AQRP Monthly Technical Report

PROJECT TITLE	**Using Satellite Observations to Quantify Surface $PM_{2.5}$ Impacts from Biomass Burning Smoke**	**PROJECT #**	20-005
PROJECT PARTICIPANTS	Matthew Alvarado, Archana Dayalu, Qiang Sun (AER)	**DATE SUBMITTED**	02/08/2021
REPORTING PERIOD	**From:** 01/01/2020 **To:** 01/31/2020	**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 for reporting period

We continued our data analysis (Tasks 1 and Task 2.1) and finalized the Daily Smoke Visualizer Graphical User Interface (Smoke GUI).

We created daily smoke "grand merge" data files where all relevant data from Tasks 1 and 2.1 are gridded to the same coordinates. The daily "grand merge" data are standalone datasets that form the basis for all subsequent tasks and analyses. We used the grand merge dataset to create an archive of figures and tables for the entire 93-day aggregate analysis, as well as for individual days. We also used the grand merge data set to conduct a detailed Figure-of-Merit in space analysis where we analyzed smoke product overlap (i) across all 93 days; (ii) broken down by hour across all 93 days; (iii) daily; (iv) daily by hour.

For Task 2.2 (HYSPLIT plume analysis) we subset "grand merge" data to a significantly narrowed-down list of locations and times for pixels corresponding to (i) medium and high Smoke Confidence Index (SCI) values, and (ii) "Brown Carbon Dominant". Furthermore, as Task 2.2 specifically pertains to plume analysis, the data subset only includes instances for which GOES aerosol optical depth (AOD) measurements and, therefore, Plume Height estimates are available. The Task 2.2 subset incorporates all relevant auxiliary variables including NH_3/CO ratio, CO Total Column.

The grand merge data set will also be the basis for Task 3, where we examine the ability of our smoke product (including AOD and the value of the SCI) to predict surface PM2.5, regressed against surface PM2.5 observations.

Preliminary Analysis

Grand Merge Data Set: General Data Analysis
Table 1 summarizes the aggregate statistics of relevant variables over the full 93-day period, for each SCI, Brown Carbon (BrC), and smoke flag (SF) category. Overall, we find that BrC

dominant and/or high SCI values are associated with higher means and quantiles of smoke-relevant variables. In general, we see that pixels only identified as smoke by GOES (SF = 2) were consistently associated with higher statistics of smoke-relevant variables suggesting higher confidence in GOES smoke identification algorithm. We note that due to different overpass times and measurement frequencies, high SCI (value of 3) instances were rare and occurred only 89 times over the entire 93-day subset. However, while the small sample size prevents us from drawing any significant conclusions from the SCI=3 category, we provide the results for reference. We further note that due to the higher sample size of GOES and HMS, the SCI=2 values are biased toward the GOES+HMS smoke flag of 11.

As an additional independent check, we found that the median BrC cluster associated with an SCI of 2 (and SF of 11 or 12) was "BrC Dominant", providing further confidence in both our smoke index and brown carbon algorithm. For all other SCI and SF categories the median BrC cluster was the very broad "BrC mixtures" category. The associated mean Absorption:Extinction Ångstrom Exponent ratio (AAE/EAE) used to derive BrC content associated with "BrC Dominant" is 3.4 (25^{th}, 75^{th} quantiles: 3.2, 3.6) (Table 1).

Table 1. Aggregated statistics for smoke-relevant variables (spatiotemporally aggregated over study domain, 93 days). Variables are binned by SCI, qualitative BrC content, and SF.

