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**	05/08/2017
REPORTING PERIOD	**From:** 04/01/2017 **To:** 04/30/2017	**REPORT #**	7

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: Cyclone tracks and center distribution were mapped by month and by year.

Task 2: None this period.

Task 3: Passive tracers were implemented in the GEOS-Chem model to track air mass origins. Improved quantification of fire impacts in the model was conducted based on air mass classification using the passive tracers.

Task 4: None this period.

Preliminary Analysis

Task 1:

In the last report, we conducted preliminary analysis of cyclone days and found that those days did not see a clear change of MDA8 and background ozone in the HGB region. This is because the cyclone days we selected include the whole life cycle of cyclones whose effects on HGB ozone may vary. In this month, we reexamined the seasonality and distributions of the cyclone data.

Figure 1 and Figure 2 shows the tracks of cyclone centers and cyclone counts in each month of the ozone season during 2000-2015. Cyclone distributions show great variations in each month. The number of cyclones is largest in spring (e.g. April) and fall (e.g. October), and smallest in July and August. In addition, the cyclone centers become far away from Texas during the summer (July and August). Considering the large variability of cyclone center distributions by month and by year, we do not expect every cyclone identified above would exert an influence on HGB ozone. The challenge is to define a method that could automatically screen the cycle data to select those whose cold front had passed through the eastern half of Texas and influenced HGB ozone. This issue will be the focus of our ongoing work.

