AIR QUALITY RESEARCH PROGRAM

Texas Commission on Environmental Quality
Contract Number 582-15-50047
Awarded to The University of Texas at Austin

Annual Report

September 1, 2016 through August 31, 2017

Submitted to

David Brymer
Texas Commission on Environmental Quality
12100 Park 35 Circle
Austin, TX 78753

Prepared by

David T. Allen, Principal Investigator
The University of Texas at Austin
10100 Burnet Rd. MC R7100
Austin, TX 78758

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Texas Air Quality Research Program

Annual Report

September 1, 2016 – August 31, 2017

OVERVIEW

The goals of the State of Texas Air Quality Research Program (AQRP) are:

(i) to support scientific research related to Texas air quality, in the areas of emissions inventory development, atmospheric chemistry, meteorology and air quality modeling,

(ii) to integrate AQRP research with the work of other organizations, and

(iii) to communicate the results of AQRP research to air quality decision-makers and stakeholders.

PROGRAM ACTIVITIES FOR THE YEAR

At the beginning of the reporting period, in September 2016, the latest round of AQRP projects were just beginning. Master Agreements, which describe the general terms and conditions of contracting with The University of Texas at Austin under the AQRP, were negotiated with each of the universities and businesses that were awarded research projects. As this was taking place, Project Managers assisted the project Principal Investigators with the development of the project Statements of Work, Budgets and Budget Justifications, and Quality Assurance Project Plans (QAPPs), in total referred to as the project Work Plans. During the first quarter, 8 of the 10 research projects' Work Plans were approved by AQRP Project Managers and were recommended to move forward by TCEQ Liaisons. The two remaining project Work Plans were finalized in the second quarter.

Once Work Plans were approved, a Task Order was issued to the entity performing each of the research projects. The Task Order is a project specific contractual document that outlines the period of performance, budget, and scope of work to be performed. At the end of the first quarter, Task Orders were fully executed for 6 of the projects. The remaining Task Orders were executed before the end of the second quarter.

When the final Work Plans were approved, the Project Managers worked with the Investigators to ensure that all project activities were underway. Investigators were informed of all reporting requirements, both technical and financial. Throughout the year, Project Managers worked with the Investigators to ensure that all project activities were moving forward and all technical reporting requirements were being met.

Projects began invoicing during the second quarter and the Program Administration worked with each institution to ensure that the invoices were complete and all expenses were allowable. This continued throughout the term of each of the projects and, dependent upon the size of the project, and the project activities taking place, at times, took a significant amount of effort. Projects that had extended field work, for example, required considerable analysis of each invoice to ensure all costs were allowable and properly allocated.

In March 2017, the Texas Commission on Environmental Quality (TCEQ) contacted the AQRP Administration requesting additional oversight on projects taking place in the San Antonio area in May 2017. The San Antonio Field Study project was proposed and then approved by the ITAC and the Advisory Council. Funding was allocated from funds remaining (unallocated) in the research project category. This project, led by Dr. David Sullivan at UT Austin, assisted the San Antonio Field Study PIs with finding acceptable sites to take measurements, gaining permission from those site owners to utilize those locations, and preparing the sites, including providing fencing and electrical hook-ups. The primary site was at the University of Texas at San Antonio. The field study took place in May 2017. More information on the field study activities can be found in the individual project summaries below.

In early August 2017, the AQRP Workshop was held at the UT Austin Pickle Research Campus. During the Workshop, each Investigator presented a summary of his or her project activities and research findings. Attendees included Investigators from each of the projects, AQRP Program Administration members, Project Managers, Independent Technical Advisory Committee members, an Advisory Committee member, the TCEQ Liaisons, and other interested parties from the TCEQ. A copy of each presentation will be made available on the AQRP website.

All of the projects, with the exception of the San Antonio Field Study, were scheduled to end on August 31, 2017. Three projects requested, and received extensions to their end date. Project 16-008, performed by the University of Houston, was affected by Hurricane Harvey and needed additional time to complete the final report and data curation. Their end date was extended to October 31, 2017. Project 17-039 requested an extension to October 31, 2017, to allow time to perform additional model runs to attempt to pinpoint a performance issue with their control case and complete the satellite assimilation tasks. Project 17-007 requested an extension to November 30, 2017, as the project was originally proposed as a 13 month project and it did not receive authorization to begin until November 2016.

In the third quarter, the Program Administration began a redesign of the AQRP website. It will be launched in the 2018-2019 biennium.

Throughout the year, the Program Administration communicated regularly with the TCEQ to ensure that all program requirements were being met, and to provide information on the Program and individual project activities. Administrators provided detailed Financial Status Reports monthly, as required, and additional information whenever requested.

BACKGROUND

Section 387.010 of HB 1796 (81st Legislative Session), directs the Texas Commission on Environmental Quality (TCEQ, Commission) to establish the Texas Air Quality Research Program (AQRP).

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Sec. 387.010.  AIR QUALITY RESEARCH. (a)  The commission
shall contract with a nonprofit organization or institution of
higher education to establish and administer a program to support
research related to air quality.
       (b)  The board of directors of a nonprofit organization
establishing and administering the research program related to air
quality under this section may not have more than 11 members, must
include two persons with relevant scientific expertise to be
nominated by the commission, and may not include more than four
county judges selected from counties in the
Houston-Galveston-Brazoria and Dallas-Fort Worth nonattainment
areas. The two persons with relevant scientific expertise to be
nominated by the commission may be employees or officers of the
commission, provided that they do not participate in funding
decisions affecting the granting of funds by the commission to a
nonprofit organization on whose board they serve.
       (c)  The commission shall provide oversight as appropriate
for grants provided under the program established under this
section.
       (d)  A nonprofit organization or institution of higher
education shall submit to the commission for approval a budget for
the disposition of funds granted under the program established
under this section.
       (e)  A nonprofit organization or institution of higher
education shall be reimbursed for costs incurred in establishing
and administering the research program related to air quality under
this section. Reimbursable administrative costs of a nonprofit
organization or institution of higher education may not exceed 10
percent of the program budget.
       (f)  A nonprofit organization that receives grants from the
commission under this section is subject to Chapters 551 and 552,
Government Code.
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The University of Texas at Austin was selected by the TCEQ to administer the program. A contract for the administration of the AQRP was established between the TCEQ and the University of Texas at Austin on July 29, 2015 for the 2016-2017 biennium. Consistent with the provisions in HB 1796, up to 10% of the available funding is to be used for program administration; the remainder (90%) of the available funding is to be used for research projects, individual project management activities, and meeting expenses associated with an Independent Technical Advisory Committee (ITAC).

On September 4, 2017, the AQRP contract was renewed for the 2018 – 2019 biennium and additional funding was awarded.

RESEARCH PROJECT CYCLE

The Research Program is implemented through a 9 step cycle. The steps in the cycle are described from project concept generation to final project evaluation for a single project cycle.

1.) The project cycle is initiated by developing (in year 1) or updating (in subsequent years) the strategic research priorities. The AQRP Director, in consultation with the ITAC, the Council and the TCEQ, develop research priorities; the research priorities are released along with a Request for Proposals.

2.) Project proposals relevant to the research priorities are solicited. The Request for Proposals can be found at http://aqrp.ceer.utexas.edu/ .

3.) The Independent Technical Advisory Committee (ITAC) performs a scientific and technical evaluation of the proposals.

4.) The project proposals and ITAC recommendations are forwarded to the TCEQ. The TCEQ evaluates the project recommendations from the ITAC and comments on the relevancy of the projects to the State's air quality research needs.

5.) The recommendations from the ITAC and the TCEQ are presented to the Council and the Council selects the proposals to be funded. The Council also provides comments on the strategic research priorities.

6.) All Investigators are notified of the status of their proposals, either funded, not funded, or not funded at this time, but being held for possible reconsideration if funding becomes available.

7.) Funded projects are assigned an AQRP Project Manager at UT-Austin and a Project Liaison at TCEQ. The AQRP Project Manager is responsible for ensuring that project objectives are achieved in a timely manner and that effective communication is maintained among investigators involved in multi-institution projects. The AQRP Project Manager has responsibility for documenting progress toward project measures of success for each project. The AQRP Project Manager works with the researchers, and the TCEQ, to create an approved work plan for the project.

    The AQRP Project Manager also works with the researchers, TCEQ and the Program's Quality Assurance officer to develop an approved Quality Assurance Project Plan (QAPP) for each project. The AQRP Project Manager reviews monthly, annual and final reports from the researchers and works with the researchers to address deficiencies.

8.) The AQRP Director and the AQRP Project Manager for each project describe progress on the project in the ITAC and Council meetings dedicated to on-going project review.

9.) The project findings are communicated through multiple mechanisms. Final reports are posted to the Program web site; research briefings are developed for the public and air quality decision makers; and a bi-annual research conference/data workshop is held.

During this year the AQRP performed Steps 7-9.

Independent Technical Advisory Committee (ITAC)

The AQRP funding is to be used primarily for research projects, and one of three groups responsible for selecting the projects is the Independent Technical Advisory Committee (ITAC). The ITAC is composed of between 9 and 15 individuals with scientific expertise relevant to the Program. The ITAC is charged with recommending technical approaches, establishing research priorities, and reviewing, commenting, and advising on all projects to ensure that the projects facilitate air quality improvement in Texas. Members of the ITAC consist of the TCEQ Project Director (or designee), representatives with air quality expertise from research institutions with extensive expertise in air quality research in Texas. The members of the ITAC are listed in Table 1. The members of the ITAC are drawn from Texas universities active in air quality research, national laboratories that have participated in air quality studies in Texas, and institutions that have expertise not available in Texas and that have participated in air quality studies in Texas.

The ITAC membership is intentionally drawn from air quality researchers who have experience in Texas. These researchers and their colleagues will likely have interest in responding to the requests for research proposals issued by the AQRP. This raises potential confidentiality and conflict of interest issues, and the contract between TCEQ and the University of Texas at Austin requires that the AQRP maintain and implement an appropriate written policy on conflict of interest. Specifically for the ITAC, all members are required to certify:

> *Confidentiality:* As a member of ITAC I understand that I will have access to proposals submitted to the Air Quality Research Program. Subject to any legal requirements, I agree to keep the information in these proposals confidential until the selection process is completed and it is appropriate to release information to the public. I understand that there may be certain information that comes to me in my role as a member of ITAC that retains its confidential nature even after the process is concluded. I also understand that I will review said proposals and may have access to the reviews made by other ITAC members. I agree to keep these reviews and the identity of the reviewers confidential until such time as this information is released to the public. (NOTE: For the reviews and reviewers, this information may never be released.)
>
> *Conflict of Interest:* As a member of ITAC, I agree that I will not evaluate, comment on, or vote on proposals in which I or my home institution is involved, including but not limited to, any financial interest, or in which I have another form of conflict of interest. I understand that ITAC members with conflicts of interest must leave the meeting room or the conference line when a proposal with which they have a conflict is discussed, voted on or otherwise being considered. I understand that I must recuse myself from participating in or attempting to influence at any time the ITAC's or the AQRP Council's consideration or decision concerning such proposals. I agree to bring any issues concerning a possible conflict of interest to the attention of the Director of the Air Quality Research Program or the TCEQ Project Director. If there is a question of interpretation regarding whether a conflict of interest exists, I agree that the decision regarding whether a conflict of interest exists will be made by the Director of the Air Quality Research Program or the TCEQ Project Director.

