Scope of Work For

Project # 19-031

Project Title

Detecting events and seasonal trends in biomass burning plumes using black and brown carbon: $(BC)^2$ El Paso

Prepared for

Air Quality Research Program (AQRP)
The University of Texas at Austin

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QA Requirements: Audits of Data Quality: 10% Required
Report of QA Findings: Required in Final Report

Approvals

This Scope of Work was approved electronically on **October 24, 2018** by David Sullivan, The University of Texas at Austin

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This Scope of Work was approved electronically on **October 25, 2018** by Erik Gribbin, Texas Commission on Environmental Quality

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Project Liaison, Texas Commission on Environmental Quality

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Abstract
Recent efforts by Texas Air Quality Research Program (AQRP) and TCEQ to monitor and study air quality in Texas cities has resulted in improved understanding of the processes and sources which control urban air quality in e.g. Houston. As highlighted in the AQRP Priority Research Areas 2018-2019, El Paso is near the National Ambient Air Quality Standards for particulate matter (PM) and ozone (O_3). Reductions in anthropogenic emissions through implementation of cleaner technologies for e.g. motor vehicle exhaust, coal-fired power plants, have refocused efforts to understand the contribution of biomass burning to urban air pollution. This is particularly relevant for El Paso, which can experience large impacts of periodic biomass burning/wildfire plumes transported from out-of-state. Black carbon (BC), a marker for combustion influences on air quality, has been shown to be decreasing in urban areas across the United States due to increased regulation and the use of cleaner fuels [2]. As a result, biomass burning contributions are likely becoming more important for BC and for urban air quality in general.

We will provide critical insight on the influence of biomass burning on the air quality in El Paso, TX through the characterization of BC and brown carbon (BrC). BrC is the carbon fraction of an aerosol that selectively absorbs short wavelengths of light. The $(BC)^2$ El Paso field campaign will include the deployment of the Baylor air quality trailer, which will be outfitted with a suite of specific technologies developed to assess biomass burning through the monitoring of BC and BrC. Biomass burning plumes will be identified using aerosol composition and light absorption properties, including BC and BrC concentrations, absorption Ångström exponents (AAE), and aerosol light absorption coefficients for specific ultraviolet (UV) and visible wavelengths [3, 4]. The newest technology for real-time monitoring of aerosol absorption is the tricolor absorption photometer (TAP). The TAP measures adsorption at UV, green and red wavelengths to more specifically target biomass burning. This inexpensive and continuous photometer was designed by National Oceanic and Atmospheric Administration (NOAA) and is commercially produced by Brechtel to address issues with previous photometers, including cost, sensitivity, noise and effective scattering corrections [5]. Although it was only recently available, Baylor and UH PIs have run this instrument successfully during the 2017 San Antonio field campaign (SAFS) in the Baylor air quality trailer. The two goals of $(BC)^2$ El Paso are to 1) address scientific air quality questions of frequency, seasonality, and optical properties of biomass burning plumes in El Paso and 2) to evaluate the TAP instrument suite for application in long-term monitoring at urban sites in Texas.

Hypothesis: *Biomass burning is influencing air quality in El Paso, TX. The TAP instrument will provide a cost-effective, sensitive means of identifying biomass burning plumes in El Paso through the real-time characterization of black carbon and brown carbon.*

To assess this hypothesis, a long-term field campaign, the Black Carbon, Brown Carbon El Paso or (BC)2 El Paso campaign, will be conducted deploying a suite of small footprint, low power, low maintenance, optical instruments in El Paso, TX (Fall 2018 to June 2019). This suite includes two, three wavelength TAPs, a three wavelength nephelometer, and a seven channel aethalometer. The dual goals of this deployment are to address scientific air quality questions of frequency, seasonality, and optical properties of biomass burning plumes in El Paso as well as the instrument evaluation of the TAP for application in long-term monitoring at urban sites in Texas. The science questions will utilize aerosol absorption measurements at two different wavelengths (e.g., UV and red wavelengths) to 1) identify biomass burning plumes and 2) use the range in observed absorption Ångström exponents (AAE) to characterize the biomass

burning plumes. The results of this study could be used to develop effective strategies to improve air quality in El Paso. In addition, the instrument evaluation of the TAP will help TCEQ determine the suitability of this instrument for future deployment in Texas for characterization of biomass burning impacts.

2.0 Background

Biomass burning, which can include wildfires, agricultural burning and residential wood smoke, emits particulate matter (PM) and a wide range of gas phase pollutants. PM emissions from biomass burning are predominantly carbonaceous, with aerosol absorbance from both black carbon (BC, or elemental carbon) and brown carbon (BrC, or light absorbing organic carbon) [3]. Biomass burning plumes can also impact ozone (O_3) and secondary organic aerosol (SOA), through emission of NO_x (nitric oxide; NO and nitrogen dioxide; NO_2), sulfur dioxide, ammonia, and volatile organic compounds (VOCs). AQRP Project 16-008 and AQRP Project 16-024 identify biomass burning plumes from out-of-state as a significant sources of regional background air pollution in Texas potentially impacting both O_3 and $PM_{2.5}$.

