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**	01/08/2021
REPORTING PERIOD	**From:** 12/01/2020 **To:** 12/31/2020	**REPORT #**	5

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 created a final data set for Task 1 and the relevant portion of Task 2. As laid out in the November MTR, the 93-day data set provides a spatiotemporally resolved (2km, hourly) Smoke Confidence Index (SCI) along with key information including aerosol optical depth (AOD), Plume Height (PH) estimates, brown carbon (BrC) identification, and total column values for ammonia (NH_3) and carbon monoxide (CO). The full 93-day dataset is ~5GB. The final data set is the basis for a python-based Graphical User Interface (GUI) that we created which enables the user to obtain data visualizations from any of the 93 study dates. The GUI also provides the user with an option to visualize aggregate statistics across all 93 study dates. The visualizations include information on smoke statistics across products as well as Figure-of-Merit in Space (FMS) calculations and plume height statistics.

Preliminary Analysis

Performance of Smoke Confidence Index and Individual Smoke Products

Our hypothesis was that higher values of the SCI correspond to significantly higher values of AOD. Our analysis confirmed our hypothesis, suggesting value in assessing smoke impacts by evaluating multi-smoke product overlap (Figure 1). Specifically, AOD values corresponding to a medium or high SCI were on average over three times greater than those with a low SCI (Figure 1a). However, given the overpass time restrictions of the TROPOMI UVAI product, SCIs of 3 (i.e., high SCI) were rare, and was more a reflection of sample time mismatches from the TROPOMI UVAI product rather than ubiquitous spatial mismatching. Furthermore, of the 89 pixels that were identified with an SCI of 3, only two instances had a corresponding AOD value; the remaining instances had AOD values that were masked either through insufficient data quality or missing for other reasons. We also break down the AOD by Smoke Flag (SF) that provides more resolved information on overlap of specific products (Figure 1b). Based on AOD binning alone, we note that the GOES smoke product generally correlates with higher AOD than either HMS or UVAI alone. GOES+HMS overlap in turn correlates to higher AOD than GOES alone, but the statistical significance of this needs to be assessed. We also note that given the

relatively low sample size of TROPOMI when compared to GOES and HMS, the medium SCI values are biased toward GOES+HMS overlap (Figure 1).

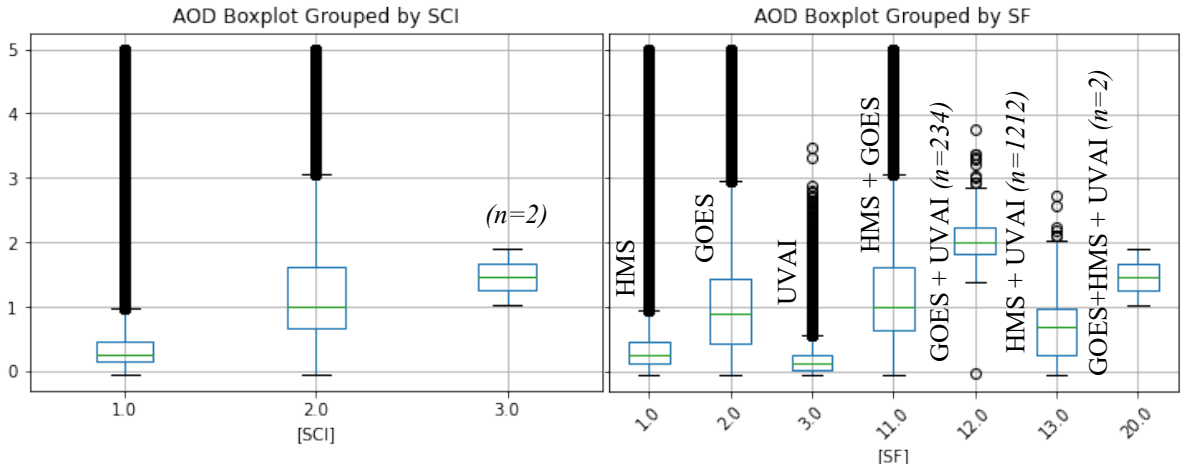

Figure 1. AOD grouped by (left) SCI and (right) SF across all hours of all 93 study days. In the case of the 89 pixels categorized as high SCI, only two instances were associated with non-missing AOD. The SCI=3 (and SF = 20) results are therefore provided for information only due to insufficient sample size. We list sample size, n, where significantly less than others.