All members of the ITAC agreed to abide by these conflict of interest and confidentiality provisions prior to participating in the review of proposals.

Table 1. Independent Technical Advisory Committee Members

Name	Title	Organization
David Allen	Gertz Regents Professor in Chemical Engineering	The University of Texas at Austin
William Carter	Emeritus Research Chemist, Center for Environmental Research and Technology	University of California - Riverside
Don Collins	Professor and Director of the Center for Atmospheric Chemistry and the Environment	Texas A&M University
James Crawford	Research Scientist, Chemistry & Dynamics Science Directorate	NASA
Peter Daum	Head, Atmospheric Science Division	Brookhaven National Lab
Mark Estes	Senior Air Quality Scientist Air Modeling and Data Analysis Section	Texas Commission on Environmental Quality
Fred Fehsenfeld	Senior Scientist, Cooperative Institute for Research in Environmental Sciences	University of Colorado – Boulder (Retired)
Joost de Gouw	Research Physicist, Earth System Research Lab	NOAA
Robert Griffin	Associate Professor, Civil and Environmental Engineering	Rice University
Tho Ching (Thomas) Ho	Aldredge Endowed Chair, Regent's Professor and Chair, Dan F. Smith Department of Chemical Engineering; Director, Texas Air Research Center	Lamar University
Bryan Lambeth	Meteorologist	TCEQ (Retired)
Golam Sarwar		EPA ORD
Christine Wiedinmyer	Scientist III, Atmospheric Chemistry Division	Nation Center for Atmospheric Research
Greg Yarwood	Principal	Ramboll Environ, Inc.

TCEQ Relevancy Review

Once the ITAC has reviewed and ranked research project proposals according to technical merit, they are submitted to the TCEQ for a relevancy review. The TCEQ reviews proposals for relevancy to the State's air quality research needs. TCEQ approval is required for a project to receive funding from the Program.

Advisory Council

The final group responsible for selecting AQRP research projects is the Advisory Council. The Council consists of between 7 and 11 members, all residents of the State of Texas. Two Council members with relevant scientific expertise are nominated by the TCEQ. As defined in the AQRP contract, up to four members of the Council can be county judges from the Houston-Galveston-Brazoria (HGB) and Dallas-Fort Worth (DFW) non-attainment counties. Additional members should have a general background in air quality and business practices, and can include elected officials, business community representatives, environmental group representatives, and members of the general public. The Council's responsibilities are to attend meetings with TCEQ Management and the AQRP to understand the statewide project goals for the funding period, to select for funding the projects reviewed by the ITAC and ranked by the TCEQ, and to assist with the presentation of project final results at locations throughout the state.

Table 2. Advisory Council Members

Name	Title	Organization
Ramon Alvarez	Senior Scientist	Environmental Defense Fund
Daniel Baker	Senior Consultant in Air Quality	Shell Global Solutions
Omar Garcia	President & CEO	South Texas Energy & Economic Roundtable
Chris Klaus	Senior Program Manager	North Central Texas Council on Governments
Ralph Marquez	Proprietor	Environmental Strategies and Policy
Chris Rabideau	Environmental Scientist	Chevron
Cyrus Reed	Conservation Director	Sierra Club
Kim Herndon	Assistant Director Air Quality Division	Texas Commission on Environmental Quality
Keith Sheedy	Technical Advisor to the Deputy Director for the Office of Air	Texas Commission on Environmental Quality

RESEARCH PROJECTS

FY 2016 – 2017 Projects

Project 16-008	STATUS: Active – September 22, 2016

High Background Ozone Events in the Houston-Galveston-Brazoria Area: Causes, Effects, and Case Studies of Central American Fires

University of Houston – Yuxuan Wang

AQRP Project Manager – Elena McDonald-Buller
TCEQ Project Liaison – Doug Boyer

Funded Amount: $191,366

Abstract
A significant fraction of surface ozone in Texas comes from regional background originating from outside the state. Background ozone is particularly variable over the Houston-Galveston-Brazoria (HGB) region due to its unique geographical location and meteorology. Prior analyses of the HGB background ozone have focused predominantly upon averages, not high concentration days or exceptional events. To bridge this gap, the objectives of this project are to identify high background ozone events across the HGB area over the past 16 years (2000-2015), characterize meteorological conditions and anomalous emissions that cause these events, and understand their effects on ozone exceedances. With regard to emission anomalies, the focus will be on fire events from Mexico and Central America, a large fire region globally of unique importance to Texas air quality in springtime and summer whose impact on Texas background ozone has not been quantified.

Integrated analyses of observations and modeling will be conducted to achieve the project objectives. Daily HGB background ozone estimated by researchers at the Texas Commission on Environmental Quality (TCEQ) will be used as the data source to identify high background ozone days. Different types of meteorological events which may be potentially associated with high background ozone (e.g., cold fronts and thunderstorms) or high local photochemical production (e.g., heat waves and stagnation) will be identified based on the analysis of meteorology data. The relationship between high background ozone days and the meteorological 'event days' will be characterized, e.g., in terms of their overlapping (or the lack of it), and background ozone difference between meteorological 'event days' and 'non-event days' will be evaluated. Anomalies in fire emissions leading to high background ozone will be mapped through spatiotemporal sampling of the Fire INventory from NCAR (FINN) along background trajectories of air masses affecting the HGB area prior to and during the selected high background ozone days. The GEOS-Chem global chemistry transport model, with the FINN inventory implemented, will be used to simulate a number of case studies of large Central American fires and estimate the perturbations caused by ozone precursor emissions from those fires on background ozone concentrations in Texas and the HGB area. Finally, we will develop a quantitative estimate of the effects of background ozone versus local production on ozone exceedance cases in the HGB area and the dependence of such effects on meteorology and Central America fire emissions.

Project Update

In this period, ozone differences between different events were calculated and compared. Figure 1 shows the ozone mixing ratio distributions during all the event days investigated in the project and their respective non-event counterparts. The median differences in peak ozone between event and non-event days are 26, -11, 3, and 11 ppbv for stagnation, thunderstorm, cold front, and post front respectively. The corresponding differences for background ozone are 16, -10, 6, and 12 ppbv, respectively.

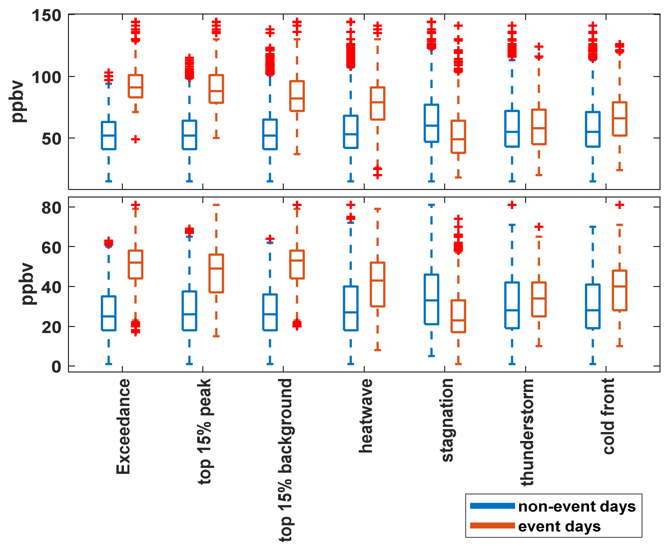

Figure 1. Boxplot of peak ozone (upper) and background ozone (lower) mixing ratio during different meteorological events.

With regard to Central American fires, the fire-impact days from GEOS-Chem passive tracer simulation were selected in conjunction with burned area statistics estimated from the Fire INventory from NCAR (FINN). The fire-impact days are those with simulated Mexico tracer at HGB exceeds 85-percentile of all days combined and burned area over Central America exceeds 70-percentile of all days combined. The GEOS-Chem based clean-Gulf days were also defined by both the transport and emissions criteria: (1) simulated Gulf tracer at HGB exceeds the 85-percentile of all days combined; and (2) burned area over Central America lower than 70-percentile. Figure 2 shows the mean HGB background ozone during April and May from 2002 to 2015 categorized by the GEOS-Chem-based fire-impact and clean-Gulf days. Compared to the clean-Gulf group, the Central America group (i.e. fire-impact days) had a mean background ozone enhancement of 8.8±1.6 ppbv. This enhancement is qualitatively consistent with the case study simulations but higher than that quantified by the back-trajectory method, presented in prior reports, because the GEOS-Chem-based method considers not only transport (via passive tracer) but also source emissions (via burned area).

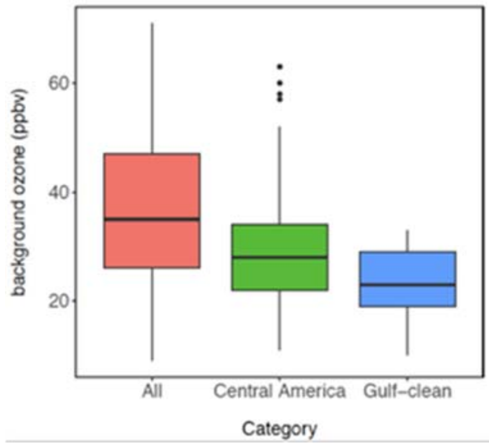

Figure 2. HGB background ozone grouped by air mass origins identified by GEOS-Chem passive tracer simulation and burned area for Apr-May from 2002 to 2015.

In this quarter, the team delivered a Draft Final Report on August 1, 2017 and presented the project findings at the AQRP Workshop on August 3, 2017. The team obtained and is in the midst of addressing the review comments from the AQRP Project Manager and the TCEQ Liaison.

The project team as impacted by Hurricane Harvey and a two month contract extension was requested and received. This extension will be used to complete the final report and to finalize the data analysis and transfer to the AQRP. The project team intends to use all funds allocated to the project by 10/31/2017 to complete the planned work tasks.

Project 16-010	STATUS: Active – October 20, 2016 Completed – August 31, 2017

MOVES-Based NOx Analyses for Urban Case Studies in Texas

Sonoma Technology, Inc. – Stephen Reid

AQRP Project Manager – Gary McGaughey
TCEQ Project Liaison – Chris Kite

Funded Amount: $69,075

Abstract

Emissions inventories are an important component of air quality planning and a key input to photochemical grid models that support air quality assessments. Findings from recent studies suggest that nitrogen oxides (NOx) emissions may be overestimated in the U.S. Environmental Protection Agency's (EPA) National Emissions Inventory (NEI), perhaps by as much as a factor of two. This overestimate has generally been attributed to the mobile source sector (e.g., on-road motor vehicles), for which emission estimates are prepared using EPA's MOVES model. A number of potential issues have been identified with MOVES, including reliance on the model's default input data rather than more representative local inputs.

