Scope of Work

AQRP Project: 18-022

Development and Evaluation of the FINNv.2 Global Model Application and Fire Emissions Estimates for the Expanded Texas Air Quality Modeling Domain

Prepared for

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

By

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August 20, 2018
Version #2

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

NOTE: The workplan package consists of the following three independent documents: Scope of Work, Quality Assurance Project Plan (QAPP), and Budget and Justification

Approvals

This Scope of Work was approved electronically on Aug. 31, 2018 by David Sullivan, The University of Texas at Austin

David Sullivan
Project Manager, Texas Air Quality Research Program

This Scope of Work was approved electronically on Aug. 31, 2018 by Stephanie Shirley, Texas Commission on Environmental Quality

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Project Liaison, Texas Commission on Environmental Quality

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1.0 Abstract

Wildland fires and open burning can be substantial sources of ozone precursors and particulate matter. Air quality in Texas can be affected by fire events that occur locally, regionally, or across longer distances from within the United States or across its international borders. With this recognition, the Texas Commission on Environmental Quality's (TCEQ's) future air quality model domain has been extended to include all of Mexico and large parts of Central America and the Caribbean. The Fire INventory from the National Center for Atmospheric Research (FINN) model estimates daily emissions of trace gases and particles from open biomass burning.
The objectives of this project are to leverage new findings and data products from ongoing laboratory studies, surface and airborne field measurement campaigns, and satellite-based sensors in the development of FINN and to produce a fully operational, next generation global FINN application. The FINN v.2 Global Application will be used to develop fire emissions estimates for 2012-2017, a time period that includes 2016, which is the base year for the U.S. Environmental Protection Agency's (EPA's) national air quality modeling platform and likely the basis for the TCEQ's future air quality modeling. FINN performance will be assessed using a new satellite algorithm, the Multi-Angle Implementation of Atmospheric Correction (MAIAC), for aerosol optical depth (AOD) retrievals, with a focus on fire events that originate from within Mexico, Central America, or the Caribbean and influence Texas air quality. The project is a collaborative effort between the University of Texas at Austin (UT Austin), Sonoma Technology, Inc. (STI), and Dr. Christine Wiedinmyer.

2.0 Background

Wildland fires and open burning can be substantial sources of ozone precursors and particulate matter. Air quality in Texas can be affected by fire events that occur locally, regionally, or across longer distances from within the United States or across international borders in Canada, Mexico, or other Latin American countries. Crop residue burning for ground clearing and soil enrichment in Mexico's Yucatan Peninsula and Central America during the spring months is an annual recurrence that has had pronounced, well-documented impacts on Texas air quality (Wang et al, 2009; Villanueva-Fierro et al., 2009; McMillan et al, 2010; TCEQ, 2013; Wang et al, 2017). Wildfires that have been shown to exacerbate Texas air pollution levels have originated from the remote boreal forests of eastern Alaska and western Canada (Morris et al., 2006) and from drought-stressed areas in closer proximity such as the recent western Oklahoma and Texas Panhandle fires during March 2017 and the Bastrop County Complex Fire in Central Texas during 2011. These events can lead to elevated pollutant levels in many of the state's most populous areas and pose risks to human health. The underlying factors that contribute to the severity and spatial and temporal patterns in biomass burning and its associated emissions are myriad and include, for example, agricultural, forest, and waste management practices, land use change, drought status, and ecosystem diversity and health. Characterization of fire events and meteorological conditions that contribute to the transport of fire emissions is necessary to understand their influences on measured ambient concentrations and associated public health risks, to provide a weight of evidence for exceptional event exclusions if necessary, and to support air quality modeling for planning and attainment demonstrations. Fire emissions also contribute to background ozone concentrations that can influence the relative effectiveness of local and regional emissions controls. Understanding and responding to the effects of biomass burning on Texas air quality demand broad perspectives and readily available, accurate observational data and modeling and decision support tools

