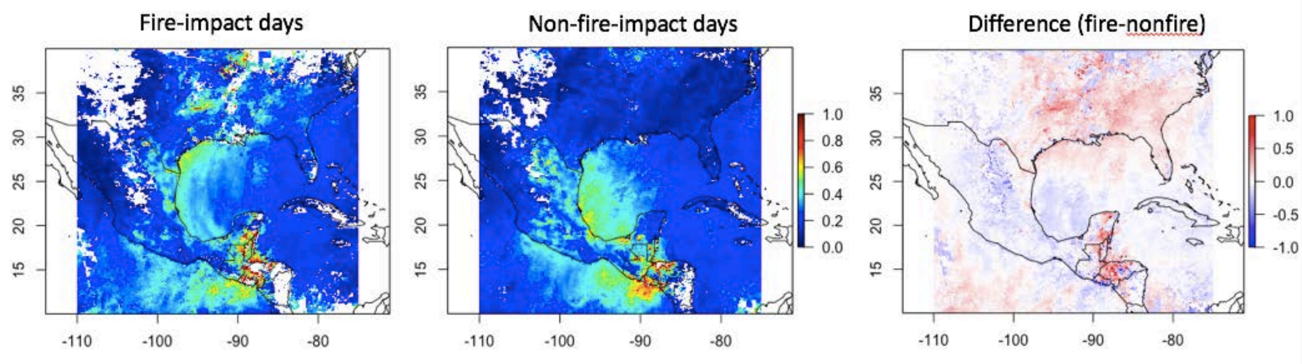

Figure 8. MODIS AOD Daily plot (Terra and Aqua average) in 2011 April and the categorization of fire-impact days is based on model (ΔO_3>1ppbv).

Figure 8 shows the same plots as Figure 7 but the fire-impact days are categorized using model simulated ΔO3 > 1ppbv. It shows the transport of fire plumes during the fire-impact days, but the signal of AOD enhancement between fire-impact days and non-fire-impact days over the US Gulf coast is weaker than that derived using back trajectory, indicating the uncertainties of using model ΔO3 as a fire-impact indicator. Indeed, literature has shown that O_3 and PM are not necessarily correlated in fire plumes because ozone is a secondary product and can be increased with a distance from fires. Also, the lifetime of PM and O3 are quite different. O3 can persist longer than PM and be transported far downwind. Therefore, we also used modeled ΔCO as another indicator to identify the fire-impact days.

Table 1 summarized the number of the fire-impact days and non-fire-impact days determined by the three different methods, illustrating the range of uncertainties in the estimate of fire-impact days. The three methods are more or less consistent for April 2011, but for May 2008 the ΔCO method gives a lot more fire-impact days than the other two methods. The meteorological fields used in back trajectory have a resolution of 32 km. By comparison, the meteorological fields used in GEOS-Chem model have a coarser resolution of around 50 km, which may lead to different fire-impact days. GEOS-Chem simulation considers the effects of convection, which facilitates the transport of fire plumes to the free troposphere where conditions are more favorable for long-range transport. Modeled ΔCO and ΔO_3 shows different number of fire impact days because O_3 is a secondary pollutant, whose production is highly dependent on chemical environment. Although fire plumes arrived in HGB, ozone might not be produced in plumes. The reasons for inconsistency of fire-impact days in these methods will be investigated in detail in future analysis. Based on the two months, we tentatively estimated the uncertainty of fire-impact days to be 30%.

Table 1. The number of fire-impact days and non-fire-impact days determined by different methods in two months.

	Number of fire-impact days (April 2011)	Number of non-fire-impact days (April 2011)	Number of fire-impact days (May 2008)	Number of non-fire-impact days (May 2008)
Back trajectory	18	12	16	15
Model ΔO3>1 ppbv	10	20	16	15
Model ΔCO>5ppbv	14	16	27	4
Mean	14	16	19.7	11.3

Standard Deviation	4	4	6.35	6.35

In summary, based on the analysis of model bias, we know that the model high bias of HGB ozone is not really related to the model's ability of simulating Central American fires. According to AOD observation, the fire plumes indeed arrived the US Gulf coast during the fire-impact days. However, fire-impact days identified by different methods have an uncertainty of about 30% and this uncertainty will affect the estimated ozone enhancement from both observations and model. Further analysis will focus on the factors causing the uncertainties in these methods.

Data Collected

Task 1

1. Cold fronts from Northern Hemisphere Cyclone Locations and Characteristics from NCEP/NCAR Reanalysis Data (https://nsidc.org/data/docs/daac/nsidc0423_cyclone/).
2. Thunderstorms from historical weather record Weather Underground (https://www.wunderground.com).

Identify Problems or Issues Encountered and Proposed Solutions or Adjustments

None this period.

Goals and Anticipated Issues for the Succeeding Reporting Period

Task 2: 1) Effect of cold fronts will be further discussed. For example, post-front days may show different effects with during-front days. 2) Background behavior will be further discussed since it showed more clear seasonal variations of mixing ratio probability curve.

Task 3: Analysis of other cases and factors which cause the uncertainties in back trajectory and model-determined fire-impact days.

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

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Submitted to AQRP by

Principal Investigators: Yuxuan Wang and Robert Talbot