El Paso is also impacted by regional biomass burning: meteorological conditions can drive biomass burning plumes into the city from across state and international boundaries [6]. The complexity of El Paso regional air pollution is heightened by its arid climate, topography, frequent temperature inversions and proximity to Ciudad Juarez, Mexico; all of which have resulted in periodic increases in O_3, carbon monoxide (CO), and PM [7]. The Texas AQRP Priority Research Areas for 2018-2019 identified El Paso, Texas, as an area which needs additional O_3 and PM studies, including deployment of new monitoring technologies to identify episodes of biomass burning using continuous BC and BrC measurements.

Background and rationale for instrumentation:

Since the optical properties of BC and BrC will be utilized for source identification of biomass burning, a brief overview is warranted. Andreae and Gelencsér wrote a classic review of light absorbing aerosols focused on BC and BrC [8]. BC is defined both by its light absorption and by its refractory nature (Fig. 1). It is formed during combustion as nearly pure elemental carbon that has a graphitic-like structure and absorbs across the visible spectrum with a mass absorption efficiency of $7.5\pm1.2 m^2 g^{-1}$ [8, 9]. Brown carbon, BrC or light absorbing organic carbon [8], has been identified in emissions from smoldering biomass burning fires and unlike BC, it's absorption has a strong wavelength dependence (peaking in the UV). BrC has a very low absorbance in the visible and longer wavelengths, which are typically utilized by filter-based absorption techniques to determine BC (e.g., 600-900 nm). This difference in wavelength dependence for BrC vs BC, combined with the emission source differences, has resulted in utilization of BrC to BC ratios to identify biomass burning plumes [3, 10-16].

Considerable work has been done to quantify and characterize BC and aerosol absorption in the atmosphere using a variety of instrumentation and protocols [3-5, 17-27]. The most effective campaigns for investigation of BC and BrC have included more than one absorption instrument. This guarantees that the results can be compared across a variety of previous studies, but still incorporate the advancements of new technologies. Therefore, (BC)2 El Paso will include both TAP and aetholometer instruments for BC and BrC measurement.

Cost effective options for real-time monitoring have included many filter-based techniques, where light transmission through a filter media is measured at short intervals while atmospheric PM is slowly accumulating. There are uncertainties associated with this type of measurement, which can be large. Uncertainties associated with the filter can include: a lack of reference standard for quantification of BC, uncertainty in the scattering correction by the filter and PM loading resulting in shadowing effects [26, 28]. Additional uncertainties include specificity of light source wavelength, flow rate, and definition of size of sample area [26]. To assess the "best" instrument for a given application, these uncertainties need to be taken into account.

To address on-going issues with other filter-based, realtime BC and BrC instruments (i.e. high frequency of manual filter changes, problematic and contentious correction schemes for aerosol scattering and other filter effects), NOAA developed and constructed an aerosol absorption instrument, the continuous light absorption photometer or CLAP (TAP is the commercial version) that fulfilled the needs of long-term monitoring, improved corrections, multiple wavelengths, high sensitivity and low noise, precisely defined filter spot areas, temperature stabilization, uses same correction as the Particle Soot Absorption Photometer (PSAP), very low cost and very small instrument footprint [5]. To minimize uncertainty in absorption measurements, the $(BC)^2$ El Paso campaign will deploy a three-wavelength nephelometer to achieve the most accurate optical properties [3, 5]. The TAP represents the cutting edge of filter-based photometers and will be purchased, deployed, and validated for long-term application during $(BC)^2$ El Paso in 2018-19.

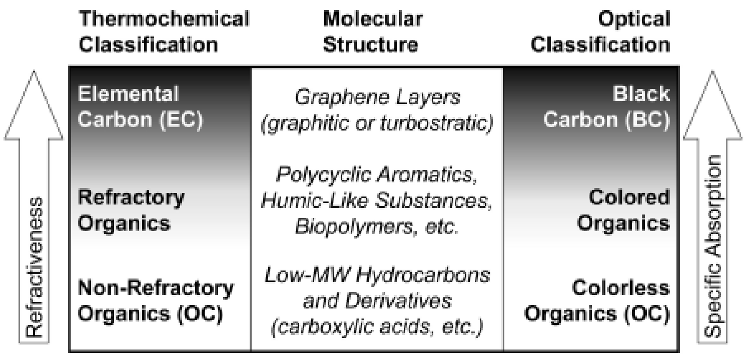

Figure 1 Figure of continuum of thermal and optical properties of carbon. Brown carbon would fall on the continuum under "colored organics". Figure based on Pöschl et al [1]. Thermochemical properties highlight differences in potential atmospheric processing, while chemical composition differences highlight the utility of absorption measures for monitoring.