FINN is a global fire emissions model that estimates daily emissions of trace gases and particles from open biomass burning (Wiedinmyer et al., 2011). FINN v.1 was released in 2010. Global fire emissions estimates using the most recent version of FINN, v.1.5, are publicly accessible from the National Center for Atmospheric Research (NCAR) data portal: http://bai.acom.ucar.edu/Data/fire/. The Texas Air Quality Research Program (AQRP) has been instrumental in the ongoing development of FINN. AQRP Project 12-018 (McDonald-Buller et al., 2013) evaluated the sensitivity of FINN v.1 emissions estimates to the variability in input parameters, including land cover, emission factors, fire detection, burned area, and fuel loading and investigated the effects on modeled air quality. AQRP Project 14-011 (McDonald-Buller et al., 2015) made targeted improvements to FINN with a special focus on needs for Texas. A new approach was developed that dramatically improved the way in which burned area was estimated from satellite-derived fire detections. Other improvements included better spatial resolution of land cover and fuel loadings in the United States, new satellite-based estimates of barren land and vegetative cover, and options to use crop-specific emission factors and fuel loadings for the United States and different land cover data resources. These modifications served as the foundation for the ongoing development of the next generation of the model, FINN v.2, and emissions estimates from AQRP Project 14-011 have been used in air quality modeling for Texas ozone nonattainment areas conducted by the TCEQ.

Although the FINN v.2 application developed as an outcome of AQRP Project 14-011 can be run on regional scale for Texas and the CONUS, the model is not running on a global scale, because of its current computational demands, as would be required for global chemical transport modeling (CTM) applications that provide the boundary conditions for regional model applications. Ongoing laboratory studies, surface and airborne field measurement campaigns, and satellite-based sensors since the time of AQRP Project 14-011 are providing new insights on fire detections and emissions and their physical and chemical transformations over different spatial scales of transport. New data products have become available that can be used to support improvements in FINN. Advances in data products derived from satellite sensors can also provide essential resources for evaluation of FINN emissions estimates. Satellite measurements of aerosol optical depth (AOD), for example, have broad spatial and temporal coverage and are thus an effective tool for assessing emissions of particulate matter (PM) from wildfires. Prior work has shown success in using satellite AOD retrievals for assessing emissions models for biomass burning in operational and research settings (e.g., Park et al., 2003; Rolph et al., 2009). Recently, a new satellite AOD algorithm, the Multi-Angle Implementation of Atmospheric Correction (MAIAC), has become available that addresses limitations in earlier widely-used remotely sensed AOD products and provides broad spatial coverage, including over Mexico, Central America, and the Caribbean. The MAIAC AOD dataset presents a key new opportunity to assess wildfire smoke emissions, since it has finer spatial resolution than other AOD products from the Moderate Resolution Imaging Spectroradiometer (MODIS), is tuned to prevent masking of smoke as cloud (Lyapustin et al., 2012), and effectively retrieves AOD over a broad range of land cover types.

3.0 Objectives

The project has the following objectives:

- Leverage new findings and data products, in particular for fire detection, in the development of FINN;
- Produce and port to TCEQ, with availability to the broader air quality research and management communities, a fully operational, documented global FINN application;

- Generate fire emissions estimates to support the TCEQ's and EPA's recent air quality model development efforts; and
- Assess FINN performance by comparing modeled AOD, based on the output of simulations with the Comprehensive Air Quality Model with Extensions (CAMx) that use fire emissions estimates from the new global FINN application as input, to the MAIAC AOD product. A special focus will be on fire events that originate from within Mexico, Central America, or the Caribbean and influence Texas air quality.

The project is a collaborative effort between UT Austin, STI, and Dr. Christine Wiedinmyer of the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder, who will serve in an independent leadership and advisory role for the project. This project will be led by Dr. Elena McDonald-Buller (Principal Investigator) from UT Austin, Mr. Fred Lurmann (Co-Principal Investigator) from STI, and Dr. Wiedinmyer (Co-Principal Investigator). Other key project personnel include Dr. Yosuke Kimura of UT Austin and Dr. Steve Brown and Mr. Nathan Pavlovic from STI.