Figure-of-Merit in Space Analysis

We are also conducting FMS-type analyses over the study domain, both in aggregate and for specific seasons/times. The purpose of the temporal FMS analysis is to (1) assess the performance of the varying smoke products during times of known and more intense smoke activity (April and May seasonal Mexico/Yucatán agricultural fires) versus other times of the year, and (2) by time of day, to account for greater coverage by certain products at particular times of day.

A basic FMS calculation (intersection:union) across all dates indicates low overlap among products. The highest overlap is 0.67% for (GOES∩HMS)/(GOES∪HMS); product intersections with TROPOMI UVAI are much less, primarily due to less temporal coverage of the TROPOMI product. In the peak April/May biomass burning season, the (GOES∩HMS)/(GOES∪HMS) is still low (0.87%) but represents a 30% increase relative to the full 93 day data set.

Plume Height Analysis

Table 1. Plume Height estimates based on average AOD in seven bins.

	AOD_Mean	AOD_0.25_quartile	AOD_0.75_quartile	PH_m_Mean	PH_m_25qtl	PH_m_75qtl
0	0.257203	0.167063	0.335839	135.546201	88.041999	176.987375
1	0.655576	0.562088	0.737476	345.488728	296.220157	388.649942
2	1.052560	0.957367	1.134489	554.699110	504.532316	597.875860
3	1.507726	1.386284	1.617843	794.571830	730.571556	852.603452
4	1.989615	1.870721	2.093578	1048.526914	985.869748	1103.315682
5	2.455782	2.363600	2.534734	1294.197122	1245.617145	1335.804711
6	3.423601	2.852407	3.496252	1804.237609	1503.218572	1842.524705

Cheeseman et al. (2020) showed that, for binned AOD values, PH = 527* AOD (R^2=0.97). The relation was found to hold specifically for binned AOD; the relation was not significant for collocated AOD and PH values. Similarly, we created seven bins for our GOES AOD. We calculated PH for each bin's mean AOD using the Cheeseman et al. (2020) relation. Table 1 summarizes the statistics for this analysis, conducted for AOD values across all 93 days.

User-friendly GUI development

We developed a python-based GUI that enables a user to visualize and save figures for specific dates from the study in addition to aggregate statistics. A screenshot of the GUI and a sample of some of the output plots from the daily visualization are shown in Figure 2.