BC and BrC for identification of biomass burning plumes: Biomass burning plumes will be identified utilizing the absorption measurements of BC and BrC, using methodology based on recently published studies [3, 10, 12, 13, 29]. Specifically, high AAE values indicate the presence of BrC (2-4.5), while BC should have a lower AAE value, near 1. BrC has a higher AAE value due to its ability to selectively absorb short wavelengths. Motor vehicle exhaust, or similar fossil fuel combustion has been demonstrated to have an AAE value dominated by BC while biomass burning has been demonstrated to contribute the higher, BrC-influenced AAE [30]. AAE values are calculated for specific absorption coefficient pairs (see Figure 2 Inlay). The combination of TAP and seven channel aethalometer in $(BC)^2$ El Paso will allow several wavelength pairs to be tested. Most recently, Laing et al., outlines the use of TAP aerosol light absorption coefficient measurements (σ_{abs}), nephelometer aerosol light scattering coefficient measurements (σ_{scat}) and CO to further characterize the potential differences in the AAE of transported biomass burning plumes [3]. Laing et al. identified that long-range transport events had lower AAE values and higher σ_{abs} to CO enhancement ratios ($\Delta\sigma_{abs}/\Delta CO$) as compared to more regional transport. This difference in AAE values was attributed to two different possibilities. The first explanation was BrC loss during transport (e.g. photobleaching, volatilization, and aerosol reaction). This is important for our consideration as the Paso del Norte region, in which El Paso resides, experiences both regional and long-range transport of biomass burning plumes. Chalbot et al., examined the monthly variation of fires to impact the region (2001-2010) and found that regional (400-800 km) fires were pervasive in May and June and the presence of a bimodal distribution (March-April and July-August) for long-range transport events (1600-4800 km) [6]. Secondly, the flaming condition (e.g. flaming, flames and smoldering, and smoldering) of the fire are capable of altering the contribution of BC and BrC. During a 2016 Balcones National Wildlife Refuge field campaign, PI Sheesley, utilized AAE to assess the relative contributions of BC and BrC emitted under different flaming conditions (e.g. flaming, flames and smoldering, and smoldering; see Fig. 2). It should be noted that during the Balcones field campaign the aethalometer struggled under moderately high aerosol loading, (50 to 100 µg/m^3), which resulted in more frequent filter advancements and few data points. We hypothesize that El Paso, TX will experience a range in AAE values which can be utilized to derive impact from biomass burning events. Thus, (BC)^2 El Paso will characterize biomass-burning events in El Paso utilizing AAE, nephelometer and co-located CO instruments.

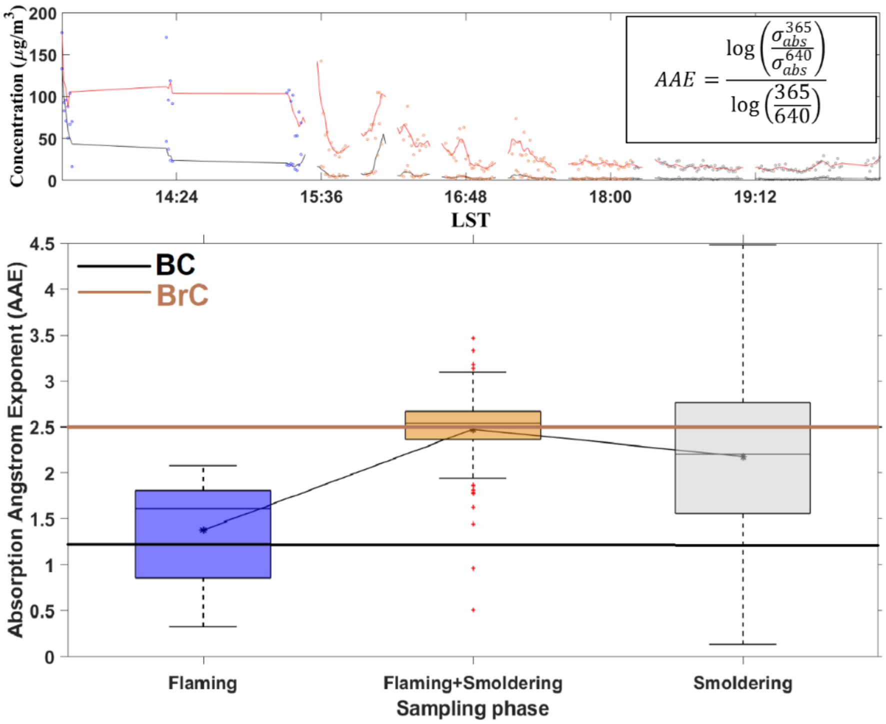

Figure 2. Flaming condition from a prescribed burn in the Balcones Canyonlands and National Wildlife Refuge (2016) were characterized using AAE. During periods of flaming the BC dominated the AAE with values near 1.2. Periods that included smoldering had higher AAE values near 2.5. Inlay. Equation for AAE calculations, using 365 and 640 nm.