We

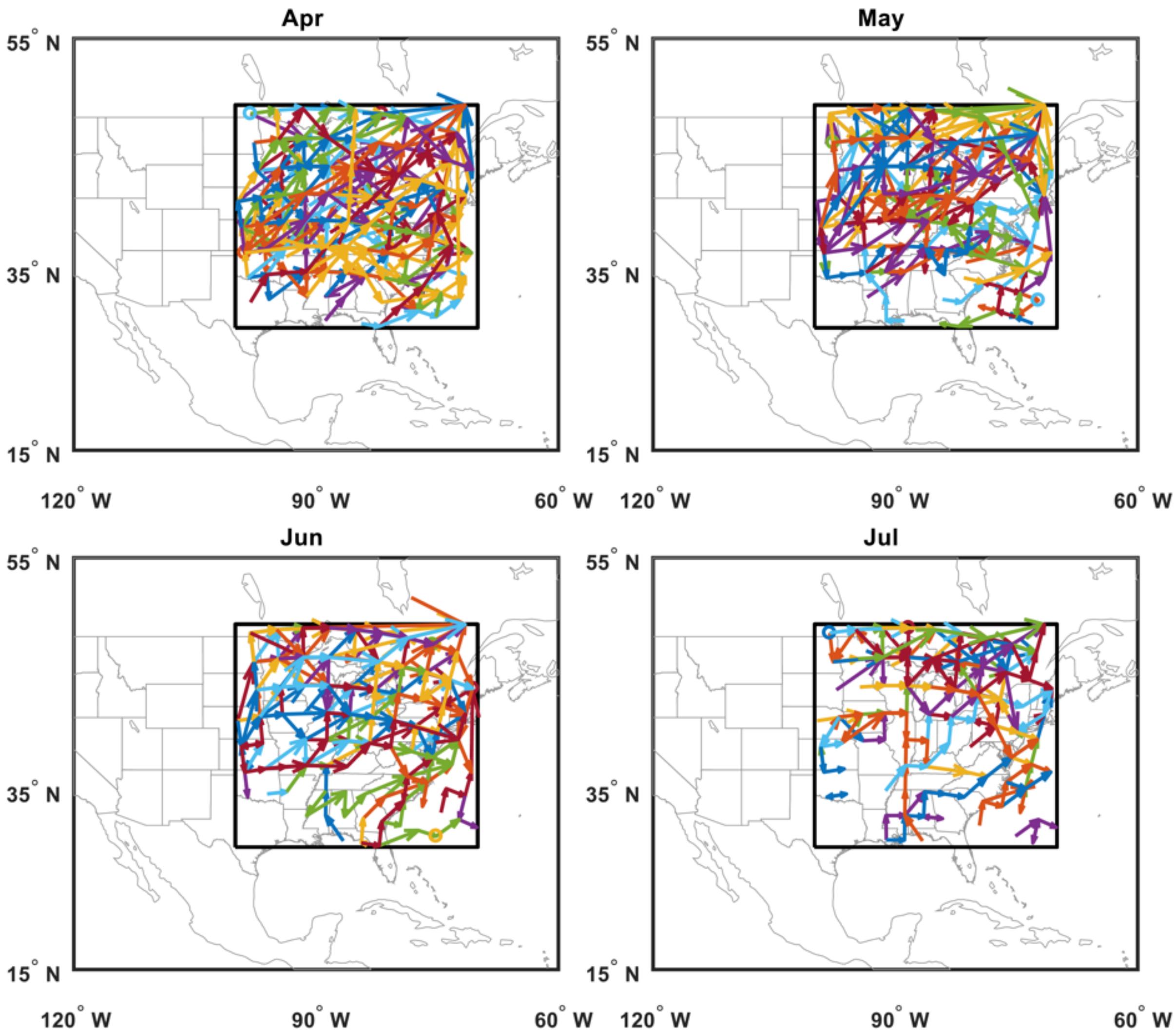

Figure 1. Cyclone center tracks in (a) April, (b) May, (c) June and (d) July during 2000-2015