	Mean GOES AOD (Quantiles 25, 75)	Mean IASI NH_3/CO (Quantiles 25,75)	Mean IASI CO (Quantiles 25, 75)	Mean OMI AAE/EAE (Quantiles 25, 75)
SCI=1(Low)	0.35 (0.15, 0.48)	0.005 (0.002, 0.006)	2.6 (2.1, 3.0)E+018	2.2 (1.7, 2.7)
SCI=2(Med)	1.2 (0.66, 1.6)	0.008 (0.004, 0.011)	3.9 (2.6, 4.7)E+018	3.0 (2.0, 3.6)
SCI=3(High)	*1.5 (1.3, 1.7) *n=2*	0.005 (0.002, 0.007)	3.1 (1.7, 3.8)E+018	2.3 (1.7, 2.5)
BrC Mix	0.23 (0.09, 0.31)	0.004 (0.002, 0.006)	2.2 (1.9, 2.5)E+018	1.8 (1.7, 1.7)
Other Aerosol	0.16 (0.06, 0.22)	0.003 (0.001, 0.004)	1.8 (1.6, 2.0)E+018	3.3 (2.5, 4.1)
BrC Dominant	0.58 (0.23, 0.80)	0.007 (0.003, 0.009)	3.2 (2.5, 3.6)E+018	3.4 (3.2, 3.6)
SF =1 (HMS)	0.35 (0.14, 0.47)	0.005 (0.002, 0.006)	2.6 (2.1, 3.0)E+018	2.2 (1.7, 2.7)
SF =2 (GOES)	1.0 (0.43, 1.4)	0.006 (0.002, 0.009)	3.1 (2.1, 3.8)E+018	2.6 (1.7, 3.5)
SF = 3 (UVAI)	0.22 (0.04, 0.25)	0.003 (0.001, 0.004)	2.0 (1.7, 2.2)E+018	2.9 (1.7, 3.9)
SF =11 (H+G)	1.2 (0.66, 1.6)	0.008 (0.004, 0.011)	4.0 (2.6, 4.7)E+018	3.0 (2.0, 3.6)
SF = 12 (G+U)	2.1 (1.8, 2.3)	0.013 (0.010, 0.016)	4.9 (3.7, 5.6)E+018	3.4 (3.5, 3.6)
SF = 13 (H+U)	0.65 (0.27, 0.99)	0.006 (0.003, 0.008)	2.8 (2.1, 3.2)E+018	2.7 (1.8, 3.4)

We also conducted an analysis by month of year to evaluate any seasonal patterns; these results are shown in Figure 1. While all 93 dates were selected as potential smoke-heavy dates, Figure 1 shows that, as expected, all smoke-relevant variables for the region peak in the April/May Yucatán/Mexico biomass burning period.

Finalized Smoke GUI

The smoke GUI has been finalized as a "daily smoke visualizer" tool and enables the user to select a date from a calendar and scroll through/zoom in/save daily plots. We chose not to include an aggregate statistics option, as creating those images from the entire grand merge data set is computationally intensive and impractical for a simple GUI. The figures and tables for the aggregate data set are available in the static figure archive. While the daily plots are also available in the static figure archive, the GUI provides an additional user-friendly option for quick access to daily figures. The GUI was introduced along with a figure in the previous MTR. Figure output from the GUI includes maps of SCI, SF, NH_3/CO, CO, BrC, AOD, Plume Height, and daily FMS broken down by hour.