The AAEs reported in other studies may be site specific as transport time, combustion conditions and local mixing of sources may have an impact on the resultant optical properties. Additional validation/instrumentation will be used during this project to confirm wildfire impacts (i.e., CO, and $PM_{2.5}$ from TCEQ monitoring sites in El Paso). Once validation is completed for a specific site, the absorption instruments may be sufficient in themselves to identify and quantify biomass burning contribution. This will be investigated during the (BC)^2 El Paso project, where a nephelometer will be deployed with the TAPs and aethalometer while synoptic TCEQ monitoring network data will be utilized for confirmation and further characterization.

3.0 Objectives

Research objective: Improve identification and quantification of biomass burning plumes impacting El Paso, TX through new long-term monitoring technologies for black carbon and brown carbon. This is a critical component of developing a strategy to meet National Ambient Air Quality Standards (NAAQS) in El Paso.

4.0 Task Descriptions

4.1 Identify the peak season for local and Mexican biomass burning that impacts El Paso.

a. El Paso, TX air quality field campaign

This evaluation task will be ongoing over the course of the project and progress towards this particular task will be provided in the Monthly Reports. To meet the objective, answer the science questions, and evaluate the TAP, a nine-month field campaign with deployment of two TAPs (Brechtel model 2901-UV (365, 520, and 640 nm), Hayward, CA, USA), a seven-channel aethalometer (Magee Scientific AE42 with seven wavelengths from 370-950 nm, Berkeley, CA, USA), and nephelometer (TSI 3563 for 450 nm (blue), 550 nm (green), and 700 nm (red); Shoreview, MN, USA) is proposed. This task starts with TAP purchasing and field preparation of existing instruments. TAPs use a 47mm glass fiber filter that rotates for 10 spots and two white reference spots. Manual changes of the filter are the primary maintenance. The operation of the instrument will be optimized for low operator intervention. The instrument will rotate to a new spot at a set attenuation (i.e. start with the recommended 70%). This attenuation-based rotation can be optimized for operation in El Paso. The flow rate is adjustable to lengthen filter life, with a lower flow rate (down to 0.5 $l\ min^{-1}$) under high aerosol concentration events. The nephelometer will be used for scattering correction which will also allow the TAP to run at higher attenuation (higher aerosol loading). The two TAPs will be configured to run alternately every half hour over the course of the campaign. This will extend filter life.

The BC and BrC measurements will be combined with monitoring data from the TCEQ network in El Paso to identify biomass burning events. These will be initially identified by changes in optical properties for the BC and BrC and changes in concentration for BC. BrC absorption is hypothesized to increase during biomass burning events, which would drive an concurrent increase in AAE over the "normal" El Paso urban signal. The long term nature of the campaign will allow for a more robust characterization of the normal range of AAE, BC and BrC in El Paso. Co-located CO measurements (these are available at select TCEQ monitoring sites in El Paso, including the University of Texas at El Paso, UTEP), will be used to support identification of biomass burning events. CO mixing ratios are available from real-time measurements at UTEP, and approach the time resolution and realtime accessibility (with unofficial data updated hourly on the TCEQ website) to the $(BC)^2$ El Paso field data. Speciation data for particulate matter (e.g. potassium, organic and elemental carbon in PM) can also be used to support biomass burning event characterization, but is available on a lower time resolution and with a delay for off-line analysis. Thus, short term data interpretation will be based off realtime instrumentation and incorporation of PM speciation will be limited by data availability and timeliness. Enhancement ratios ($\Delta Y/\Delta X$) for aerosol absorption and scattering [3, 31] at specific wavelengths (365, 528, and 652), which utilize the change in absorption or scattering for a change in CO, will be calculated to identify biomass burning events. These will be calculated using updated schemes for background CO, scattering and absorption [31].

Deliverables: Monthly reports describing progress made towards the successful completion of the field campaign (e.g. site visits, instrument ordering and testing, site setup and operation). Raw preliminary data from absorption and scattering measurements will be presented in the form of a graph. The occurrence of a potential biomass burning will be described. If necessary, specific problems and actions conducted or proposed solutions will be described as it relates to sampling efforts and logistics. The final report will include identification of peak biomass burning season based on the TAP, aethalometer, and nephelometer characterization of BC and BrC optical properties (e.g., AAE) with support from co-located TCEQ air quality monitoring data (e.g. CO mixing ratios).

Schedule: The schedule for Task 4.1 Deliverables is shown in Section 7. Special note, the field campaign will commence 8-10 weeks after the finalization of the contract. This reflects a 6-8 week lead time in the ordering of the TAPs and 2 weeks for in-house testing prior to field deployment.

4.2 Identify differences in optical properties between biomass burning plumes and "normal" urban pollution in El Paso. This will include characterization of the range of absorption Ångström exponents for biomass burning in El Paso.