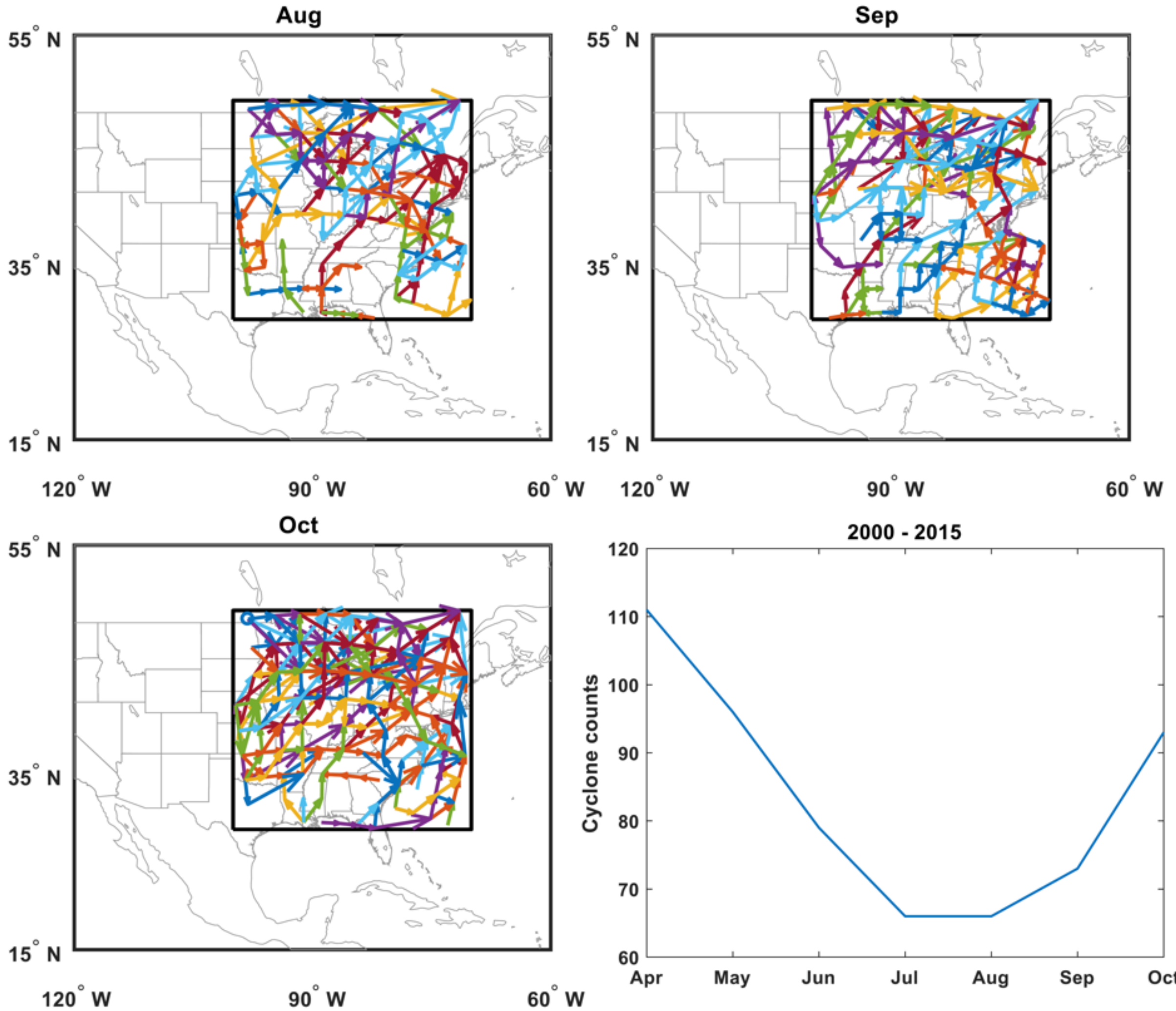

Figure 2. Cyclone center tracks in (a) August, (b) September, (c) October, and (d) Cyclone counts April to October during 2000-2015

<u>Task 3</u>:

The previous report showed that the GEOS-Chem model simulation of surface ozone in HGB for the two selected cases have large positive biases (mean bias of 6.98 and 15.6 ppbv for April 2011 and May 2008 respectively). While such high ozone bases along the Gulf coast are a well-known and long-standing challenge facing photochemical grid models, we suspect that the magnitude of the biases is dependent on the origin of air masses reaching HGB. Therefore, there is a need to track air masses in the GEOS-Chem model so as to better quantify the extent to which those biases affect the model-estimated fire impacts on HGB ozone.

We developed passive tracer simulations in GEOS-Chem to track the possible sources influencing HGB air quality. Six synthetic passive tracers were added in the model with a fixed lifetime of 30 days, which resembles CO lifetime in the warm season, and those tracers were emitted at a constant rate from the following six source regions of importance to HGB air quality: Houston, Texas (excluding Houston), US (excluding TX), Gulf of Mexico (referred to as the Gulf tracer), Mexico, and the Rest of Central America (RCA). Figure 3 shows the masks of each source region.

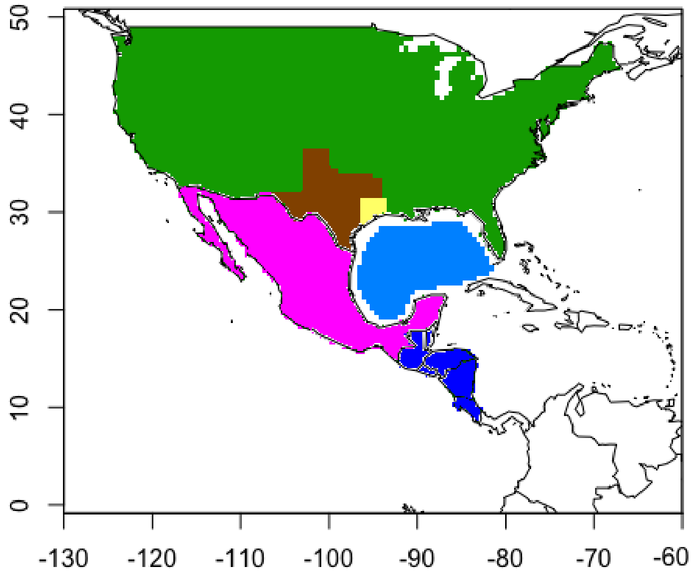

Figure 3. Source regions of the six passive tracers in GEOS-Chem: US (excluding Texas; green), Texas (excluding Houston; brown), Houston (yellow), Mexico (pink), Gulf of Mexico (light blue), and the rest of Central America (RCA; dark blue). The mask file is at a resolution of 0.5°x0.5°.