4.0 Task Descriptions

4.1 Development and Release of the FINN v.2 Global Application

This task includes several components described below that will result in a fully operational, documented global FINN application that reflects the state of the science. This task will be lead by Dr. Wiedinmyer and Dr. McDonald-Buller with technical support from Dr. Kimura.

4.1.1 Preprocessor and Model Development

The current version of the FINN preprocessor was developed to use MODIS Rapid Fire Detections, with a spatial resolution of ~1km. The Visible Infrared Imaging Radiometer Suite (VIIRS) fire detection product offers greater spatial resolution (375m) than the current MODIS default product in FINN. In this work, VIIRS fire detections will be obtained from the FIRMS Active Fire data archive tool: https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data. The VIIRS product will be used in place of and/or in conjunction with MODIS observations in FINN. For time periods when the VIIRS product is unavailable, the resolution will remain at 1km, the resolution of the MODIS fire detections. Results from multiple efforts, including the recent FIREX, FLAME-4 and SEAC^{4}RS studies, have been published that present new emission factors, fuel loadings, and other information about fire emissions. This work will also incorporate any updates to these model parameters based on the most recent literature available between 2014-2018.

4.1.2 Accessibility for Global Scale Application

In this work, the FINN preprocessor will be implemented on a public domain spatial database PostGIS for better scalability to a global application. The new preprocessor tool and Interactive Data Language (IDL) code for FINN will be designed to run at a global scale on PC (desktop/workstation) systems with reasonable time expectations and produce emission estimates in an appropriate format for application in global or regional CTMs.

4.1.3. Porting and Testing

Once the development work has been completed, the FINN v.2 Global Application code will be ported along with descriptions, instructions for installation and use, and a sample application for testing on one or more systems at the TCEQ to ensure that it meets expectations.

4.2 FINN v.2 Global Emissions Estimates

Emissions estimates will be created using the FINN v.2 Global Application for 2012-2017. This time period overlaps with the MAIAC AOD availability and several major laboratory and field study intensives specifically addressing fires. It includes 2012, which has been the base year for TCEQ's regulatory air quality modeling to date and the first complete year of operation for the VIIRS sensor. This time period includes 2016, the base year for EPA's national air quality modeling platform and likely the basis for future TCEQ air quality modeling. Fire emissions estimates for different geographic regions will be compared between years and seasons. This task will be lead by Dr. Wiedinmyer and Dr. McDonald-Buller with technical support from Dr. Kimura.

4.3 Assessment of FINN Performance Using Satellite Observations

The MAIAC AOD data will be used to evaluate both FINN emissions estimates and CAMx modeled air quality that applies FINN emissions estimates as input. The smoke emissions inventories from FINN for 2012 through 2017 (refer to Section 4.2) will be run through the HYSPLIT dispersion model using Global Data Assimilation System (GDAS0P5) meteorological data. HYSPLIT will be run using the BlueSky modeling framework, which facilitates simple dispersion modeling for wildfire smoke emissions. FINN output with both MODIS and VIIRS input fire activity will be generated and the results will be compared to understand the sensitivity of FINN to different fire activity datasets.

Next, comparisons of daily estimates will be made between CAMx model output and satellite AOD for available years. At this time, simulations will be conducted using the TCEQ's 2012 CAMx modeling. This process will be repeated for a 2016 CAMx episode if it becomes available from the TCEQ within a reasonable time period prior to the end of the project and has the capabilities for PM modeling. Speciated $PM_{2.5}$ and meteorological conditions from the CAMx model output will be used to calculate model-estimated AOD (Pitchford et al., 2007). The modeled AOD will be compared with MAIAC AOD retrievals. Assessments will be performed on a daily and monthly basis at the spatial resolution of the CAMx modeling domain (i.e., 36-km grid cell resolution) that covers the majority of Mexico, Central America, and the Caribbean. Using the model results, detailed quantitative and qualitative analyses will also be performed for several selected fire events that had substantial impacts on air quality in Texas in consultation with the TCEQ. We will assess agreement between CAMx model output and satellite observations of AOD using daily maps, scatter plots, and time series plots for the selected fire events. We will also assess statistical measures of agreement including correlation, coefficient of determination, normalized mean square error, bias, and fraction of data for which predictions are within a factor of two of observations. Dr. Lurmann will lead this task with technical support from Mr. Nathan Pavlovic and Dr. Steve Brown from STI and Dr. Kimura from UT.