This evaluation will be ongoing over the course of the project and progress towards this particular task will be provided in the Monthly Reports. Biomass burning plumes will be characterized utilizing the absorption measurements of BC and BrC. Specifically, AAE values are calculated for specific absorption coefficient pairs (see Figure 2 Inlay). Previous studies using an aethalometer have utilized UV (~370 nm) and infrared (~880 nm), while studies using the TAP have utilized UV (~365 nm) and green (~660 nm). High AAE values indicated the presence of BrC (2-4.5), while BC should have a lower AAE value, near 1. BrC has a higher AAE value due to its ability to selectively absorb short wavelengths. Most recently, Laing et al., outlines the use of TAP aerosol light absorption coefficient measurements (σ_{abs}), nephelometer aerosol light scattering coefficient measurements (σ_{scat}) and CO to identify both regional and long-range biomass burning events at MT Bachelor, Oregon [3]. For example, biomass burning events will be identified using thresholds for BrC (e.g. AAE, concentration or response and duration).

AAE values will be described for the entirety of the event. Variability in AAE will be investigated using a wide range of parameters including meteorological variables, trace gases (e.g. CO), and aerosol scattering. AAE will be calculated using the absorption measurements from the TAPs and the aethalometer.

Deliverables: Monthly reports describing preliminary AAE values (see Figure 2 Inlay) for biomass burning events (if available) and non-biomass burning periods. Biomass burning events will also be identified using CO (concentrations and durations) and aerosol scattering. If necessary, specific problems and actions conducted or proposed solutions will be described as it relates to sampling efforts and logistics.

Schedule: The schedule for Task 4.1 Deliverables is shown in Section 7

4.3 How does the new TAP compare to the older aethalometer for the following questions:

1. Instrument noise, downtime, maintenance, sensitivity, precision?

2. Operation under the high loading conditions of biomass burning plumes?

3. Which wavelengths are recommended specifically to monitor impacts of biomass burning based on TAP and seven channel aethalometer comparison?

To compare the aethalometer with the TAPs, corrections are needed for filter loading and multiple scattering. For the TAP, corrections will be accomplished using the same protocol as NOAA for the CLAP [5, 28]. For the aethalometer, several correction schemes will be considered. These potential correction schemes are further outlined in the QAPP. Weingartner et al. [32] proposed aethalometer correction factors for attenuation effect due to the filter-loading and determined the calibration constant for different types of aerosols to correct for the multiple scattering in the filter matrix. The proposed empirical correction for these biases requires information on the light scattering behavior of the sampled particles, which was obtained using a nephelometer. Arnott et al. [33] proposed a theoretically based scattering correction. Schmid et al. [34] proposed a correction that includes firstly a constant filter-loading correction which is a parameter estimated as the slope of the attenuation coefficient versus filter attenuation curves, and secondly the multiple scattering correction developed by Weingartner et al. [32].

Deliverables: This evaluation will be ongoing over the course of the project and progress towards this particular task will be provided in the Monthly Reports. Monthly reports will compare both TAP instruments and aethalometer in terms of ongoing operation (e.g. user time and maintenance) as well as sensitivity and selectivity of the optical measurements under periods of relatively low and high loading and relative humidity. Monthly reports will also compare the two instruments in terms of downtime. If necessary, specific problems and actions conducted or proposed solutions will be described as it relates to sampling efforts and logistics.

Schedule: The schedule for Task 4.1 Deliverables is shown in Section 7

4.4 What is the annual cost/time investment for the operation of a TAP at a monitoring site?

Deliverables: This evaluation will be ongoing over the course of the project and progress towards this particular task will be provided in the Monthly Reports. Evaluation over the course of the project will be included in the final report.

Schedule: The schedule for Task 4.1 Deliverables is shown in Section 7

4.5 How well does the biomass burning identification compare to identification from existing TCEQ monitoring (i.e. filter-based potassium as available, real-time $PM_{2.5}$, NO_x, etc? This includes determination of how well the TAP integrates with co-located instrumentation (nephelometer, TEOM, CO) to accurately determine biomass burning influence in El Paso.

This evaluation will be ongoing over the course of the project and progress towards this particular task will be provided in the Monthly Reports.

Deliverables: Correlation of absorption and BC data with TCEQ monitoring data for El Paso (e.g. PM, CO, NO_x, etc) that is available by Jun 30, 2019 will be included in the final report. Monthly reports describing the TAPs ability to identify biomass burning with and without co-located instruments (nephelometer, TEOM, etc). This will be the net result of the combined previous Tasks, with special attention paid to the corrective power added by the co-located nephelometer, the seven channel aethalometer, and the CO measurements. To address this task, the PIs will assess whether accurate absorption coefficients in El Paso require correction for scattering with co-located nephelometer measurements or can be corrected using a standard scattering correction. The PIs will also assess whether co-located TEOM or CO monitoring is needed to conclusively determine biomass burning event influence.

Schedule: The schedule for Task 4.1 Deliverables is shown in Section 7

5.0 Project Participants and Responsibilities

Provide a table or bulleted list that summarizes the individual participants and their responsibilities.