To test the utility of the passive tracer simulations, they were run at a coarser resolution of 2°x 2.5° for the two case months (April 2011 and May 2008). Since they are synthetic tracers with emissions and lifetimes chosen quite arbitrarily, comparing the absolute concentrations between different tracers is not warranted. Instead, time series of each tracer concentration at the HGB grid box were standardized by the mean and standardized deviation of its own, so as to focus on the variability. Figure 4 shows the time series of the standardized tracer concentrations over HGB for April 2011 (left) and May 2008 (right). Each tracer appears to have its own variability, while a northern tracer (e.g. TX or US) exhibits similar variations to those of another northern tracer and so does a southern tracer (e.g. Mexico, RCA, or Gulf). It is also clear that the northern tracers show variation patterns that are distinctively different from those of the southern tracers.

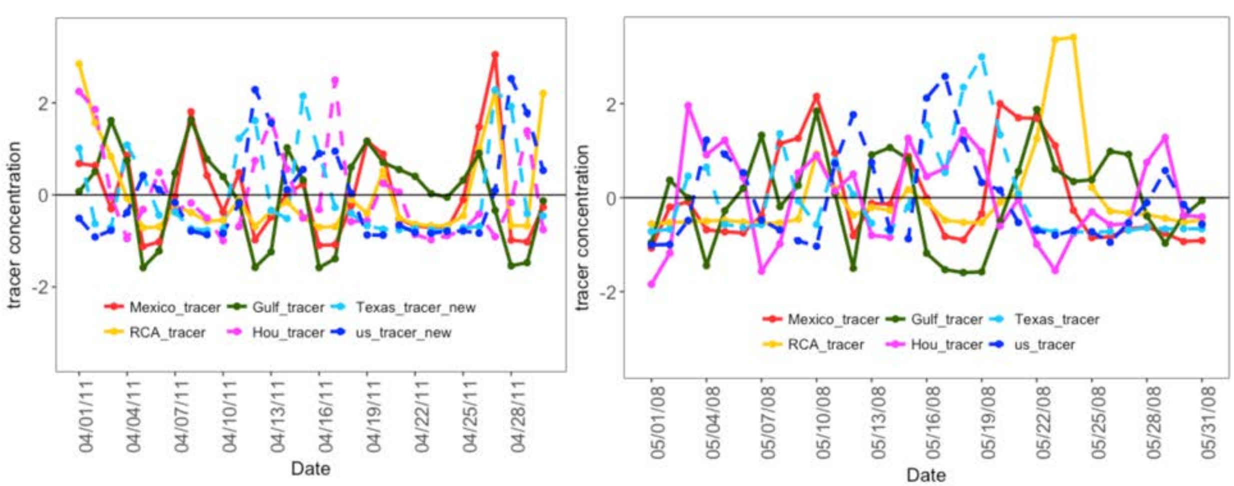

Figure 4. Time series of standardized tracer concentration over HGB region of April 2011(left) and May 2008(right).

In order to determine the days when HGB is predominantly influenced by northerly or southerly flows, we developed a composite indicator (CI) to separate the northerly and southerly flows in the model. CI is calculated according to Equation (1). That is, CI is the sum of the northern tracers (including Texas and the US tracer described above) minus the sum of the southern tracers (including the Gulf, Mexico and RCA tracer described above). All the tracer concentrations included in the calculation are standardized.

$$Composite\ indicator\ (CI) = (US + TX) - (Mexico + Gulf + RCA) \quad (1)$$

For example, when the northerly flow prevails at HGB, the standardized northern tracers will be positive and the southern tracers negative, hence CI is positive. Therefore, when CI is positive, it represents that the impact of northerly air masses is dominant at HGB. While CI is negative, the impact of southerly air masses is dominant. A Gulf-clean day is also defined when the standardized Gulf tracer is positive and all other tracers are negative, indicating HGB receives dominant influences from clean marine air from the Gulf of Mexico.