The overall goals of this project were to examine MOVES emission estimates at the local scale and identify which input parameters have the greatest influence on NOx emission estimates. Specifically, we used a well-established emissions reconciliation technique to quantitatively compare MOVES emission results with ambient near-road monitoring data. These analyses were performed for case studies in three Texas metropolitan areas: Dallas-Fort Worth, Houston, and El Paso. In addition, we performed sensitivity analyses comparing MOVES emission results using default vs. local data to identify key parameters that have substantial influence on NOx emissions. The results of this work will support emissions inventory development and air quality management efforts in Texas by providing information on the accuracy of current MOVES emission estimates and MOVES input parameters, for which local data are critical.

Project Update

During this reporting period (June to August, 2017), the project team collected concentration data from three near-road monitoring sites in El Paso, Houston, and Fort Worth, as well as MOVES modeling data obtained from TCEQ (Texas Commission on Environmental Quality), NCTCOG (North Central Texas Council of Government), and H-GAC (Houston-Galveston Area Council). The team completed calculation and comparison of ambient and emission-based CO/NO_x ratios. The team also completed MOVES modeling runs and sensitivity analyses for a range of testing scenarios related to four key input parameters (fleet mix, vehicle speed, vehicle age, and meteorology).

The team delivered a Draft Final Report on August 1, 2017 and presented the project findings at the AQRP Workshop on August 3, 2017. The team obtained and addressed the review comments from the AQRP Project Manager and the TCEQ Liaison, and delivered the Final Report on August 31, 2017.

There were no delays or issues related to the project during this reporting time period. The project team intends to use all funds allocated to the project by August 31, 2017 to complete the planned work tasks.

Project 16-011	STATUS: Active – October 6, 2016 Completed – August 31, 2017

A Next Generation Modeling System for Estimating Texas Biogenic VOC Emissions

Ramboll Environ US Corporation – Gregory Yarwood

AQRP Project Manager – Elena McDonald-Buller
TCEQ Project Liaison – Doug Boyer

Funded Amount: $158,134

Abstract
The exchange of gases and aerosols between the Earth's surface and the atmosphere is an important factor in determining atmospheric composition and regional air quality. Emissions of reactive gases from the earth's surface drive the production of ozone and aerosol and other atmospheric constituents relevant for regional air quality. Emissions of some compounds, including biogenic volatile organic compounds (BVOCs), are highly variable and can vary more than an order of magnitude over spatial scales of a few kilometers and time scales of less than a day. This makes estimation of these emissions especially challenging and yet accurate quantification and simulation of these fluxes is a necessary step towards developing air pollution control strategies and for attributing observed atmospheric composition changes to their causes.

The overall goal of this project was to improve numerical model predictions of regional ozone and aerosol distributions in Texas by reducing uncertainties associated with quantitative estimates of BVOC emissions from Texas and the surrounding region. Although there have been significant advancements in the procedures used to simulate BVOC emissions, there are still major uncertainties that affect the reliability of Texas air quality simulations. This includes significant gaps in our understanding of BVOC emissions and their implementation in numerical models including 1) isoprene emission factors, 2) missing compounds, and 3) and unrepresented processes including canopy heterogeneity and stress induced emissions. In this project, we developed new emission factors and incorporated missing BVOC compounds and unrepresented BVOC emission processes into the Model of Emissions of Gases and Aerosols from Nature (MEGAN) framework. To accomplish this, we developed a transparent and comprehensive approach to assigning isoprene and monoterpene emission factors and updated MEGAN to include additional BVOC and processes including stress induced emissions and canopy heterogeneity. We evaluated MEGAN BVOC emission inventories for Texas and surrounding regions using surface and aircraft observations and a photochemical model.

The overall benefit of this project is more accurate VOC emission estimates for the Texas air quality simulations that are critical for scientific understanding and the development of regulatory control strategies that will enhance efforts to improve and maintain clean air.

Project Update
The project consisted of five tasks: (1) develop and apply a transparent approach for estimating BVOC emission factor distributions, (2) synthesize, reconcile and calculate isoprene and monoterpene (terpenoid) emission factors for Texas and the surrounding region, (3) develop the MEGAN3 model, (4) perform a MEGAN3 evaluation and sensitivity study and (5) project

management and reporting. The project began on October 6, 2016. Progress to date is described below. We anticipate that all funds allocated for the project will be utilized by August 31, 2017.

During the June 2017- August 2017 quarter, work was carried out on Tasks 1, 3, 4 and 5.

Task 1: Development and Application of a Transparent Approach for Estimating BVOC Emission Factor Distributions

During June, Ramboll Environ incorporated updated emissions input data from Dr. Guenther into the emission factor (EF) processor (Figure 1) and evaluated results from the EF processor. Ramboll Environ assisted Dr. Guenther assessing gaps in the EF output and made minor updates to the EF processor source code. The EF processor was completed during July.

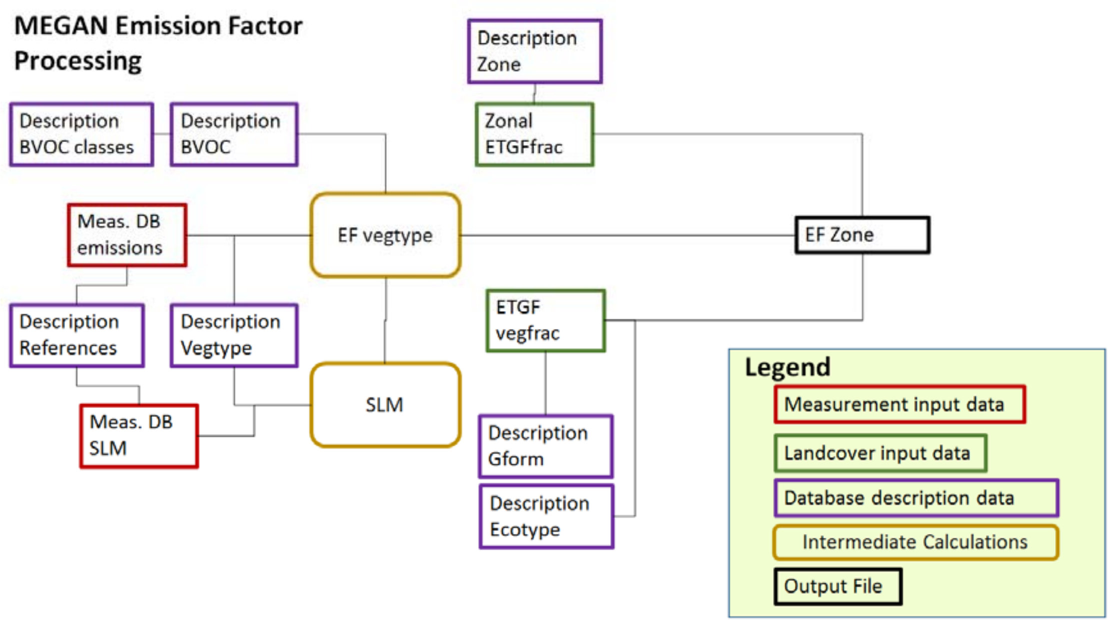

Figure 3. Schematic of MEGAN emission factor processing.

Task 2: Emission Factor Development

Task 2 was completed during Quarter #3; no work was performed on this task during Quarter #4.

Task 3: Development of MEGAN3

During June, Dr. Guenther and Ramboll Environ continued evaluation and assessment of the MEGAN3 code and continued writing documentation for code and inputs. We implemented an improved mapping of MEGAN compounds to chemical mechanism model species supplied by Dr. Greg Yarwood so that MEGAN3 can support the following chemical mechanisms: CB6, CB05, CBMZ, S07, RACM, and CRIv2-R5. We implemented a user option that allows inclusion of stress-induced factors in the calculation of MEGAN3 emissions and performed test runs of the new MEGAN3 code.

During July and August, Dr. Guenther and Ramboll Environ completed evaluation and assessment of the MEGAN code and completed writing documentation for the MEGAN3 code and provided guidance for development of model inputs.

Task 4: MEGAN Evaluation and Sensitivity Study

Task 4 was completed in early August. MEGAN3 emissions were evaluated against aircraft flux data from the 2013 Southeast Atmosphere Study (SAS) and compared with two other MEGAN emission inventories: (1) MEGAN v2.1 using the default landcover database and emission factors, and (2) MEGAN v2.1 updated high-resolution landcover database and emission factors from AQRP Project 14-016. Emissions sensitivity tests were carried out with MEGAN3 to evaluate changes in emissions due to use of different J-rating (input data quality) criteria in the EF processor. We completed base case photochemical modeling of the June 1-July 15, 2013 period that encompassed all of the SAS C-130 and P-3 aircraft flights using MEGAN v2.1 biogenic emissions and using the most recent versions of the CAMx model and CB6r4 chemical mechanism. We performed CAMx sensitivity tests using MEGAN3 emissions with differing J-ratings and without stress factors. Model performance for all CAMx runs was evaluated against surface data and SAS aircraft data.

Task 5: Project Management and Reporting

Task 5 was completed in late August. Dr. Guenther delivered a presentation summarizing Project 16-011 at the August AQRP Meeting. The draft report was completed and the AQRP Project Manager and TCEQ Liaison provided comments on the report. Dr. Guenther and Ramboll Environ revised the report in response to their comments and submitted the resulting final report. All modeling files, including the new MEGAN3 model and the emission factor processor were provided to the AQRP Project Manager on a disk drive.

Project 16-019	STATUS: Active – September. 30, 2016 Completed – August 31, 2017

The Influence of Alkyl Nitrates from Anthropogenic and Biogenic Precursors on Regional Air Quality in Eastern Texas

University of Texas at Austin – Elena McDonald-Buller
Ramboll Environ US Corporation – Gregory Yarwood

AQRP Project Manager – David Sullivan
TCEQ Project Liaison – Jim Smith

Funded Amount: $180,641
($118,019 UT Austin, $62,622 Ramboll Environ)

Abstract

Mono and multifunctional alkyl nitrates (ANs) are formed from the oxidation of biogenic or anthropogenic volatile organic compound (VOC) precursors and serve as a reservoir or sink of nitrogen oxides (NO_x). Alkyl nitrates have sufficiently long atmospheric chemical lifetimes (hours to days), such that they can influence tropospheric ozone and secondary organic aerosol (SOA) formation over regional to global spatial scales. Their functionalities, yields, and fates are known to depend upon the size and structure of the VOC. Depending on their structure, ANs can be transported, chemically processed, removed by deposition to vegetation and other surfaces, or undergo partitioning to and from the aerosol phase where hydrolysis is thought to be a loss mechanism. Although knowledge gaps still exist, recent laboratory and field studies have provided new insights on these processes for ANs formed from biogenic and anthropogenic hydrocarbon precursors. An ongoing need will be to incorporate these findings into the chemical mechanisms of photochemical models used to assess regional air quality. The objectives of this work were to apply the findings of ongoing experimental studies examining alkyl nitrates formed from the OH-initiated oxidation of C8-C11 alkanes at the University of Texas at Austin in addition to those of new publications that have focused on other hydrocarbon precursor classes relevant to Texas emissions inventories to improve how ANs are represented in the version 6 of the Carbon Bond mechanism (CB6). Revision 4 of CB6 (CB6r4) will soon be available in version 6.32 of the Comprehensive Air quality Model with extensions (CAMx v6.32). Sensitivity tests with CAMx evaluated the formation and fate of ANs in central and southeastern Texas, the influence of ANs on regional ozone by recycling NO_x, and dependencies on organic aerosol concentrations.

