Scope of Work For

Project 14-025
Development and Evaluation of an Interactive Sub-Grid Cloud Framework for the CAMx Photochemical Model

Prepared for

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

by

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1.0 STATEMENT OF WORK

1.1 Introduction

This document provides the work plan for the Texas Air Quality Research Program (AQRP) project 14-025 "Development and Evaluation of an Interactive Sub-Grid Cloud Framework for the CAMx Photochemical Model." The project Co-Principal Investigators (PI) include Mr. Christopher Emery of ENVIRON, and Drs. John Nielsen-Gammon, Kenneth Bowman, and Renyi Zhang of Texas A&M University (TAMU). The AQRP project manager is Mr. Gary McGaughey at the University of Texas, Austin. The project liaison for the Texas Commission on Environmental Quality (TCEQ) is Dr. Khalid Al-Wali. All work under this project will be completed by June 30, 2015.

The US Environmental Protection Agency (EPA) requires the use of photochemical models to demonstrate that local emission control plans will achieve the federal standard for ground-level ozone (EPA, 2007). The TCEQ uses the Comprehensive Air quality Model with extensions (CAMx; ENVIRON, 2014) for research and regulatory photochemical modeling.

Moist convection at sub-grid scales is an important mechanism for exchanging boundary layer air with the free troposphere and for chemical processing, yet CAMx does not explicitly treat such processes. The current sub-grid cloud approach within CAMx influences photolysis rates, wet deposition, and aqueous chemistry at grid scale, but does not include convective transport. Under AQRP Project 14-025, ENVIRON and collaborators at TAMU will incorporate and extensively evaluate an explicit sub-grid cloud model within CAMx. The primary goal of this work is to introduce shallow and deep convective cloud mixing at sub-grid scales. Further, we will develop an approach to improve interactions with chemistry and wet deposition to operate explicitly at sub-grid scales in tandem with the cloud mixing scheme. Our proposal directly addresses two AQRP priority research areas: (1) improving the simulation of clouds in air quality modeling, especially at sub-grid-scales; and (2) global and regional transport of pollutants into Texas, using data collected by aircraft, ozonesondes, and satellites, and modeling analyses.

Our approach will tie into recent updates implemented in the Weather Research and Forecasting (WRF) model by Alapaty et al. (2012), whereby specific sub-grid cloud fields will be passed to CAMx to define their spatial/temporal distributions and mixing rates for the sub-grid cloud algorithm in CAMx. This will yield a consistent cloud-mixing-chemistry system across the WRF and CAMx models. The new CAMx treatment will be tested for three convective episodes that occurred during the September 2013 Houston DISCOVER-AQ field study and the Spring 2008 START08 field study, particularly addressing tropospheric profiles of NOx, ozone, and other chemical tracers by comparing to in situ profiles from aircraft measurements. The new model will be provided to TCEQ to support future regulatory and research-oriented ozone and PM modeling.

1.2 Background

Small-scale clouds are often widespread but they are not explicitly resolved by the grid scales employed in regional meteorological and photochemical modeling applications. The physical effects from these sub-grid clouds are difficult to characterize accurately, but they can substantially influence many different atmospheric processes, including: boundary layer mixing, ventilation, and deep vertical transport of heat, moisture, and chemical tracers; radiative transfer and surface heat budgets; spatio-temporal precipitation patterns, intensity and wet scavenging rates; chemistry via photolysis and aqueous reactions; and certain environmentally-sensitive emission sectors (e.g., biogenics).

Sub-grid cloud parameterizations are employed in meteorological models to adjust grid-resolved vertical profiles of heat and moisture from the effects of moist convection. The Kain-Fritsch (K-F) parameterization (Kain, 2004) is perhaps the most widely used option in the WRF model (Skamarock et al., 2008) when it is run to support "off-line" photochemical models like CAMx. However, these parameterizations in WRF have not historically interacted with other important processes such as radiative transfer, which can lead to errors in surface temperature and boundary layer mixing, and in turn feed back into the evolution of cloud and precipitation fields.

Alapaty et al. (2012) have made improvements to WRF by using cloud parameters derived from the K-F scheme to internally adjust the grid-scale cloud fields that feed into WRF's radiation treatments. They show that simulated surface temperature and precipitation fields are improved relative to the unmodified version of WRF. Additionally, Alapaty et al. have added K-F cloud variables to the WRF output registry to support better coupling with off-line photochemical models. The group is also developing new multi-scale treatments for K-F to extend its applicability over a wider range of grid resolutions. These update are scheduled to be available in the next public distribution of WRF in Spring 2014.