Task	Participant	Responsibilities
1. Identify the peak season for local and Mexican biomass burning that impacts El Paso		
	PI Sheesley	Oversee project, coordinate PIs and students, mentor graduate student, do site visits, submit monthly reports, interpret data
	Co-PI Usenko	Coordinate purchase and in-lab testing of instrument, do field logistics planning, interpret data, assist with monthly reports
	Co-PI Flynn	Act as instrument expert for nephelometer, do site visits,

		act as networking and data expert, coordinate site setup
2. Identify differences in optical properties between biomass burning plumes and “normal” urban pollution in El Paso.		
	PI Sheesley	Interpret data, coordinate data interpretation among PIs and grad student,
	Co-PI Usenko	Interpret BC, BrC and PM data
	Co-PI Flynn	Interpret trace gas and nephelometer data
3. How does the new TAP compare to the older aethalometer?		
	PI Sheesley	Evalute for ability to identify biomass burning plumes.
	Co-PI Usenko	Evalute for ability to identify biomass burning plumes and add cost/time assessment for both instruments.
4. What is the annual cost/time investment for the operation of a TAP at a monitoring site?		
	Co-PI Usenko	Estimate cost/time of running suite of instruments.
	Co-PI Flynn	Estimate cost/time of running suite of instruments.
5. How well does the TAP integrate with co-located instrumentation (nephelometer, CO, TEOM, $PM_{2.5}$ speciation) to accurately determine biomass burning influence in El Paso		
	PI Sheesley	Interpret data, coordinate data interpretation among PIs and grad student,
	Co-PI Usenko	Interpret BC, BrC and PM data
	Co-PI Flynn	Interpret trace gas and nephelometer data

6.0 Timeline

Provide a table or bulleted schedule of project activities including a timeline for each task defined in Section 4.0.

The project will begin in September 2018 and will be completed by August 31, 2019. A timeline of proposed activities and deadlines are provided below.

Timeline of proposed and activities: BC^2 El Paso		2018						2019					
	Activity	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
BC^2 Campaign	TASK 1 BB peak season												
	TASK 2 BB optical properties												
	TASK 3 TAP to aethalometer comparison												
	TASK 4 Annual cost/time investment for TAP												
	TASK 5 TAP BB Identification: Comparison w/ other												
Reporting	• Work Plan, QAPP, SOW, and Budget												
	• Montly Technical Reports												
	• Financial Status Reports												
	• Quarterly												
	• Draft Final Report												
	• Final Report												
	• Presentations - Texas Workshop												
	• Publications												

BB indicates Biomass Burning

7.0 Deliverables

AQRP requires certain reports to be submitted on a timely basis and at regular intervals. A description of the specific reports to be submitted and their due dates are outlined below. One report per project will be submitted (collaborators will not submit separate reports), with the exception of the Financial Status Reports (FSRs). The lead PI will submit the reports, unless that responsibility is otherwise delegated with the approval of the Project Manager. All reports will be written in third person and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources. Report templates and accessibility guidelines found on the AQRP website at http://aqrp.ceer.utexas.edu/ will be followed.

Abstract: At the beginning of the project, an Abstract will be submitted to the Project Manager for use on the AQRP website. The Abstract will provide a brief description of the planned project activities, and will be written for a non-technical audience.

Abstract Due Date: Friday, August 31, 2018

Quarterly Reports: Each Quarterly Report will provide a summary of the project status for each reporting period. It will be submitted to the Project Manager as a Microsoft Word file. It will not exceed 2 pages and will be text only. No cover page is required. This document will be inserted into an AQRP compiled report to the TCEQ.

Quarterly Report Due Dates:

Report	Period Covered	Due Date
Nov2018 Quarterly Report	September, October, November 2018	Friday, November 30, 2018
Feb2019 Quarterly Report	December 2018, January & February 2019	Thursday, February 28, 2019
May2019 Quarterly Report	March, April, May 2019	Friday, May 31, 2019
Aug2019 Quarterly Report	June, July, August 2019	Friday, August 30, 2019

Monthly Technical Reports (MTRs): Technical Reports will be submitted monthly to the Project Manager and TCEQ Liaison in Microsoft Word format using the AQRP FY16-17 MTR Template found on the AQRP website.

MTR Due Dates:

Report	Period Covered	Due Date
Oct2018 MTR	October 1 - 31, 2018	Thursday, November 8, 2018
Nov2018 MTR	November 1 - 30 2018	Monday, December 10, 2018
Dec2018 MTR	December 1 - 31, 2018	Tuesday, January 8, 2019
Jan2019 MTR	January 1 - 31, 2019	Friday, February 8, 2019
Feb2019 MTR	February 1 - 28, 2019	Friday, March 8, 2019
Mar2019 MTR	March 1 - 31, 2019	Monday, April 8, 2019
Apr2019 MTR	April 1 - 28, 2019	Wednesday, May 8, 2019
May2019 MTR	May 1 - 31, 2019	Monday, June 10, 2019
Jun2019 MTR	June 1 - 30, 2019	Monday, July 8, 2019
Jul2019 MTR	July 1 - 31, 2019	Thursday, August 8, 2019

Financial Status Reports (FSRs): Financial Status Reports will be submitted monthly to the AQRP Grant Manager (Maria Stanzione) by each institution on the project using the AQRP FY16-17 FSR Template found on the AQRP website.