Project Update

The project included three tasks: (1) develop modifications to the CB6r4 mechanism in CAMx, (2) evaluate the CB6r4 updates in CAMx modeling during the time period of the DISCOVER-AQ campaign through sensitivity studies that evaluate the formation and fate of ANs and effects on regional ozone and organic aerosol concentrations in central and southeastern Texas, and (3) disseminate results through reporting, publications, and presentations. The most recent release of CAMx, v.6.40, uses the CB6r4 gas-phase mechanism. Updates to the CB6 chemical mechanism in CAMx (from a starting point of CB6r4 in the base case) focused on alkyl nitrates formed from biogenic monoterpene precursors and anthropogenic alkane precursors relevant to Texas emission inventories as well as characterization of the loss of alkyl nitrates due to hydrolysis. Sensitivity studies were conducted with CAMx that considered the individual and net effects of modifications to the CB6r4 gas-phase mechanism and SOA yields of the base case. Results from the project were presented at the AQRP Data Workshop on August 3, 2017. The final report with all tasks completed was submitted on August 30, 2017. Major findings from the project are summarized below.

Hydrolysis of Multifunctional Organic Nitrates

Hydrolysis of multifunctional organic nitrates was represented in the base case CB6r4 mechanism as a pseudo gas-phase reaction producing nitric acid (HNO_3) with lifetime of 6-hours. The lifetime against hydrolysis was reduced to 1-hour consistent with recent findings that very short lifetimes are appropriate for acidic aerosols. Regional ozone concentrations were insensitive to more rapid hydrolysis. Hourly total $PM_{2.5}$ mass concentrations increased by as much as 0.5 $\mu g/m^3$ on average due to an increase in particulate NO_3. Maximum increases in total $PM_{2.5}$ mass concentrations were approximately 6 $\mu g/m^3$ and occurred in areas where the sensitivity of multifunctional organic nitrates to biogenic volatile organic compound (BVOC) emissions dominated anthropogenic emissions.

Monoterpene Chemistry

Recent studies have indicated the importance of nitrate radical (NO_3)-monoteprene chemistry to secondary organic aerosol (SOA) formation, but that SOA yields are variable, with α-pinene consistently lower than for other monoterpenes. The CB6r4 mechanism was modified to split terpenes to α-pinene (APIN) and other terpenes (TERP). Revisions were made to the gas-phase reactions of TERP and APIN with hydroxyl radical (OH), ozone (O_3), and NO_3 and to SOA yields for TERP and APIN reactions with NO_3. The impacts of these modifications primarily occurred in terpene-rich areas of the modeling domain including northeastern Texas, western Louisiana, southwestern Arkansas, and southern Mississippi. Average decreases in hourly ozone concentrations were 0.5 ppb with a maximum of 1 to 2 ppb. Differences in hourly total $PM_{2.5}$ mass and organic aerosol were within ±0.5 $\mu g/m^3$ on average with maximum differences of -2 to +5 $\mu g/m^3$.

Alkane Chemistry

Long-chain alkanes are precursors to alkyl nitrates that contribute to SOA formation and serve as a potential NO_x sink via hydrolysis. Alkanes were split into PAR and PARH, which has a high AN yield, according to chain length. Revisions were made to the gas-phase reactions for PAR and PARH as well as ketones. PAR and PARH fractions were applied by emissions source sector with, for example, lower PARH fractions applied for the oil and gas sector (10%) than mobile sources (20%). Total $PM_{2.5}$ mass concentrations were relatively insensitive to the modifications in AN yields using the PARH scheme. Widespread increases in ozone were 1-2 ppb. Application of the PARH scheme decreased the total alkyl nitrate burden and increased ozone sensitivity to VOC emissions from the oil and gas sector and other anthropogenic sources.

It is expected that all funds allocated for the project will be utilized by the end date of August 31, 2017.

Project 16-031 **STATUS: Active – October 18, 2016**
Completed – August 31, 2017

Condensed Chemical Mechanisms for Ozone and Particulate Matter Incorporating the Latest in Isoprene Chemistry

University of North Carolina – Chapel Hill – William Vizuete

AQRP Project Manager – Elena McDonald-Buller
TCEQ Project Liaison – Jim Price

Funded Amount: $225,000

Abstract
Isoprene, the most emitted non-methane hydrocarbon on the planet, is known to influence ozone (O_3) formation in Houston, Texas. Eastern Texas and northern Louisiana feature some of the largest biogenic emission sources of isoprene in the United States. It is also now known that the photochemical oxidation of isoprene, when mixed with anthropogenic emissions from urban areas like those found in Houston, can produce significant yields of fine particulate matter ($PM_{2.5}$) through acid-catalyzed multiphase chemistry of isoprene epoxydiols (IEPOX) that leads to secondary organic aerosol (SOA) formation. Next-generation regulatory models in Houston will attempt to capture this recent discovery even though there exists great uncertainty in both gas-phase isoprene oxidation and SOA formation chemistry. This work produced a fully updated condensed gas-phase mechanism based on SAPRC-07 and PM formation parameters suitable for use in a regulatory air quality model. The updated parameters were evaluated against an archive of UNC smog chamber experiments, including new isoprene SOA experiments that investigate the effect of organic coatings/mixtures on the acid-catalyzed multiphase chemistry of IEPOX.

Our previously funded Air Quality Research Program (AQRP) work has directly derived the multiphase kinetics of IEPOX only on pure inorganic aerosols. In the atmosphere, however, IEPOX will more likely encounter mixed particles containing both pre-existing organics and acidic sulfate. As a result, there is a need to constrain the impact of pre-existing organics within acidic sulfate aerosol on the kinetics of IEPOX multiphase chemistry. We also produced a regulatory air quality modeling episode focused on Houston to test these new updates in a simulated urban environment. This work directly addresses the stated priority area of improving the understanding of O_3 and PM formation and the interaction with PM precursors. Further, the regulatory air quality modeling system developed by this work can begin to address the stated priority of quantifying the impacts of uncertainty due to the treatment of atmospheric chemical processes by condensed models.

Project Update
During this reporting period, the following progress has been made towards project goals:

Task 1 Updated SAPRC-07 and Aerosol Module for Isoprene Oxidation

Preliminary Analysis
We have completed the quality assurance of the output files from our box modeling system of the SAPRC16 chemical mechanism and prepared analysis for the final report.

Data Collected
Produced output files from our box modeling system of the SAPRC16 chemical mechanism.

Identify Problems or Issues Encountered and Proposed Solutions or Adjustments
N/A

Detailed Analysis of the Progress of the Task Order to Date
N/A

Task 2 Chamber Experiments: Interplay of Particle-Phase Composition, Phase, and Viscosity on IEPOX Multiphase Chemistry

Preliminary Analysis
We have completed processing and quality assuring data from online measurements and obtaining γ_{IEPOX} for toluene and naphthalene coating experiments. We have also completed the quality assurance of the nucleation experiments. We prepared this analysis for the final report.

Data Collected
Data produced from coating and nucleation experiments.

Identify Problems or Issues Encountered and Proposed Solutions or Adjustments
N/A

Detailed Analysis of the Progress of the Task Order to Date
N/A

Task 3 Implementation in a regulatory air quality model

Preliminary Analysis
We completed our analysis of our 0-D model simulations with and without an updated aerosol phase diffusivity and henry's law constant that is influenced by organic coating of the aerosol. We prepared this analysis for the final report.

Data Collected
We have produced model performance evaluation against the Look Rock Site observational data from the SOAS campaign.

Identify Problems or Issues Encountered and Proposed Solutions or Adjustments
N/A

Detailed Analysis of the Progress of the Task Order to Date
N/A

In this quarter, the team delivered a Draft Final Report and presented the project findings at the AQRP Workshop on August 3, 2017. The team obtained and is in the midst of addressing the review comments from the AQRP Project Manager and the TCEQ Liaison.

Project 17-007	STATUS: Active – November 3, 2016

Evaluating Methods for Determining the Vapor Pressure of Heavy Refinery Liquids

University of Texas at Austin – Vincent Torres

AQRP Project Manager – Gary McGaughey
TCEQ Project Liaison – Russell Nettles

Funded Amount: $205,500

Abstract

During the last five years, crude oil and natural gas production and petroleum refinery operations have seen an increased focus on their emissions of volatile organic compounds (VOCs), hazardous air pollutants (HAPS) and greenhouse gases (GHGs), especially those from storage tanks. These actions have been taken by the United States Environmental Protection Agency (US EPA) "because EPA and state investigations have identified Clean Air Act compliance concerns regarding significant emissions from storage vessels, such as tanks or containers at onshore oil and natural gas production facilities" and to "collect information on processing characteristics, crude slate, emission inventories, and limited source testing to fill information gaps". State and federal laws require certain facilities to design, install, operate and maintain effective pollution control measures to minimize the emissions of VOCs and HAPs. For example, the federal New Source Performance Standards for Crude Oil and Natural Gas Production "requires that new, reconstructed or modified storage vessels with the potential for VOC emissions of equal to or greater than six tons per year reduce VOC emissions by at least 95%." The Texas Commission on Environmental Quality (TCEQ) funded two projects recently to better understand the composition and properties of heavy refinery liquids and the most appropriate method of determining their true vapor pressure (TVP).

The purpose of this research is to improve the estimates of VOC emissions from storage tanks holding heavy refinery liquids. These tanks are found at storage terminals and refineries and are frequently heated in order to reduce the viscosity of their contents and make them pumpable. Evidence is mounting that the emissions from these tanks are underreported and may explain some of the VOC inventory gap in parts of Texas.

During the course of this project, the most accurate, reliable, convenient, and reasonably priced means of measuring the TVP of heavy refinery liquids stored in tanks will be identified. Identifying an appropriate means of measuring the TVP of these heavy refinery liquids is important because direct measurement of VOC emissions from storage tanks is inherently inexact and expensive, so equations are used to estimate emissions from storage tanks. The value used for the TVP in these equations has a profound impact on the results. The results of this research will facilitate efforts being made by the US EPA, TCEQ, and agencies in other states to better understand, more accurately estimate, and manage emissions from tanks holding heavy refinery liquids.