5.0 Project Reporting and Presentations

As required, monthly technical, monthly financial status, and quarterly reports as well as an abstract at project initiation and, near the end of the project, the draft final and final reports will

be submitted according to the schedule shown in Section 8.0. Dr. McDonald-Buller or her designee will electronically submit each report to both the AQRP and TCEQ liaisons and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources (http://aqrp.ceer.utexas.edu/). Dr. McDonald-Buller and Mr. Pavlovic anticipate attending and presenting at the AQRP data workshop. Draft copies of any planned presentations (such as at technical conferences) or manuscripts to be submitted for publication resulting from this project will be provided to both the AQRP and TCEQ liaisons per the Publication/Publicity Guidelines included in Attachment G of the subaward. Final project data and associated metadata will be prepared and submitted to the AQRP archive.

Dr. McDonald-Buller will lead the project reporting activities with Mr. Lurmann and Dr. Wiedinmyer and with assistance from team members at UT and STI. Deliverables include the abstract, monthly technical reports, monthly financial status reports, quarterly reports, draft final report, final report, attendance and presentation at AQRP data workshop, submissions of presentations and manuscripts, project data and associated metadata. The schedule for deliverables is shown in Section 8.0.

6.0 Project Participants and Responsibilities

Project roles and responsibilities for UT Austin, STI, and Dr. Wiedinmyer are described in this section.

The University of Texas at Austin

- ***Dr. Elena McDonald-Buller*** will provide overall supervision and integration of the technical work and will be responsible for the preparation and submission of the monthly progress, quarterly progress, and final reports.

- ***Dr. Yosuke Kimura*** will work on the development of the FINN v.2 Global Application and fire emissions estimates. He will conduct the CAMx simulations to support the assessment of FINN performance.

Sonoma Technology, Inc.

- ***Mr. Fred Lurmann*** will provide high-level coordination with Dr. McDonald-Buller and staff members at STI. Mr. Lurmann will consult with staff members at STI on the FINN/MAIAC model assessment and advise on results reporting in collaboration with Dr. McDonald-Buller and Dr. Wiedinmyer.

- ***Dr. Steve Brown*** will provide overall guidance and coordination for completion of technical work with Dr. McDonald-Buller and Dr. Wiedinmyer. Dr. Brown will be partially responsible for preparation of technical reports and presentations.

- ***Mr. Nathan Pavlovic*** will be responsible for obtaining and preparing meteorological and satellite data sets, performing HYSPLIT dispersion modeling, comparing dispersion model results with satellite observations, comparing CAMx-estimated AOD with satellite observations, and investigating smoke impact events. Mr. Pavlovic will also be partially responsible for drafting reports and presentations in coordination with Dr. Brown and Mr. Lurmann.

Dr. Christine Wiedinmyer will provide guidance and supervision of the technical work including the development of the FINN v.2 Global Application and fire emissions estimates and

interpretation of the FINN evaluation. She will assist Dr. McDonald-Buller with the preparation and submission of the monthly progress, quarterly progress, and final reports.

7.0 Timeline

A timeline of project activities is shown in Table 1.

Table 1. Schedule of project activities (tasks are bolded).

ID	Task	Aug 2018	Sept 2018	Oct 2018	Nov 2018	Dec 2018	Jan 2019	Feb 2019	Mar 2019	Apr 2019	May 2019	Jun 2019	July 2019	Aug 2019
1	***Development & Release of FINN v.2 Global***													
1a	*Preprocessor and Model Development*	X	X	X	X									
1b	*Accessibility for Global Scale Application*	X	X	X	X									
1c	*Porting and Testing*				X	X								
2	***FINN v.2 Global Emissions Estimates***				X	X	X	X						
3	***Assessment of FINN Performance***						X	X	X	X	X			
R	*Monthly Technical & Financial Progress*	X	X	X	X	X	X	X	X	X	X	X	X	X
R	*Quarterly*		X			X			X			X		
R	*Draft Final*											X	X	
R	*Final*													X
R	*AQRP Workshop*													X

8.0 Deliverables

Project reporting and presentation requirements are described in Section 5.0. Deadlines for required deliverables are presented below.