From the air quality perspective, moist convection is an important component for long-range transport of ozone, PM, and precursors. The effects of sub-grid clouds on vertical transport, chemistry, and wet scavenging are addressed to varying degrees in off-line photochemical models (Zhao et al., 2009; Foley et al., 2010; Belikov et al., 2013), but the spatial/temporal distributions of such clouds must be re-diagnosed because meteorological models do not export necessary information from their sub-grid cloud parameterizations. This leads to potentially large inconsistencies between the models. CAMx implicitly addresses the influence of sub-grid clouds by diagnosing their presence according to resolved wind and thermodynamic fields from meteorological models, and blending their properties into the resolved cloud fields (Emery et al., 2010). The final blended cloud fields are used to adjust photolysis rates, perform aqueous chemistry, and remove pollutants via wet scavenging at grid scale – no separate sub-grid cloud processes are explicitly treated. Furthermore, CAMx does not include a cloud convective mixing treatment.

Two recent studies conducted by Kemball-Cook et al. (2012, 2013) evaluated tropospheric NOx profiles simulated by CAMx throughout the south-central and southeast US against aircraft measurements and satellite remote sensing products. The comparison of CAMx-modeled NO_2 columns with satellite retrieved columns showed that, like other regional and global models, CAMx underestimates NOx and NOy above 8 km in the troposphere. Satellite instruments have higher sensitivity in the upper troposphere, so satellite-model column comparisons are more heavily weighted aloft and model errors aloft can confound the inter-comparisons. Simple experiments that extended boundary layer mixing deep into the upper troposphere in the presence of diagnosed sub-grid convection tended to improve modeled under predictions of NOx in the upper troposphere. Kemball-Cook et al. (2013) concluded that improvements to the CAMx modeling system, including a sub-grid convection treatment, are necessary to reduce the low bias in upper tropospheric NO_2 and PAN and to more accurately represent the NOy budget aloft.

1.3 Objectives

The project team will develop a shallow and deep sub-grid convective cloud mixing scheme for CAMx, incorporating chemistry, wet deposition, and vertical mixing processes into an interactive cloud modeling system. Our approach will be complementary with the WRF updates developed by Alapaty et al. (2012), whereby additional sub-grid cloud output fields will be passed to CAMx to define spatial/temporal distributions and mixing rates for the sub-grid cloud algorithm in CAMx. Through a cooperative arrangement, Dr. Kiran Alapaty's group at EPA has agreed to interact with our team to provide interim and final versions of WRF and to make specific variables available from WRF to support sub-grid cloud modeling in CAMx.

The new CAMx treatment will be tested for a convective period that occurred during the September 2013 Houston DISCOVER-AQ field study, particularly addressing convective cumulus impacts to tropospheric profiles of NOx, ozone, and other chemical tracers by comparing to *in situ* concentration and tropospheric column profiles from aircraft measurements. Through a cooperative arrangement, Dr. Ken Pickering's group at NASA has agreed to provide data products from the DISCOVER-AQ campaign. Convection occurred during the first week of the field campaign, particularly on September 4, 6, and 11. These data products should be available by Spring 2014. CAMx will also be run and evaluated against aircraft data from the 2008 START08 monitoring campaign, for which field data are already available at TAMU. The new model will be provided to TCEQ to support future regulatory and research-oriented ozone and PM modeling.

1.4 Task Descriptions

1.4.1 Task 1: Preparation and Software Design

The project team will develop a project Work Plan (this document) and a Quality Assurance Project Plan (QAPP), per AQRP requirements and following appropriate EPA guidelines. Upon AQRP review and approval of these documents, the team will commence modeling database setup and measurement data acquisition by coordinating with EPA and NASA groups to obtain the latest WRF model source code and necessary data from DISCOVER-AQ, respectively. We will discuss with Dr. Alapaty's group at EPA to define the specific K-F cumulus variables available to support the CAMx cloud model framework. From this we will further refine details of the methodology to incorporate a sub-grid cloud model in CAMx.

We plan to develop a comprehensive interactive sub-grid cloud framework in CAMx that addresses shallow mixing, deep convective transport, gas and aqueous chemistry, and wet scavenging. All processes will be driven by specific data obtained from output fields generated by the WRF K-F scheme. The K-F cumulus parameterization scheme is fundamentally a mass flux scheme (Kain 2004). Changes to grid-scale temperature and moisture are calculated from the parameterized properties of entraining/detraining plumes that constitute convective updrafts and convective downdrafts, and from ambient mass fluxes (i.e., compensating subsidence outside the cloud) necessary to maintain mass conservation. This places the K-F scheme within a subset of cumulus parameterization schemes for which constituent transport is already implicit. Outside the convective volume, the ambient mass fluxes will be output from WRF as an effective compensating vertical velocity that would be added to grid-resolved vertical wind for the core CAMx vertical advection scheme. Within the convective volume, updraft and downdraft plumes produce non-local (multi-layer) transport, so WRF will be modified to calculate, store, and output the fractional sources of air from each model level that constitute the resulting mixture of post-convection air at each model level. Decisions will need to be made on the relative mixing within the updraft and downdraft plumes, and on interactions between smaller-scale, short-lived convection and larger-scale, steady-state convection.