FSR Due Dates:

Report	Period Covered	Due Date
Oct2018 FSR	October 1 - 31, 2018	Thursday, November 15, 2018
Nov2018 FSR	November 1 - 30 2018	Monday, December 17, 2018
Dec2018 FSR	December 1 - 31, 2018	Tuesday, January 18, 2019
Jan2019 FSR	January 1 - 31, 2019	Friday, February 15, 2019

Feb2019 FSR	February 1 - 28, 2019	Friday, March 15, 2019
Mar2019 FSR	March 1 - 31, 2019	Monday, April 15, 2019
Apr2019 FSR	April 1 - 28, 2019	Wednesday, May 15, 2019
May2019 FSR	May 1 - 31, 2019	Monday, June 17, 2019
Jun2019 FSR	June 1 - 30, 2019	Monday, July 15, 2019
Jul2019 FSR	July 1 - 31, 2019	Thursday, August 15, 2019
Aug2019 FSR	August 1 - 31, 2019	Monday, September 16, 2019
FINAL FSR	Final FSR	Tuesday, October 15, 2019

Draft Final Report: A Draft Final Report will be submitted to the Project Manager and the TCEQ Liaison. It will include an Executive Summary. It will be written in third person and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources. It will also include a report of the QA findings.

Draft Final Report Due Date: Thursday, August 1, 2019

Final Report: A Final Report incorporating comments from the AQRP and TCEQ review of the Draft Final Report will be submitted to the Project Manager and the TCEQ Liaison. It will be written in third person and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources.

Final Report Due Date: Tuesday, September 3, 2019

Project Data: All project data including but not limited to QA/QC measurement data, metadata, databases, modeling inputs and outputs, etc., will be submitted to the AQRP Project Manager within 30 days of project completion (September 30, 2019). The data will be submitted in a format that will allow AQRP or TCEQ or other outside parties to utilize the information. It will also include a report of the QA findings.

AQRP Workshop: A representative from the project will present at the AQRP Workshop in the first half of August 2019.

Presentations and Publications/Posters: All data and other information developed under this project which is included in **published papers, symposia, presentations, press releases, websites and/or other publications** shall be submitted to the AQRP Project Manager and the TCEQ Liaison per the Publication/Publicity Guidelines included in Attachment G of the Subaward.

8.0 References

1. Poschl, U., *Aerosol particle analysis: challenges and progress.* Analytical and Bioanalytical Chemistry, 2003. **375**(1): p. 30-32.
2. Kirchstetter, T.W., et al., *Large reductions in urban black carbon concentrations in the United States between 1965 and 2000.* Atmospheric Environment, 2017. **151**: p. 17-23.
3. Laing, J.R., D.A. Jaffe, and J.R. Hee, *Physical and optical properties of aged biomass burning aerosol from wildfires in Siberia and the Western USA at the Mt. Bachelor Observatory.* Atmos. Chem. Phys., 2016. **16**(23): p. 15185-15197.
4. Sandradewi, J., et al., *Using aerosol light absorption measurements for the quantitative determination of wood burning and traffic emission contributions to particulate matter.* Environmental Science & Technology, 2008. **42**(9): p. 3316-3323.
5. Ogren, J.A., et al., *Continuous light absorption photometer for long-term studies.* Atmos. Meas. Tech., 2017. **10**(12): p. 4805-4818.
6. Chalbot, M.-C., I.G. Kavouras, and D.W. Dubois, *Assessment of the contribution of wildfires to ozone concentrations in the central US-Mexico border region.* Aerosol Air Qual. Res, 2013. **13**: p. 838-848.
7. Currie, J., et al., *Does pollution increase school absences?* The Review of Economics and Statistics, 2009. **91**(4): p. 682-694.
8. Andreae, M.O. and A. Gelencser, *Black carbon or brown carbon? The nature of light-absorbing carbonaceous aerosols.* Atmospheric Chemistry and Physics, 2006. **6**: p. 3131-3148.
9. Bond, T.C. and R.W. Bergstrom, *Light absorption by carbonaceous particles: An investigative review.* Aerosol science and technology, 2006. **40**(1): p. 27-67.
10. Becerril-Valle, M., et al., *Characterization of atmospheric black carbon and co-pollutants in urban and rural areas of Spain.* Atmospheric Environment, 2017. **169**: p. 36-53.
11. Tasoglou, A., et al., *Absorption of chemically aged biomass burning carbonaceous aerosol.* Journal of Aerosol Science, 2017. **113**: p. 141-152.
12. Healy, R.M., et al., *Ambient measurements and source apportionment of fossil fuel and biomass burning black carbon in Ontario.* Atmospheric Environment, 2017. **161**: p. 34-47.
13. Titos, G., et al., *Spatial and temporal variability of carbonaceous aerosols: Assessing the impact of biomass burning in the urban environment.* Science of the Total Environment, 2017. **578**: p. 613-625.
14. Briggs, N.L. and C.M. Long, *Critical review of black carbon and elemental carbon source apportionment in Europe and the United States.* Atmospheric Environment, 2016. **144**: p. 409-427.
15. Brown, S.G., et al., *Wintertime Residential Biomass Burning in Las Vegas, Nevada; Marker Components and Apportionment Methods.* Atmosphere, 2016. **7**(4).
16. Garg, S., et al., *Limitation of the Use of the Absorption Angstrom Exponent for Source Apportionment of Equivalent Black Carbon: a Case Study from the North West Indo-Gangetic Plain.* Environmental Science & Technology, 2016. **50**(2): p. 814-824.
17. Sinha, P.R., et al., *Evaluation of ground-based black carbon measurements by filter-based photometers at two Arctic sites.* Journal of Geophysical Research-Atmospheres, 2017. **122**(6): p. 3544-3572.
18. Zhi, G.R., et al., *Comparison of elemental and black carbon measurements during normal and heavy haze periods: implications for research.* Environmental Monitoring and Assessment, 2014. **186**(10): p. 6097-6106.
19. Dallmann, T.R., et al., *Characterization of particulate matter emissions from on-road gasoline and diesel vehicles using a soot particle aerosol mass spectrometer.* Atmospheric Chemistry and Physics, 2014. **14**(14): p. 7585-7599.
20. Schwarz, J.P., et al., *Assessing recent measurement techniques for quantifying black carbon concentration in snow.* Atmos. Meas. Tech. Discuss., 2012. **5**(3): p. 3771-3795.