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

Abstract Due Date: Friday, August 31, 2018

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

Quarterly Report Due Dates:

Report	Period Covered	Due Date
Aug2018 Quarterly Report	June, July, August 2018	Friday, August 31, 2018
Nov2018 Quarterly Report	September, October, November 2018	Friday, November 30, 2018
Feb2019 Quarterly Report	December 2018, January & February 2019	Thursday, February 28, 2019
May2019 Quarterly Report	March, April, May 2019	Friday, May 31, 2019
Aug2019 Quarterly Report	June, July, August 2019	Friday, August 30, 2019
Nov2019 Quarterly Report	September, October, November 2019	Friday, November 29, 2019

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

MTR Due Dates:

Report	Period Covered	Due Date
Aug2018 MTR	Project Start - August 31, 2018	Monday, September 10, 2018
Sep2018 MTR	September 1 - 30, 2018	Monday, October 8, 2018
Oct2018 MTR	October 1 - 31, 2018	Thursday, November 8, 2018
Nov2018 MTR	November 1 - 30 2018	Monday, December 10, 2018
Dec2018 MTR	December 1 - 31, 2018	Tuesday, January 8, 2019
Jan2019 MTR	January 1 - 31, 2019	Friday, February 8, 2019
Feb2019 MTR	February 1 - 28, 2019	Friday, March 8, 2019
Mar2019 MTR	March 1 - 31, 2019	Monday, April 8, 2019
Apr2019 MTR	April 1 - 28, 2019	Wednesday, May 8, 2019
May2019 MTR	May 1 - 31, 2019	Monday, June 10, 2019
Jun2019 MTR	June 1 - 30, 2019	Monday, July 8, 2019
Jul2019 MTR	July 1 - 31, 2019	Thursday, August 8, 2019

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

FSR Due Dates:

Report	Period Covered	Due Date
Aug2018 FSR	Project Start - August 31	Monday, September 17, 2018
Sep2018 FSR	September 1 - 30, 2018	Monday, October 15, 2018
Oct2018 FSR	October 1 - 31, 2018	Thursday, November 15, 2018
Nov2018 FSR	November 1 - 30 2018	Monday, December 17, 2018
Dec2018 FSR	December 1 - 31, 2018	Tuesday, January 18, 2019

Jan2019 FSR	January 1 - 31, 2019	Friday, February 15, 2019
Feb2019 FSR	February 1 - 28, 2019	Friday, March 15, 2019
Mar2019 FSR	March 1 - 31, 2019	Monday, April 15, 2019
Apr2019 FSR	April 1 - 28, 2019	Wednesday, May 15, 2019
May2019 FSR	May 1 - 31, 2019	Monday, June 17, 2019
Jun2019 FSR	June 1 - 30, 2019	Monday, July 15, 2019
Jul2019 FSR	July 1 - 31, 2019	Thursday, August 15, 2019
Aug2019 FSR	August 1 - 31, 2019	Monday, September 16, 2019
FINAL FSR	Final FSR	Tuesday, October 15, 2019

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

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

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

Final Report Due Date: Tuesday, September 3, 2019

Project Data: All required FINN data inputs, the FINN preprocessor code, IDL FINN code and ancillary files, instructions for model installation and use, emissions estimates for all study years, CAMx outputs for the available episode years, and results of the comparisons with the MAIAC AOD product will be submitted to the AQRP Project Manager within 30 days of project completion (September 30, 2019). The data will be submitted in a format that will allow AQRP or TCEQ or other outside parties to utilize the information. The draft and final project reports will describe the QA findings.

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

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

9.0 References

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