Figure 5 illustrates how the CI value can catch the influence of different sources on HGB background ozone, as they show a good positive correlation despite being completely independent from each other (i.e. CI is derived from GEOS-Chem, while background ozone is derived from surface ozone monitors). On one hand, those background ozone peaks caused by transport of air pollutants from the north (e.g. continental US) can be identified when they overlap with positive CI values. The overall positive correlation between background ozone and CI indicates that the northern influence is the primary factor for high background ozone in HGB in the springtime. On the other hand, not all the background ozone peaks are associated with positive CIs. The few background ozone peaks which coincide with negative CI values are most likely caused by the transport of pollutants from Central American fires. A visual examination of Figure 5 suggests that April 27, 2011 and May 22, 2008 are those fire transport events in the model, which will be investigated in our subsequent analysis.

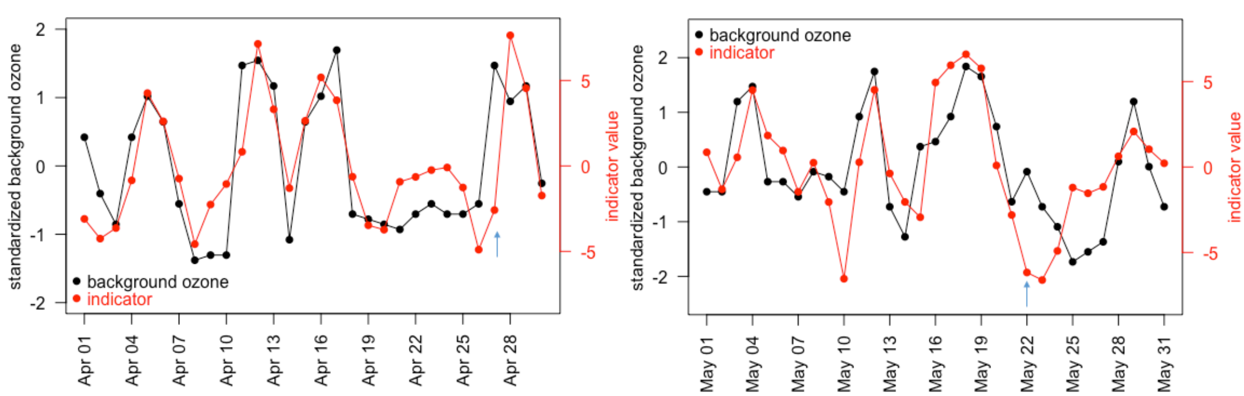

Figure 5. Time series of standardized background ozone and composite indicator over HGB region of April 2011 (left) and May 2008 (right).

Additionally, we found large positive model biases of ozone are often linked with negative CIs, indicating that the model bias is primarily caused by overestimating ozone when southerly flows dominate (Figure 6). This reflects the deficiency of the model to simulate ozone in the maritime boundary layer. Negative model biases are often associated with large values of the standardized Houston tracer, suggesting that the negative model bias is due to underestimation of local ozone formation (Figure 7).