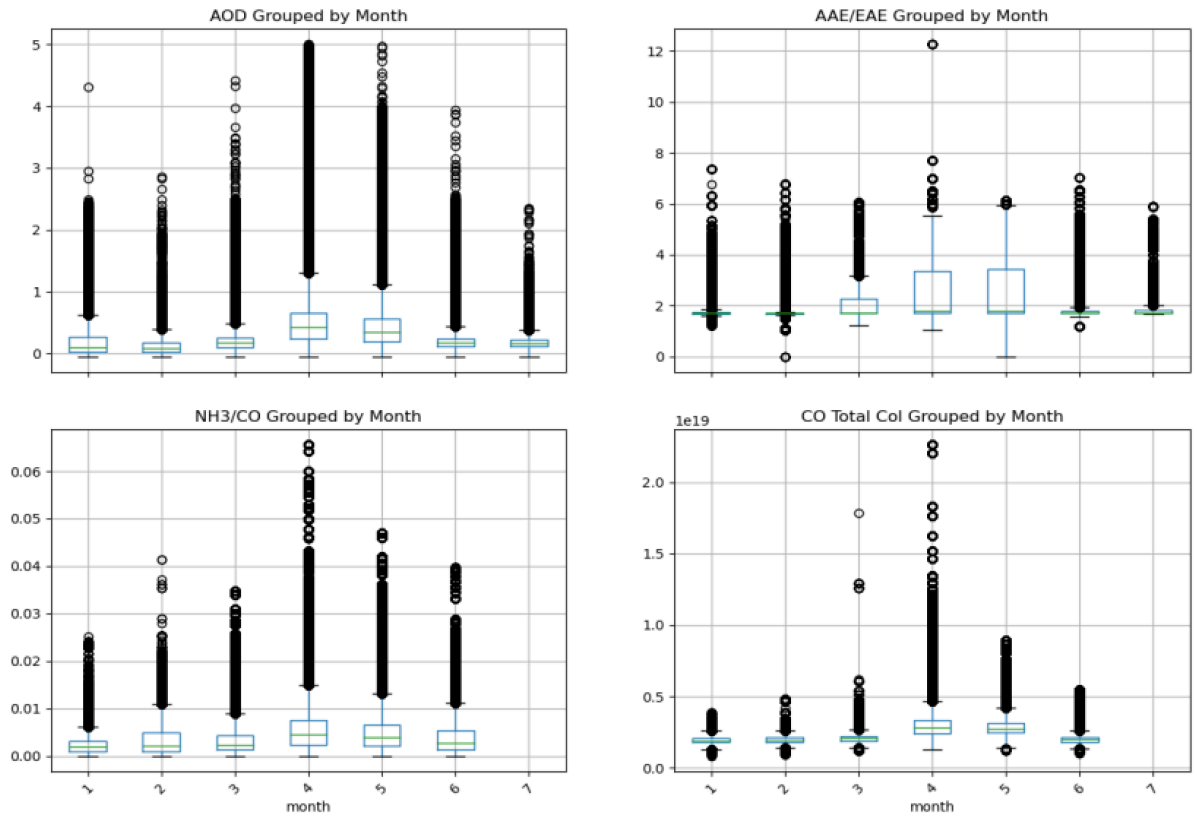

Figure 1. Smoke-relevant variables for all pixels in study domain grouped by month of year (January – July 2020). July IASI NH_3 and CO data were not yet available at the time of raw data processing.

Figure-of-Merit in Space (FMS) Analysis

We conducted FMS analyses over the entire study time period and for each day. Because measurement hours differed across smoke products, we further conducted FMS analyses for each hour, aggregated over the 93 days as well as for each day. All FMS results have been tabulated, with daily FMS results by hour additionally saved to the figure archive and displayed in the GUI. A sample figure of daily FMS (broken down by hour) is shown in Figure 2 (top panel) for the sample date 2020-04-17. On this date, FMS calculated across the entire day for GOES+HMS overlap was 0.8%, but we see from the hourly breakdown that the peak was actually significantly higher (>4%) at hour 22, with additional peaks >1% over the course of the day. Therefore, without the hourly break down, the true FMS metric would be significantly underestimated if we aggregated across all hours. The large number of pixels across all hours would create a large union denominator that would obscure a relevant intersection.

In the future, a second potentially useful FMS metric could include a more qualitative daily assessment. Figure 2 (bottom panel) illustrates the value of such an approach: over the course of the day, the HMS and GOES overlap is much greater than 4%. Such a daily-scale assessment is temporally coarser but nevertheless provides useful daily information. A daily-scale assessment would therefore involve counting a pixel as an FMS overlap if it is intersected by two or more smoke products at least once over the course of that day. In the case of GOES+HMS overlap on 2020-04-17, Figure 2 suggests a daily-scale overlap of ~25%. We will continue to refine components of our FMS analysis scheme.