Project Update

The project team (PT) prepared samples of the five materials in appropriate size vials as required by each of the four commercial labs. These samples were sent to labs with material data sheets to make vapor pressure (VP) measurements using the ASTM standard methods prescribed by the project. During the month of July and half of August, the commercial labs performed their measurements and sent their results the PT. The PT began reviewing their measurements as they were received and continued to do so through the end of the quarter. This review and analysis continues.

In early June, the PT received the Grabner VP Vision mini method instrument. Before it was able to start using the instrument, it failed to boot up properly. Over the next three months, the project team tried using three iterations of this instrument to make VP measurements and has only been able to obtain a very limited set of measurements using this instrument. In mid August, the latest version of the instrument failed and was returned again to the manufacturer. At this time, it is unlikely that a working unit will be provided in time to attempt to make the VP measurements desired by project before the project ends.

During this quarter, the PT also used the Eralytics ERAVAP Model EV10 mini method instrument to make VP measurements of the five materials samples. The instrument was able to make measurements of three of the five materials but the PT identified numerous problems with the measurement results. In review of the results soon after they were performed, a hypothesis of each problem was proposed to and investigated and confirmed by the manufacturer. A detailed result of these problems with be provided in the final report as some were still being confirmed at the end of the quarter. The nature of the problems appear to be the result of programming errors with the operation of the instrument, the handling of the raw measurements and the curve fit of the raw VP measurements. After numerous discussions with the Eralytics engineers, it does not appear that the problems with this instrument can be addressed before the project ends. The PT is continuing to analyze the data and will report the results of the analysis and assessment of the measurements in the final report.

The PT made a presentation of the progress of the project at the AQRP Workshop on August 3. On August 4, the PT repeated the same presentation to parties interested in this project and provided them a tour of the UT Austin PT lab.

While the PT has encountered challenges using the two mini method instruments in making VP measurements, the information learned and data gathered in assessing these challenges is invaluable. It will provide qualitative results for the project and will contribute greatly to understanding the ability of each instrument as currently configured in making VP measurements in the VP range of heavy liquids and of those specifically used on the project.

The project team intends to use all funds allocated to the project by 11/30/2017 to complete the planned work tasks.

Project 17-024 **STATUS: Active – October 17, 2016**
Completed – August 31, 2017

Improving the Modeling of Wildfire Impacts on Ozone and Particulate Matter for Texas Air Quality Planning

Atmospheric and Environmental Research, Inc. – Matthew Alvarado

AQRP Project Manager – Elena McDonald-Buller
TCEQ Project Liaison – Erik Gribbin

Funded Amount: $170,039

Abstract
Fires can have a large impact on ozone and particulate matter concentrations, and thus air quality, in Texas. Current air quality models (also called chemical transport models) take estimates of the primary emissions from biomass burning (such as forest and grass fires) and unphysically dilute them, which can lead to incorrect estimates of the impact of biomass burning on air quality. Smaller scale models like AER's Aerosol Simulation Program allow us to examine the chemical and physical transformations of trace gases and aerosols within biomass burning plumes and to develop new methods for accurately including this aging process in standard air quality models. In this project, we improved our understanding of the impacts of local and out-of-state fires on air quality in Texas by implementing an improved approach for modeling the near-source chemistry of biomass burning plumes into the CAMx (Comprehensive Air Quality Model with Extensions) model used in Texas air quality planning. This improved approach allows CAMx to better represent the impact of forest and grass fires on air pollutants such as ozone and fine particulate matter ($PM_{2.5}$). We also investigated the impact that long-range transport of wildfire smoke has on air quality in Texas. This project thus addresses two strategic topics of the Texas Air Quality Research Program: "Improving the understanding of ozone and particulate matter (PM) formation [and] the interactions of ozone and PM precursors" and "Investigating global, international, and regional transport of pollutants using data and modeling analyses."

Project Update
The overarching goal of this project was to use an advanced smoke plume chemistry model (AER's Aerosol Simulation Program, or ASP) to improve understanding of the formation of O_3 and $PM_{2.5}$ in biomass burning (BB) plumes, and improve estimates of the impacts of in-state and out-of-state biomass burning on Texas air quality. The project is split into the following two tasks:

- To develop and evaluate an improved sub-grid scale parameterization of biomass burning for CAMx based on ASP coupled with the large eddy simulation model SAM (SAM-ASP) and an analysis of O_3 and SOA production in fire plumes observed during BBOP.
- To explore the impact of BB plumes on the boundary conditions used for CAMx and the resulting impact on Texas air quality with ASP coupled with the Lagrangian particle dispersion model STILT (STILT-ASP).

The progress during this reporting period (June – August 2017) and challenges encountered for each task are discussed below. We plan to use all of the funds allocated to this project by 08/31/2017.

Task 1: Develop improved parameterization and assess the impact on Texas air quality

We performed a detailed evaluation of the GEM-based parameterization that was developed last quarter. However, our evaluation of the GEM parameterization showed that it is not of sufficient quality for use in regional air quality modeling. The GEM parameterization is able to represent the dependence of O_3 formation in the plume on fuel type, temperature, day of year, and latitude reasonably well, but the dependence on time of day is unrealistic, as the GEM prediction for the O_3 enhancement ratio ($\Delta O_3/\Delta CO$) is negative for plumes emitted at 14:00 local time in the summer, when these plumes should still be forming O_3 at the end of the simulation at 19:00 (7 PM) local solar time in the summer. Comparisons of the parameterization to the observations from the Williams Fire show that the GEM parameterization underestimates the measured $\Delta O_3/\Delta CO$ for these conditions (GEM value of 0.04 mol/mol, as opposed to measurements of 0.10 mol/mol), similar to the results of a custom SAM-ASP simulation for these conditions (0.05 mol/mol). The GEM predictions for NO_x and other NO_y species have more serious deficiencies, with the parameterization overestimating the NO_x downwind relative to both observations and SAM-ASP simulations, and GEM predictions of the formation of PAN and HNO_3 being inconsistent with the GEM predictions of the loss rate of NO_x. Further work on the GEM parameterization training would be needed to correct these errors.

Thus, rather than implement the GEM parameterization into CAMx, we instead implemented the parameterization of Lonsdale et al. (2015) into CAMx. This parameterization modifies the emissions of O_3, NO_y species, and OA from fires based on a look-up-table (LUT) that is built from many runs of the ASP model within a simple Lagrangian parcel dispersion model. We added code to CAMx to read the FINN fire emission files directly and use them to initialize a biomass-burning-specific Plume-in-Grid (PiG) module. We used the modeling configuration from the 2012 CAMx modeling episode from TCEQ (May 16 – June 30, 2012) to evaluate the impact of the parameterization. The parameterization reduced the predicted impacts of fires on O_3 near the sources by ~30%, as expected (Figure 4).

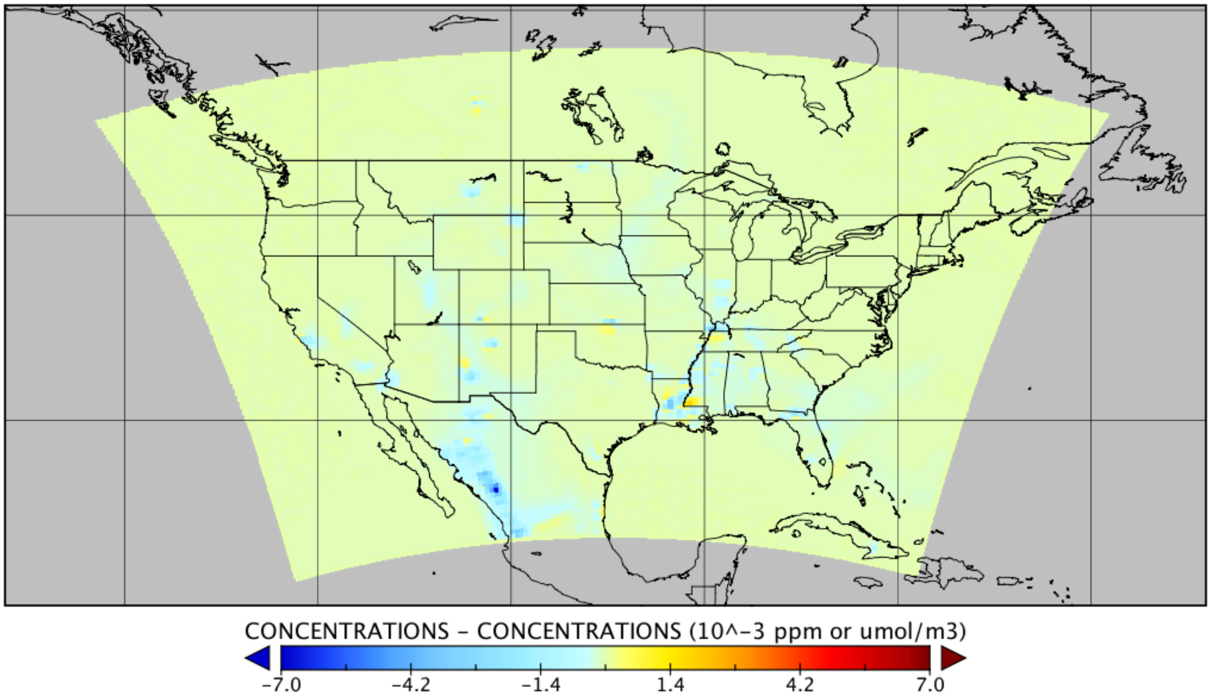

Figure 4. Difference in O_3 (ppbv) between the sub-grid parameterized fire case and the "grid fire" case at 17:00 CST on June 4, 2012.

Task 2: Investigate the impact of long-range transport of BB pollution on Texas air quality

We expanded the number of receptors we looked at for fire impacts along the southern boundary of the TCEQ modeling domain. The STILT-ASP v2.0 simulations show a lot of fine structure in the impacts of fires on CO along the boundaries that is not captured by the low-resolution boundary conditions from GEOS-Chem. In addition, the STILT-ASP v2.0 estimate of the $\Delta O_3/\Delta CO$ ratio during these events (mean of 0.15 mol/mol) is consistent with the review of Jaffe and Wigder (2012). However, the STILT-ASP v2.0 prediction of O_3 was high relative to GEOS-Chem, which appears to be due to an error in the simulation of the diurnal cycle of O_3, especially at night. Predictions of NO_x and PAN were both much lower than the GEOS-Chem values, and suggests the S/IVOC chemical mechanism of ASP v2.1 (up to 5 hours) may need to be re-examined for the longer one to seven day runs of STILT-ASP v2.0.