21. Bahadur, R., et al., *Solar absorption by elemental and brown carbon determined from spectral observations.* Proceedings of the National Academy of Sciences of the United States of America, 2012. **109**(43): p. 17366-17371.
22. Ram, K., M.M. Sarin, and S.N. Tripathi, *Inter-comparison of thermal and optical methods for determination of atmospheric black carbon and attenuation coefficient from an urban location in northern India.* Atmospheric Research, 2010. **97**(3): p. 335-342.
23. Subramanian, R., et al., *Black carbon over Mexico: the effect of atmospheric transport on mixing state, mass absorption cross-section, and BC/CO ratios.* Atmospheric Chemistry and Physics, 2010. **10**(1): p. 219-237.
24. Ram, K. and M.M. Sarin, *Absorption Coefficient and Site-Specific Mass Absorption Efficiency of Elemental Carbon in Aerosols over Urban, Rural, and High-Altitude Sites in India.* Environmental Science & Technology, 2009. **43**(21): p. 8233-8239.
25. Snyder, D.C. and J.J. Schauer, *An inter-comparison of two black carbon aerosol instruments and a semi-continuous elemental carbon instrument in the urban environment.* Aerosol Science And Technology, 2007. **41**(5): p. 463-474.
26. Müller, T., et al., *Characterization and intercomparison of aerosol absorption photometers: result of two intercomparison workshops.* Atmos. Meas. Tech., 2011. **4**(2): p. 245-268.
27. Kondo, Y., et al., *Emissions of black carbon, organic, and inorganic aerosols from biomass burning in North America and Asia in 2008.* Journal of Geophysical Research-Atmospheres, 2011. **116**.
28. Bond, T.C., T.L. Anderson, and D. Campbell, *Calibration and intercomparison of filter-based measurements of visible light absorption by aerosols.* Aerosol Science & Technology, 1999. **30**(6): p. 582-600.
29. Wang, X., et al., *Deriving brown carbon from multiwavelength absorption measurements: method and application to AERONET and Aethalometer observations.* Atmospheric Chemistry and Physics, 2016. **16**(19): p. 12733-12752.
30. Sandradewi, J., et al., *Using aerosol light absorption measurements for the quantitative determination of wood burning and traffic emission contributions to particulate matter.* Environmental science & technology, 2008. **42**(9): p. 3316-3323.
31. Briggs, N.L., et al., *Particulate matter, ozone, and nitrogen species in aged wildfire plumes observed at the Mount Bachelor Observatory.* Aerosol and Air Quality Research, 2016. **16**(12).
32. Weingartner, E., et al., *Absorption of light by soot particles: determination of the absorption coefficient by means of aethalometers.* Journal of Aerosol Science, 2003. **34**(10): p. 1445-1463.
33. Arnott, W.P., et al., *Towards aerosol light-absorption measurements with a 7-wavelength Aethalometer: Evaluation with a photoacoustic instrument and 3-wavelength nephelometer.* Aerosol Science and Technology, 2005. **39**(1): p. 17-29.
34. Schmid, O., et al., *Spectral light absorption by ambient aerosols influenced by biomass burning in the Amazon Basin. I: Comparison and field calibration of absorption measurement techniques.* Atmospheric Chemistry and Physics, 2006. **6**: p. 3443-3462.