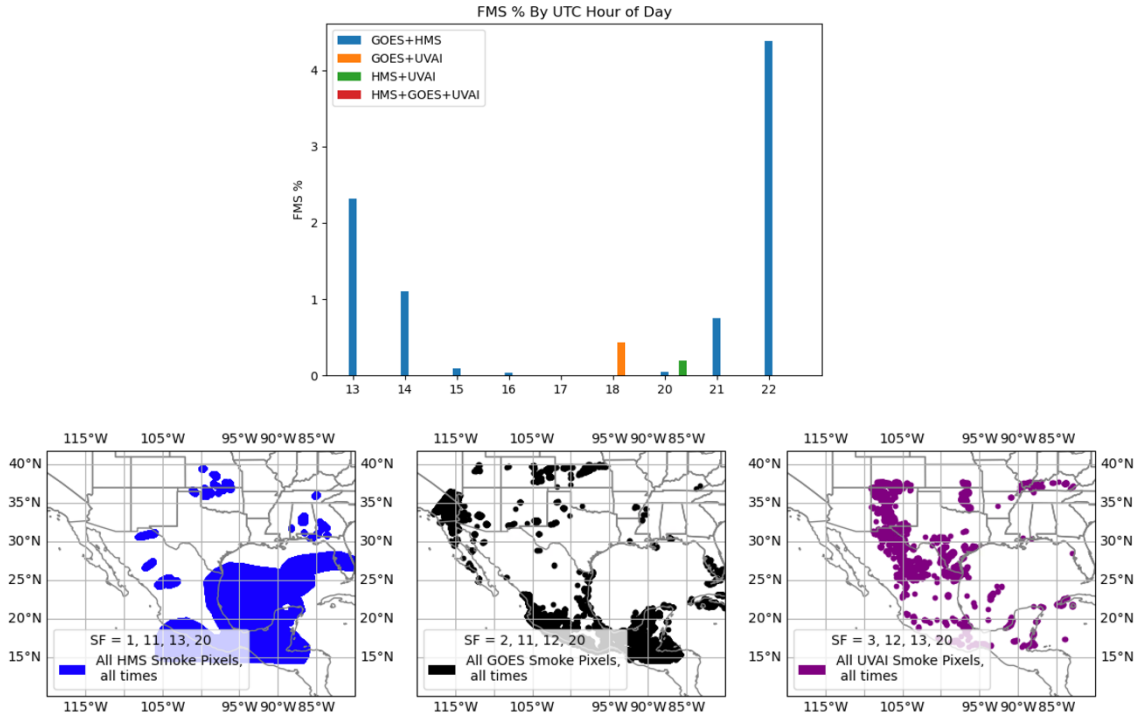

Figure 2. FMS and smoke pixel results on 2020-04-17. Top panel: FMS% broken down by hour of day. Bottom panel: HMS (blue), GOES (black) and TROPOMI UVAI (purple) smoke pixels for all times of day.

Task 2.2 HYSPLIT Data Subset Overview.
The Task 2.2 data subset has been significantly reduced from the large "grand merge" parent data set. It contains 78,783 coordinate pairs over 38 days; as expected, the majority of the 38 days (33/38) falls in the April/May peak Yucatán biomass burning season. The Task 2.2 data subset will be the basis of the Task 2.2 HYSPLIT plume analysis. The Task 2.2 list can be further narrowed down using an hourly FMS-type analysis as described above.

Data Collected

None

Identify Any Problems or Issues Encountered and Proposed Solutions or Adjustments

None

Goals and Anticipated Issues for the Succeeding Reporting Period

Over the next months, we will begin the HYSPLIT plume analysis on the Task 2.2 subset data. We will also begin Task 3, where we examine the ability of our smoke product (including AOD and the value of the SCI) to predict surface PM2.5, regressed against surface PM2.5 observations.

Detailed Analysis of the Progress of the Task Order to Date

We have selected 93 dates between January and July 2020 with suspected smoke intrusions in the Texas area. For these dates:

- We have merged all the Task 1 and 2 components thus far and placed them on a common grid.
- We have performed aggregate, seasonal, and daily analysis of the 93-day smoke data set, incorporating multiple auxiliary products (NH_3, CO, OMI BrC, AOD, PH) where relevant.
- We have developed a Smoke Confidence Index within a standalone data set that enables a user to perform multiple calculations including FMS, PH, etc.
- We have calculated PH from AOD bins based on Cheeseman et al. (2020) MAIAC PH/AOD relation.
- We have performed FMS analyses, aggregated over all times as well as broken down by day and measurement hour.
- We have developed a python-based GUI to visualize daily results from a user-selected date.
- We have subset relevant data for HYSPLIT Plume Analysis (Task 2.2)

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

Working title: Identification and evaluation of biomass burning events: a data assimilation approach over Texas
Journal: Journal of the Air and Waste Management Association
A draft of this manuscript will be provided to AQRP prior to submission.

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 (ie: publications that cite the project) 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

Identifying Smoke-Impacted Regions using the Optical Properties of Brown Carbon Aerosol, oral presentation at the CMAS Fall Meeting

Identifying Smoke-Impacted Regions using the Optical Properties of Brown Carbon Aerosol, poster at AGU Fall Meeting

Have any personnel changes occurred that were not listed in the original proposal? If so, please include a detailed description of the personnel change(s) below.

☒ **Yes** ☐ **No**

We added AER Sr. Research Associate Qiang Sun to the project to help gather and process data for Task 1.

Are any delays expected in the progress of the research? If so, please include a detailed description of the potential delay below.

☐ **Yes** ☒ **No**

Describe any possible concerns/issues (technical or non-technical) that AQRP should be made aware of.

None

Are you anticipating using all the available funds allocated to this project by the end date? If not, why and approximately what is the amount to be returned?

☒ **Yes** ☐ **No**

Submitted to AQRP by
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