We also used STILT-ASP v2.0 to examine the impact of fires on air quality during three days where the Austin/Round Rock urban area was impacted by fires from Central Mexico and the Yucatan. On the day with the highest MDA8 O_3 (May 11), the model predictions of O_3, CO, and NO_x were all consistent with the observations, with O_3 slightly overestimated (MB of +3.6 ppbv, RMSE of 5.9 ppbv) and NO_x slightly overestimated (MB of +0.3 ppbv, RMSE of 1.9 ppbv). However, $PM_{2.5}$ was substantially overestimated, likely due to an underestimation of $PM_{2.5}$ deposition. However, as deposition should affect all aerosol sources relatively evenly, the STILT-ASP v2.0 results can be used to estimate the relative fraction of $PM_{2.5}$ at the receptor that is due to fires, which for this day was 12% (0.9 $\mu g/m^3$). However, due to the loss of NO_x during S/IVOC chemistry, the impact on O_3 was a decrease of 0.9 ppbv of the MDA8 O_3.

However, the results for May 5 and May 25 Austin cases were very different, with STILT-ASP v2.0 strongly overestimating O_3 (MB = +40 ppbv) and underestimating NO_x (MB = -2.6 ppbv) on these days, but with less severe overestimates of $PM_{2.5}$. The model suggests that fires had small but positive impacts on MDA8 O_3 on these days (0.2 and 0.3 ppbv, respectively), but noticeable impacts on $PM_{2.5}$ (2.6 and 4.0 μg/m^3, respectively).

In order to compare the STILT-ASP v2.0 predictions of the impacts of wildfires on O_3 and $PM_{2.5}$ with the CAMx simulations of McDonald-Buller et al. (2015), we ran STILT-ASP for the CAMS 12 site in El Paso on two dates (June 4th and June 28th) that were shown to have significant fire impacts on O_3 in McDonald-Buller et al. (2015). However, the STILT-ASP v2.0 estimates of the impacts of fires on CO were small (2-3 ppbv), likely due to the use of the FINN v1.5 emissions rather than the FINN v2.1 emissions used by McDonald-Buller et al. (2015). Furthermore, the STILT-ASP v2.0 estimate of the impact of fires on MDA8 O_3 is small and negative (-0.1 to -0.4 ppbv), but this may be due to errors in the S/IVOC chemistry as discussed above.

Lonsdale, C. R., M. J. Alvarado, R. J. Yokelson, S. K. Akagi, E. Fischer, K. Travis, T. Soni, J. S. Craven. J. W. Taylor, G. R. McMeeking, I. R. Burling, S. P. Urbanski, C. E. Wold, J. H. Seinfeld, H. Coe, and D. R. Weise (2015), Using the Aerosol Simulation Program to parameterize biomass-burning plumes for global air quality models, American Association for Aerosol Research, Minneapolis, MN, October 12-16.

McDonald-Buller, E., Y. Kimura, C. Wiedinmyer, C. Emery, Z. Liu, and G. Yarwood (2015), *Targeted Improvements in the Fire Inventory form NCAR (FINN) Model for Texas Air Quality Planning,* Final Report to Texas Air Quality Research Program (AQRP) for Project 14-011, December 2015.

Project 17-032	STATUS: Active – December 6, 2016 Completed – August 31, 2017

Spatial Mapping of Ozone Formation near San Antonio

Drexel University – Ezra Wood

AQRP Project Manager – Gary McGaughey
TCEQ Project Liaison – Mark Estes

Funded Amount: $59,000

Abstract
Ozone (O_3) is the main component of smog and causes adverse effects on human health, especially to sensitive groups such as children and the elderly. Unlike "primary" pollutants which are emitted directly from vehicles and industrial processes, ozone is formed in the atmosphere from photochemical reactions involving volatile organic compounds (VOCs) and nitrogen oxides ("NO_x"). In order for San Antonio to comply with the new National Ambient Air Quality Standard for ozone of 70 ppb, regulators will need to make science-based decisions on effective mitigation strategies, including emission reduction programs. Such decisions will require knowledge of the amount of ozone that is transported into the city from upwind regions (usually located southeast of San Antonio), the absolute rates of ozone formation in and around San Antonio, the relative importance and interaction of emissions from various sources (e.g., upwind oil and gas activity and urban emissions from the city itself), and when and where ozone formation occurs under "NO_x-limited" or "VOC-limited" conditions. In contrast to Houston and Dallas, little is known about ozone formation in San Antonio. This research project addressed this major shortcoming and elucidated the mechanisms and rates of ozone formation that affect air quality in San Antonio using novel measurements of peroxy radicals aboard a mobile supersite during a 3-week field project during late spring of 2017. Instantaneous ozone production rates $P(O_3)$ were quantified aboard the Aerodyne Mobile Laboratory using new but tested measurements of total peroxy radicals. These measurements were used to "map" the rate of ozone formation upwind, downwind, and inside of the urban core of San Antonio. Measurements of organic nitrates were also used to investigate the role of alkanes and organic nitrate formation as a terminator of ozone chemistry.

The main goals of the project were to quantify how much ozone is produced inside the city compared to upwind, and to quantify the role of alkanes in ozone formation.

Project Update
Major activities for the reporting period (June – August 2017) are listed below:

1. The two instruments that were deployed by the Drexel team to the San Antonio Field Study (the "ECHAMP" peroxy radical sensor and "TD-CAPS" organic nitrate sensor) were shipped back to Drexel University following the conclusion of the San Antonio Field Study in May and set up in the laboratory. Additional calibrations were performed for the ECHAMP sensor to better characterize its response to peroxy radicals as measured during the field study. This instrument was then deployed to Bloomington, IN as part of a separate project from mid-July to mid-August that focused on the accuracy of peroxy radical measurements by several different techniques.

2. Preliminary analysis was undertaken on the data collected during the San Antonio Field Study in preparation for the August 3 Science meeting in Austin, TX. The PI (E. Wood) presented an overview of the measurements from the field study during this meeting.

Figure 5 shows time series data for O_3, $RO_2 + HO_2$, NO, O_3 photolysis rates (j_{O1D}), and calculated ozone production rates $P(O_3)$ for the first deployment at UTSA.

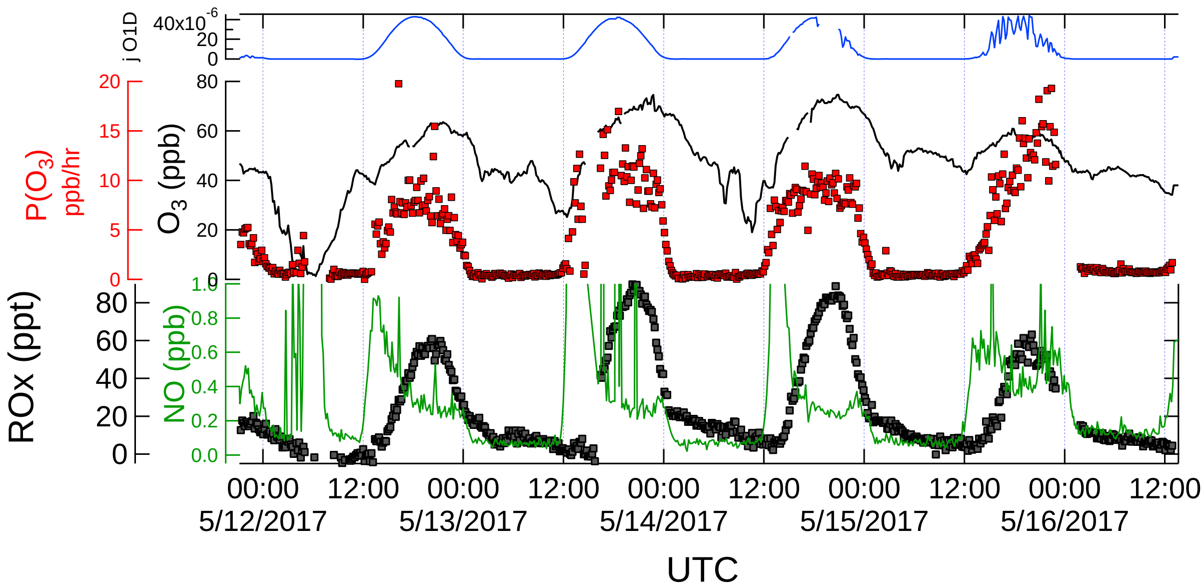

Figure 5. Time series of [NO], [ROx], [O_3], j_{O1D}, and $P(O_3)$ at UTSA.

$P(O_3)$ is calculated using equation 1:

$P(O_3)$ (ppb/hr) = k_{HO2+NO}([HO_2]+[RO_2][NO] Eq 1.

where k_{HO2+NO} is the bimolecular rate constant for the reaction between HO_2 and NO, which forms NO_2 (and O_3 following photolysis). The sum of [RO_2] and [HO_2] was measured by ECHAMP and NO was measured by a Thermo model 42i-TL chemiluminescence sensor. Overall it appears that at all three measurements sites (the University of Texas at San Antonio, Floresville, and Lake Corpus Christi State Park), ozone formation was limited by the availability of nitrogen oxides. This implies that, at least in those locations, future changes in NOx emissions are much more likely to impact ozone formation rates than are future changes in VOC emissions.

Ozone formation rates were overall “moderate”, i.e. rarely above 15 ppb/hr.

All funds are anticipated to be spent by 8/31/2017.

Project 17-039	STATUS: Active – November 16, 2016

Use of Satellite Data to Improve Specifications of Land Surface Parameters

University of Alabama - Huntsville – Richard McNider

AQRP Project Manager – Elena McDonald-Buller
TCEQ Project Liaison – Bright Dornblaser

Funded Amount: $149,227

Abstract
It is the purpose of this project to continue a process to evaluate and improve the performance of the land surface models used in WRF by the use of satellite skin temperatures to better specify physical parameters associated with land use classes. Improved temperature performance impacts biogenic emissions, thermal decomposition (chemical chain lengths and slopes of ozone/NOy curves) and thermally driven winds. Also, land surface parameters control surface deposition which impacts the efficacy of long-range transport. Physical parameters such as heat capacity, thermal resistance, roughness, surface moisture availability, albedo etc. associated with a land use class are actually used in the land surface model. Many of the land use class associated parameters such as surface moisture availability are dynamic and ill-observed depending on antecedent precipitation and evaporation, soil transport, the phenological state of the vegetation, irrigation applications etc. Other parameters such as heat capacity, thermal resistance or deep soil temperature are not only difficult to observe they are often unknowable *a priori*. Despite the difficulty in specifying these parameters they are incredibly important to model predictions of turbulence, temperature, boundary layer heights and winds.

This project is directed toward the Meteorology and Air Quality Modeling and Biogenic Emissions Priority. Biogenic emissions are highly sensitive to temperature. Improvement in temperature predictions in conjunction with improved radiation inputs into biogenic emission model (MEGAN or BEIS) should increase the quality of biogenic emissions. The project is responsive to three areas in the Meteorology and Air Quality Modeling Priority- (1) boundary layer performance can impact local circulations driven by thermal gradients and the strength of low level jets is controlled by nighttime surface cooling rates; (2) boundary layers can impact clouds both boundary layer topped cumulus and clouds in sea breeze convergence zones; (3) dry deposition of ozone and nitrogen species is often controlled by stomatal uptake which depends on soil moisture.