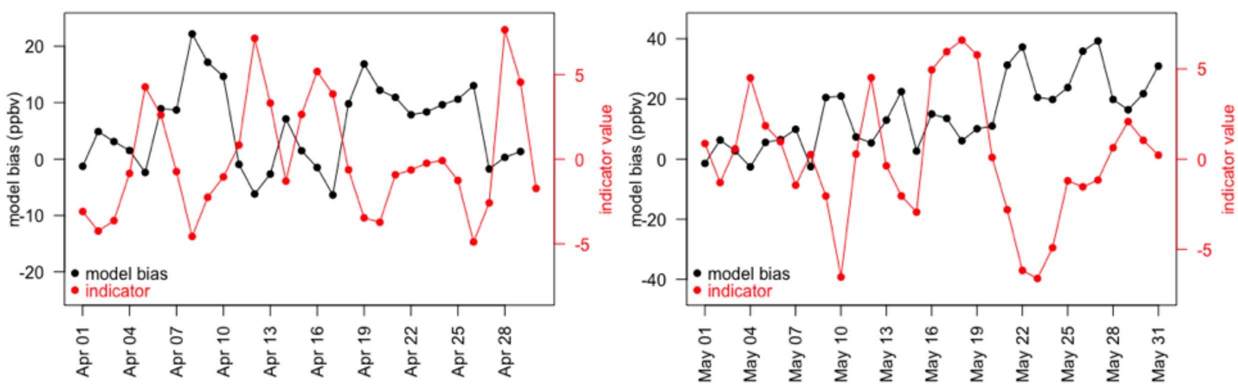

Figure 6. Time series of standardized model bias and composite indicator over HGB region of April 2011 (left) and May 2008 (right).

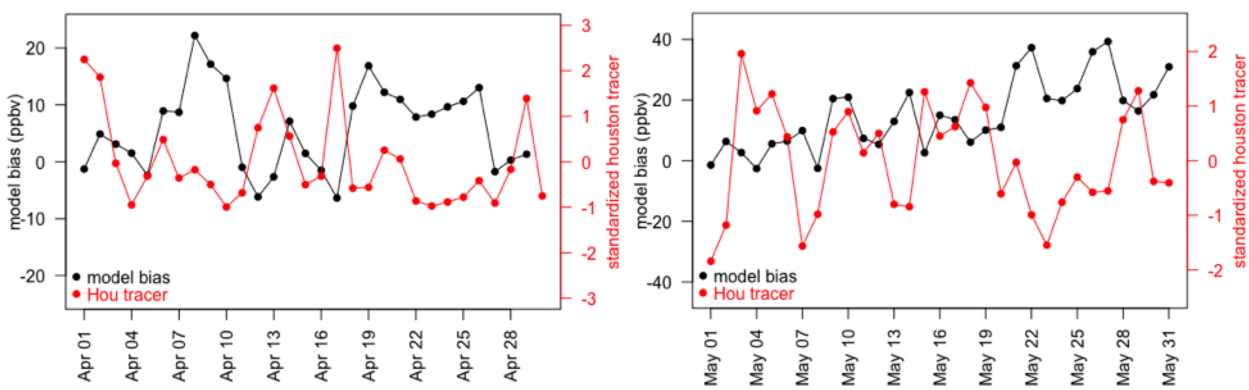

Figure 7. Time series of standardized model bias and standardized Houston tracer over HGB region of April 2011 (left) and May 2008 (right).

Based on the CI values, we classified the days of predominantly northern impact, southern fires impact, and the clean Gulf impact. Here the southern fires refer to fires from Central America. Figure 8 shows the boxplot of model and observed HGB MDA8 ozone in each category for April 2011 and May 2008. The model tends to overestimate MDA8 ozone in the clean Gulf and the southern fires impact group in both months. The overestimation of MDA8 for the northern impact group is only shown in the May 2008 case. According to Table 1, if we take the clean Gulf group as a reference, the southern fires impact group contributes around 4 ppbv and 6 ppbv to HGB MDA8 ozone for April 2011 and May 2008, respectively, based on observations. In the model world, the southern fires impact group contributes around 3.77 ppbv and 10.56 ppbv on HGB MDA8 ozone for April 2011 and May 2008, respectively. The observed and model impact of Central American fires on HGB ozone is similar for the April 2011 case, but the two differ by ~4 ppbv for the May 2008 case which may be due to model errors in fire emissions, meteorological factors, or chemistry. Both observations and the model indicate a larger impact of Central American fires on HGB ozone in May 2008 than April 2011.