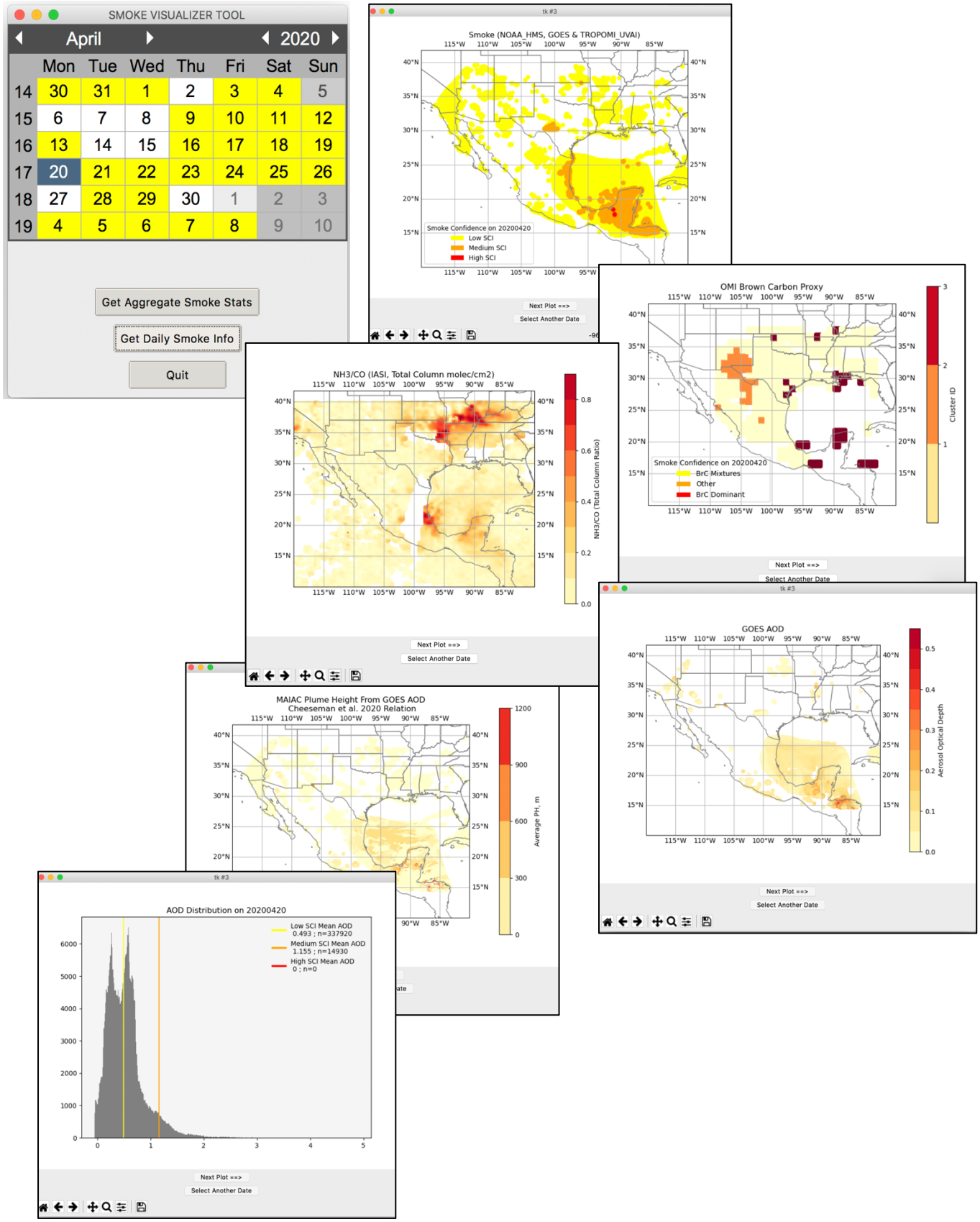

Figure 2. Example GUI Output for Daily Smoke Visualization on April 20, 2020. Additional plots (not shown) include individual smoke pixels for GOES, HMS, and TROPOMI UVAI.

Data Collected

N/A

Identify Any Problems or Issues Encountered and Proposed Solutions or Adjustments

None

Goals and Anticipated Issues for the Succeeding Reporting Period

We will continue our data analysis as well as finalize the GUI, which is still in development. We have constructed a list of locations and times for pixels corresponding to medium to high SCI values. We will further refine this list by binning according to NH3/CO ratio and potential brown carbon presence; the resulting data set will be used in the HYSPLIT plume analysis (the second part of Task 2). 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 are completing and refining our comparisons of three different smoke products, the first milestone of Task 1 from the task order. We will also incorporate time of measurement to further refine our comparisons.
- We have begun our comparison with OMI brown carbon estimates derived from AOD and AAOD measurements.
- We have also begun our comparison with IASI CO and IASI total column NH_3 data.
- We have begun our analysis of plume heights associated with smoke pixels from GOES; we are using a published relationship of MAIAC plume heights and aerosol optical depth associated with GOES smoke pixels.
- We are merging/synthesizing all the Task 1 and 2 components thus far and placing them on a common grid.
- 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 basic FMS analyses.
- We have developed a python-based GUI to visualize both daily and aggregate results.

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, Wildfire Special Issue
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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