The project will continue and expand activities under a 2015 funded AQRP project using satellite observed skin temperatures. That project was a late selected reduced scope project. Despite some initial issues with a NOAA skin temperature data set, the project ended up showing improvement in model performance for skin temperatures and in wind performance. However, the improvements were not as large as in previous uses of skin temperature data. Part of this may be due to following the Pleim-Xiu air temperature approach in the project, in which absolute differences between model and observed skin temperatures were used rather than skin temperature tendencies. Differences between the model and satellite skin temperatures not related to the boundary layer parameters such as emissivity or atmospheric correction in the satellite product might be an issue. Under this activity skin temperature tendencies will be tested

instead which avoids such problems. The DISCOVER AQ period of 2013 was an unusually cloudy and windy period over most of the Eastern U.S. and not characteristic of the conditions usually associated with ozone episodes in Texas. While significant effort went into QA for the skin temperature data set, cloud contamination in the skin temperatures may still be an issue. Under the current activity alternative skin temperature products such as MODIS data will used in conjunction with the tendency method that may reduce cloud contamination issues. Also, in consultation with TCEQ additional periods such as TEXAQS 2006 or the 2012 SIP period will be examined. Finally, the work on the previous project included emphasis on the large 12-km domain. Under this activity a greater emphasis will be given to fine scale model performance around Houston and Dallas. Particular attention will be given to wind changes due to changes in boundary layer parameters including changes in sea breezes and low level jets.

Project Update
The progress to date and challenges encountered are discussed below.

Reruns of 2013 Discovery AQ Period: As follow-up to the last biennium's project the period September 1-30 2013 period was re-run and model performance re-evaluated. Since making these runs that were reported in the last biennium project, new large scale analyses, and new nudging strategies for the large scale analysis were developed. As an example, wind nudging in the boundary layer was used in the prior runs. It is felt that for the present study that boundary layer physics should be allowed to develop both at the surface and in the residual layer. The control experiment has been run (i.e. with no satellite assimilation). An analysis of its performance compared to the previous control run was made. Unfortunately, it appeared that the control run from this year had much poorer performance statistics than the previous runs. This was especially true in the bias statistics.

A process was started in June to find the source of these differences. As part of this year's project several updates were made to the model set-ups not related to the model improvement tasks proposed under this project. These included updated land-use data sets, initial and nudging analyses and nudging strategies. Below are some of these changes.

a. WRF 3.8.1 versus 3.6.1 – it is especially noted that there were several changes in the Pleim-Xiu scheme and in other microphysics and radiation schemes
b. Updated USGS land use data sets
c. New Short-wave/Long Wave Radiation Package
d. Use of NAM analysis rather than NAAR
e. Nudging of winds

Model runs were made removing all the known differences in sequential model runs. Each of these runs was then analyzed for statistical performance. While the series of model experiments brought the new control closer to the last biennium's project statistics there were still discrepancies.

Work in July and August continued on trying to determine the cause of the discrepancies between the control case in last year's project and this year. After many runs changing inputs in a methodical manner we cannot reduce the bias statistics in the current model to that found in last year's project. We then come to the conclusion that the differences (degradation) are due to the upgrade in WRF from WRF 6.1-WRF 8.1. We have found code differences that may explain the discrepancies but we have concluded that reverting to 6.1 is difficult and since 8.1 is the newer version we see no reasons for going backwards. Thus, we decided that rather than trying to reproduce the older results we will go forward with a process to define a new control case using WRF 8.1.

Defining Control Case Inputs: Giving the issues encountered that showed that different physics choices and input data can drastically change model performance we stepped back and thought about what the control case should be. Should it be a case that has minimal error or the case that is likely to be used by the larger WRF community. Our previous model set-ups had been patterned after TCEQ inputs. However, in talking to TCEQ we found that these are fluid and have not been firmly tied down for the P-X scheme.

We thus decided that the appropriate control case would be one most likely to be used within the WRF/Air Quality Community. We thus contacted the EPA NERL group and obtained their model name list and set up. Since we are trying to show that satellite data can improve model performance in the P-X scheme it seems reasonable to use what the Pleim group at EPA would use for their control model set-up. If we picked a different control set-up and showed improvement there might be concern that we picked a control set-up that had a larger error making the use of satellite data appear better.

A control case was run with the new set-ups for both the 2013 and 2012 cases. These are the cases against which we will evaluate the satellite improvements proposed under this year's project.

Delays in the Project: The performance issue with the control case compared to the last biennium project was taken very seriously since reproducibility is a hallmark in science. The many model runs allowed us to understand the source of the differences. However, this caused a significant delay in carrying out the satellite assimilation tasks which were at the core of the project. This was presented at the Austin AQRP meeting in August. For these reasons, the project team requested, and was granted, a project extension through October 31, 2017.

Funds: Charges and time devoted the project during the first 4 months were below targets in part due to some competing projects and set up of accounts. However, charges have accelerated so that charges will meet project targets.

Project 17-053	STATUS: Active – January 10, 2017 Completed – August 31, 2017

Identifying and Apportioning Ozone Producing VOCs in Central Texas

Aerodyne Research, Inc. – Scott Herndon

AQRP Project Manager – Gary McGaughey
TCEQ Project Liaison – Mark Estes

Funding Amount: $185,193

Abstract
Aerodyne Research, Inc. conducted measurements using a mobile laboratory as a portable photochemistry super site to study ozone production and the emission sources that ultimately impact air quality in central Texas. Work was done at locations upwind, downwind and lateral to San Antonio. The suite of instrumentation was selected to quantify key oxygenated volatile organic carbon species (OVOC) and nitrogen containing species (e.g. alkyl nitrates) to pinpoint and apportion ozone within broad categories of VOC emission sectors. The instrument payload also directly quantified the instantaneous production rate of ozone to determine whether the chemical regime is NOx limited or VOC limited. An additional component of this research project was to characterize emission sources associated with oil and natural gas production in the Eagle Ford Shale play, including active medium to large processing flares, as well as oil and condensate tanks at wellpads.

The project provides scientific insight into the VOCs that are contributing to the ozone in central Texas. The effectiveness of mitigation strategies will be informed by these results. This work isolated ozone production due to VOC oxidation from biogenic sources, refinery emissions, emissions from oil producing well pads and emissions from natural gas production. The project quantified local ozone production rates and evaluated the ozone sensitivity regime.

Project Update
This report discusses the progress from June 1st to August 31st, 2017. It includes status report on the completed project, including a description of the final dataset and final report.

Activities:

- Field campaign completed.
- Data quality assurance completed, as described below.
- Research results for AQRP 16-035 completed, as summarized below.
- Additional avenues of research for future projects identified.
- Final report draft completed and submitted to AQRP for review.
- Dataset delivered to AQRP on or before September 30st 2017.
- Final report will be updated and finalized.

Field Campaign and Data Quality Assurance

A field measurement campaign was undertaken to collect data needed to identify and apportion the volatile organic compounds (VOCs) that contribute to ozone production in Central Texas. Measurement data was collected at three primary sites from May 10th to May 31st, 2017. The sites were selected to emphasize sampling air in the San Antonio urban area, the Eagle Ford oil and gas producing shale and a site near the Gulf of Mexico in Corpus Christi State Park. The composition measurements include research and commercial grade instrumentation to quantify the following classes of compounds:

1. ozone and the oxides of nitrogen
2. light hydrocarbon photoproducts such as formaldehyde, acetone and hydrogen peroxide
3. air mass tracer species such as carbon monoxide (CO), hydrogen cyanide (HCN, from biomass burning) and sulfur dioxide (SO_2, anthropogenic tracer)
4. oil and gas light alkanes such as propane, ethane and methane
5. biogenic emissions such as isoprene, terpenes and methanol
6. anthropogenic emissions such as benzene and toluene
7. particulate matter size and composition for both primary (e.g. black carbon, hydrocarbon like organic aerosol) and secondary (e.g. oxidized organic aerosol, sulfate) particulate matter
8. minor secondary photoproducts produced with ozone from a complex mixture of VOC species.

The complete composition dataset has been quality assured and is poised to identify VOC emission categories (e.g. oil & gas; biogenic; anthropogenic) and attribute the quantified production of ozone in central Texas. Two chemical regimes have been identified (e.g. “NOx limited vs VOC limited”). The goals of the State of Texas Air Quality Research Program (AQRP) are:

1. to support scientific research related to Texas air quality, in the areas of emissions inventory development, atmospheric chemistry, meteorology and air quality modeling,
2. to integrate AQRP research with the work of other organizations, and
3. to communicate the results of AQRP research to air quality decision-makers and stakeholders.

Of the ten research priorities identified in the AQRP Strategic Research Plan FY 16-17, this project addresses two. They are 1) Improving the understanding of ozone and particulate matter formation (in central Texas), and 2) Quantifying the local ozone production that impacts the design value (DV) monitors that exceed the national ambient air quality standards (NAAQS) in central Texas.

Research Results

This project focused on collecting the measurement dataset and performing the in-depth quality assurance. The analysis using the resulting dataset have resulted in the following project findings:

- The quantification of low-yield nitrogen containing species involved in isoprene oxidation suggests that *biogenic VOCs play a significant role in net ozone production in San Antonio.*
- The mixing ratio enhancements of oil and gas VOCs (e.g. ethane, propane) suggest local impact in Floresville, however it is unclear that these VOCs fuel local ozone production.
- *A credible fractional attribution of the production rate of ozone ($p(O_3)$) to oil and gas VOC emissions will require additional analysis* because the nitrogen-containing oxidation products are not yet well characterized.
- When $p(O_3)$ was between 5 – 15 ppb hr^{-1}, the chemical regime was NOx-limited.
- When $p(O_3)$, was less than 5 ppb hr^{-1} and the radical pool (e.g. HOx) was lower, either chemical regime was possible (NOx-limited or NOx-saturated).

Project 17-SAFS	STATUS: Active – April 13, 2017

San Antonio Field Study Logistics

University of Texas at Austin – David Sullivan

AQRP Project Manager – Gary McGaughey
TCEQ Project Liaison – Mark Estes

Funding Amount: $46,000

Abstract
In May 2017, AQRP and TCEQ conducted a field campaign in and around San Antonio to study the causes of ozone formation in the San Antonio area. The San Antonio Field Study 2017 (SAFS 2017) deployed mobile measurement vans, wind profilers, and ozone sondes. Air quality measurements were made by researchers from collaborating organizations, including research scientists and engineers funded wholly or in part by the AQRP and the TCEQ. This AQRP project supported the SAFS 2017 by overseeing logistical aspects of the field campaign. Specifically, it facilitated the performance of electrical work to ensure proper access to power to operate the instrumentation, and minor site improvements to ensure access to the site locations and to prevent damage to the sites that could be caused by driving large vehicles across unpaved areas. It also ensured that other project infrastructure was in place, such as wireless access, lighting, temporary fencing, and other logistical support. In all, this project centralized and coordinated the site infrastructure preparation for measurement sites selected for the San Antonio Field Study 2017 (SAFS 2017). The scope of work included in the project included all aspects of site preparation and decommissioning of the measurement sites.