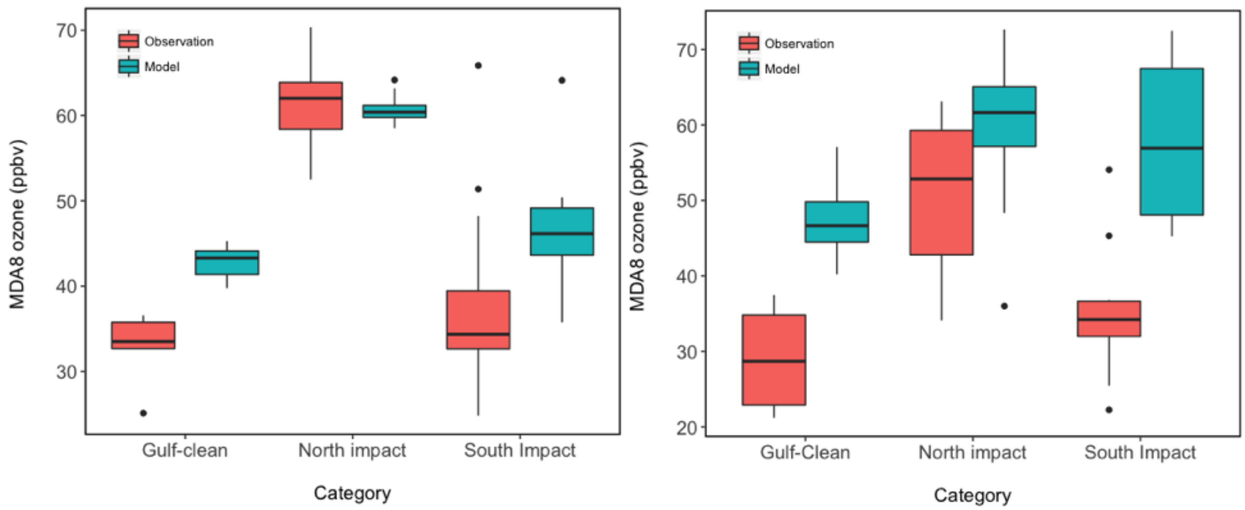

Figure 8. Boxplot of model and observed HGB MDA8 ozone in each category based on CI values for April 2011 (left) and May 2008 (right).

Table 1. The average model and observed MDA8 ozone of the northern impact group, southern fires impact group, and the clean Gulf impact groups in the two case months.

	Clean Gulf (observation)	Clean Gulf (model)	Northern impact (observation)	Northern impact (model)	Southern fires impact (observation)	Southern fires impact (model)
April 2011	32.73	42.77	61.56	60.76	36.68	46.54
May 2008	29.02	47.66	50.69	60.42	35.34	58.22

In summary, the passive tracer simulation is a convenient tool to identify source regions in the model without perturbing the ozone chemistry. The CI captures the variability of observed background ozone and thus is useful to indicate different sources of background ozone at HGB. Based on categorization using the CI, we estimated from observations that the Central American fires resulted in a 4 ppbv and 6 ppbv increase of surface MDA8 ozone at HGB during April 2011 and May 2008, respectively. The corresponding enhancement from the GEOS-Chem model is 3.8 ppbv and 10.6 ppbv, respectively.

Data Collected

None this period.

Identify Problems or Issues Encountered and Proposed Solutions or Adjustments

None this period.

Goals and Anticipated Issues for the Succeeding Reporting Period
Task 1: Investigate effects of cold fronts on ozone in the HGB area by analyzing the relationship between ozone mixing ratio and cyclone distribution.

Task 3: Identification of southern fires impact days and the clean Gulf days during April and May of 2000 to 2015 based on CI values of passive tracer simulation.

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