Project Update
This project had six (6) tasks.

Task 1. Sites selected for all research teams participating in SAFS 2017.
All sites were finalized in early May 2017. Infrastructure upgrades were made at the TCEQ's Floresville Hospital Blvd. CAMS 1038 site and at the primary site for several projects on the University of Texas at San Antonio (UTSA) campus by the Child Development Center.

Task 2. Obtain the necessary site access/use agreements from UTSA for the site on the campus.
This task was completed prior to the start of measurements in early May 2017.

Task 3. Site pad preparations.
This task was completed prior to the start of measurements in early May 2017.

Task 4. Provide limited support of researchers should problems arise with the site accommodations, which would be provided as needed.
Some historic information from another project were provided to the Aerodyne research team.

Task 5. Site Decommissioning.
At the end of the May operations of SAFS, some fencing was removed at UTSA and the parking lot was returned to its pre-SAFS condition. The power install has remained in place for the balance of the summer for the upper air measurement instruments set on the grass by the parking area.

Task 6. Prepare Project Reports and Presentations.
A presentation on this project was made at the August 3, 2017 AQRP meeting at the Pickle Research Campus. Reports have been filed in a timely manner.

FINANCIAL STATUS REPORT

Initial funding for fiscal years 2016 and 2017 was established at $1,000,000 each, for a total award of $2,000,000 for the FY 2016/2017 biennium. On September 4, 2017, the AQRP was renewed for the 2018/2019 biennium, and funding of $750,000 per year was awarded, for a total of $1,500,000. The funds were distributed across several different reporting categories as required under the contract with TCEQ. The reporting categories are:

Program Administration – limited to 10% of the overall funding (per Fiscal Year)
This category includes all staffing, materials and supplies, and equipment needed to administer the overall AQRP. It also includes the costs for the Council meetings.

ITAC
These funds are to cover the costs, largely travel expenses, for the ITAC meetings.

Project Management – limited to 8.5% of the funds allocated for Research Projects
Each research project will be assigned a Project Manager to ensure that project objectives are achieved in a timely manner and that effective communication is maintained among investigators in multi-institution projects. These funds are to support the staffing and performance of project management.

Research Projects / Contractual
These are the funds available to support the research projects that are selected for funding.

Program Administration

Program Administration includes salaries and fringe benefits for those overseeing the program as a whole, as well as, materials and supplies, travel, equipment, and other expenses. This category allows indirect costs in the amount of 10% of salaries and wages.

During the reporting period several staff members were involved, at various levels of effort, in the administration of the AQRP. Dr. David Allen, Principal Investigator and AQRP Director, was responsible for the overall administration of the AQRP. Maria Stanzione, AQRP Program Manager, assisted Dr. Allen in the program administration, while Terri Mulvey, Melanie Allbritton, and Susan McCoy each provided assistance with program organization and financial management. Denzil Smith was responsible for the AQRP Web Page development and for data management. Gina Palacios provided assistance with the website redesign.

Fringe benefits for the administration of the AQRP were initially budgeted to be 24% of salaries and wages across the term of the project. It should be noted that this was an estimate, and actual fringe benefit expenses are reported for each month. The fringe benefit amount and percentage fluctuate each month depending on the individuals being paid from the account, their salary, their FTE percentage, the selected benefit package, and other variables. For example, the amount of fringe benefits is greater for a person with family medical insurance versus a person with individual medical insurance. Actual fringe benefit expenses to date are included in the spreadsheets below.

In December the Program Administration rebudgeted FY 2016 funds within the category in order to use the funds more efficiently. The Supply and Travel budgets were reduced, and the Salary, Fringe, and IDC budgets were increased.

In July 2017, a second budget revision was done to reallocate the remaining funds. Unused supply funds were budgeted to salary, fringe benefits, and IDC. Since these changes did not exceed the 10% threshold, TCEQ approval was not required.

Table 3: Administration Budget

Administration Budget (includes Council Expenses)
FY 2016/2017

Budget Category		**FY16 Budget**	**FY17 Budget**	**Total**	**Expenses**	**Remaining Balance**
Personnel/Salary		$74,475.00	$73,890.00	$148,365.00	$125,100.61	$23,264.39
Fringe Benefits		$17,891.58	$17,721.00	$35,612.58	$30,248.78	$5,363.80
Travel		$34.00	$0.00	$34.00	$34.00	$0.00
Supplies		$151.42	$1,000.00	$1,151.42	$619.94	$531.48
Equipment						
Total Direct Costs		$92,552.00	$92,611.00	$185,163.00	$156,003.33	$29,159.67
Authorized Indirect Costs		$7,448.00	$7,389.00	$14,837.00	$12,510.06	$2,326.94
10% of Salaries and Wages						
Total Costs		**$100,000.00**	**$100,000.00**	**$200,000.00**	**$168,513.39**	**$31,486.61**

ITAC

All ITAC expenses for FY 2016 were accounted for by the end of September 2016. Since the remaining funds would not be utilized under this category, $6,216 was transferred to the Contractual/Research Project category to increase the FY 2016 funds available to the Research Projects and $2,784 was transferred to Project Management.

Table 4: ITAC Budget

ITAC Budget
FY 2016/2017

Budget Category		**FY16 Budget**	**FY17 Budget**	**Total**	**Expenses**	**Remaining Balance**
Personnel/Salary						
Fringe Benefits						
Travel		$4,076.57	$5,000.00	$9,076.57	$4,076.57	$5,000.00
Supplies		$1,079.20	$2,500.00	$3,579.20	$1,079.20	$2,500.00
Equipment						
Total Direct Costs		$5,155.77	$7,500.00	$12,655.77	$5,155.77	$7,500.00
Authorized Indirect Costs						
10% of Salaries and Wages						
Total Costs		**$5,155.77**	**$7,500.00**	**$12,655.77**	**$5,155.77**	**$7,500.00**

Project Management

In October 2016, Project Management funds were increased by $2,784 from the reduction in ITAC funds. The funds were distributed across the salary, fringe benefit, and IDC categories. In addition, the funds budgeted in the Other category, which are reported under the Project Management table, were reduced by $3,000 and moved to Contractual/Research Projects, as estimated costs for data storage (to be paid from the Other category) have decreased significantly. Currently, Project Management funds are budgeted at 8.22% of Contractual/Research Project funds, below the 8.5% threshold.

FY 2016 Project Management funds were rebudgeted within the category in December 2016 and again in July 2017 in order to better utilize the funds. Supplies and Travel were reduced and Salary, Fringe and IDC were increased. Since this did not exceed the 10% threshold, TCEQ approval was not needed to make this change. Currently, Project Management funds are budgeted at 8.5% of Contractual/Research Project funds, which is the threshold.

Table 5: Project Management Budget

Project Management Budget
FY 2016/2017

Budget Category		**FY16 Budget**	**FY17 Budget**	**Total**	**Expenses**	**Remaining Balance**
Personnel/Salary		$53,538.00	$51,450.00	$104,988.00	$85,506.31	$19,481.69
Fringe Benefits		$11,286.43	$12,405.00	$23,691.43	$18,930.34	$4,761.09
Travel		$0.00	$0.00	$0.00	$0.00	$0.00
Supplies		$0.00	$500.00	$500.00	$0.00	$500.00
Other		$0.00	$5,000.00	$5,000.00	$0.00	$5,000.00
Total Direct Costs		$64,824.43	$69,355.00	$134,179.43	$104,436.65	$23,742.78
Authorized Indirect Costs		$5,353.80	$5,145.00	$10,498.80	$8,550.63	$1,948.17
10% of Salaries and Wages						
Total Costs		**$70,178.23**	**$74,500.00**	**$144,678.23**	**$112,987.28**	**$31,690.95**

Research Projects

A total of $1,630,000.00 was originally budgeted for research projects. During the first quarter those funds were increased by $9,216, due to the reduction in funds allocated to Other and ITAC, as described above. A total of ten (10) projects were selected for funding out of fifty four (54) proposals submitted to the AQRP RFP for the 2016-2017 biennium. An eleventh project was funded in April 2017 to provide logistical support for the San Antonio Field Study. With the addition of this project, a total of $1,639,175 was awarded to the eleven 2016-2017 projects. Seven of the projects ended on August 31, 2017. Two projects requested, and were granted, contract extensions to October 31, 2017, and one project requested, and was granted, a contract extension to November 30, 2017. The San Antonio Field Study Logistics project was originally awarded with an end date of October 31, 2017. As of August 31, 2017, the projects have invoiced the AQRP for a total of $1,030,546.53. Additional invoices are anticipated from all projects.

Table 6 on the following page shows the distribution of the projects across the fiscal years and the cumulative expenditures to date.

Table 6: Research Project Expenditures

Contractual Expenses				
FY 16 Contractual Funding		**$815,000**		
FY 16 Contractual Funding Transfers		**$9,666**		
FY 16 Total Contractual Funding		**$824,666**		
Project Number		Amount Awarded (Budget)	Cumulative Expenditures	Remaining Balance
16-008	University of Houston	$191,366	$119,311.20	$72,054.80
16-010	Sonoma Technology, Inc.	$69,075	$64,295.50	$4,779.50
16-011	Ramboll Environ	$158,134	$141,531.55	$16,602.45
16-019	Univ. of Texas - Austin	$118,019	$117,551.39	$467.61
16-019	Ramboll Environ	$62,622	$52,944.71	$9,677.29
16-031	UNC - Chapel Hill	$225,000	$8,430.90	$216,569.10
FY 16 Total Contractual Funding Awarded		$824,216		
FY 16 Contractual Funds Expended (Init. Projects)			$504,065.25	
FY 16 Contractual Funds Remaining to be Spent				$320,600.75
FY 17 Contractual Funding		**$815,000**		
FY 17 Contractual Funding Transfers		**$3,000**		
FY 17 Total Contractual Funding		**$818,000**		
Project Number		Amount Awarded (Budget)	Cumulative Expenditures	Remaining Balance
17-007	Univ. of Texas - Austin	$205,500	$142,272.11	$63,227.89
17-024	Atmospheric and Environmental Research, Inc.	$170,039	$158,227.06	$11,811.94
17-032	Drexel University	$59,000	$46,298.50	$12,701.50
17-039	Univ. of Alabama - Huntsville	$149,227	$99,444.70	$49,782.30
17-053	Aerodyne Research, Inc.	$185,193	$72,099.87	$113,093.13
17-SAFS	Univ. of Texas - Austin	$46,000	$8,139.04	$37,860.96
FY 17 Total Contractual Funding Awarded		$814,959		
FY 17 Contractual Funding Expended (Init. Projects)			$526,481.28	
FY 17 Contractual Funds Remaining to be Spent				$291,518.72
Total Contractual Funding		$1,642,666		
Total Contractual Funding Awarded		$1,639,175		
Total Contractual Funding Remaining to be Awarded		$3,491		
Total Contractual Funds Expended to Date			$1,030,546.53	
Total Contractual Funds Remaining to be Spent				$612,119