The CAMx sub-grid cloud model framework will operate separately from the normal grid processes in a manner similar to the Plume-in-Grid (PiG) model (Emery et al., 2013a; ENVIRON, 2014). This “cloud-in-grid” (CiG) approach will define at each hour the physical attributes of a multi-layer cloud “reactor” (much like a PiG “puff”) according to the hourly cloud data provided by WRF. Each CiG reactor configuration would be unique to each grid column (or entirely absent from it) and characterize a steady-state sub-grid cloud environment between each meteorological update time. Fractions of pollutant vertical mass profiles from each host grid column will be allocated to each CiG reactor layer, which would then operate on that mass to include vertical transport, entrainment/ detrainment with the ambient grid column, chemistry, and wet removal.

Deliverables: Work Plan, QAPP, monthly and quarterly progress reports documenting decision points, technical issues, and progress in the evolution of software design, implementation, and testing.

1.4.2 Task 2: Implementation of Sub-grid Convective Model in CAMx

ENVIRON will implement code updates to the WRF-to-CAMx (WRFCAMx) meteorological interface program to accommodate new output fields from the latest WRF version from EPA. Basic process testing and debugging will be performed by running short (~1 day) WRF test cases through the updated WRFCAMx code.

ENVIRON will implement code updates to the CAMx model to include the CiG model framework, I/O infrastructure, and the convective mixing/transport and entrainment/ detrainment components. The CiG framework will be incorporated into the MPI and OMP parallelization used in CAMx according to the methodology developed in Task 1. Basic process testing and debugging will be performed by running short (~1 day) CAMx test cases using input data streams from the updated WRF and WRFCAMx systems.

Deliverables: Monthly and quarterly progress reports documenting coding progress, technical issues, anticipated solutions, and testing results.

1.4.3 Task 3: Implementation of Chemistry and Wet Scavenging

ENVIRON will implement code updates to the CAMx CiG model framework to incorporate gas-phase and aqueous chemistry, and wet scavenging for gasses and PM. With the amount and composition of air participating in updrafts and downdrafts known, such processes can be simulated as long as the trajectory of the air in time and thermodynamic space is known or parameterized. Special consideration will be given to photolysis rate adjustments and column wet scavenging coefficients within the CiG reactors according to the refined methodology developed in Task 1. Basic process testing and debugging will be performed using the same short CAMx test cases as in Task 2.

Deliverables: Monthly and quarterly progress reports documenting coding progress, technical issues, anticipated solutions, and testing results.

1.4.4 Task 4: Model Evaluation

TAMU will run the modified WRF with various K-F configurations for three test cases. The first subtask will be case development and meteorological validation. The cases will be selected for their variety of convective modes and the availability of measurements in the free troposphere. Then WRF output from each case will be passed through the updated WRFCAMx interface program, and CAMx will be run using pre-existing emissions and ancillary input datasets.

1.4.4.1 September 2013 DISCOVER-AQ

The first case occurred in 2013, during early DISCOVER-AQ operations between September 4 and 11, and particularly on September 6, when substantial shallow and deep convection moved inland from the Gulf of Mexico and across the Houston area. The P3 aircraft sampled vertical columns up to 12,000-15,500 feet at several locations in the Houston-Galveston area before and after the scattered deep convection moved through the area, while the B200 aircraft flew at high altitude with a downward-looking hyperspectral sensor. DISCOVER-AQ data are expected to be available for this project sometime during the first half of 2014 (K. Pickering, pers. comm.).

CAMx will be run using pre-existing emission datasets developed for the TCEQ forecasting system (Johnson et al., 2013). This case will allow us to examine CAMx performance in the context of the complex emissions profile of the Houston-Galveston airshed. Figure 1 presents the 36/12 km WRF and CAMx modeling domains used for the ozone forecasting system. These are consistent with the TCEQ SIP domains (http://www.tceq.texas.gov/airquality/airmod/rider8/modeling/domain); a 4 km domain was not included in the initial forecast modeling system. The vertical layer mapping table from the lowest 38 layers (43 total) in WRF to 28 layers in CAMx, is presented in Figure 2. The CAMx inputs for the modeling forecasting system include:

- Initial conditions extracted from GEOS-CHEM global 3-D chemical transport model simulation for 2012; used for initial 24-hour spinup;
- Boundary conditions extracted from GEOS-CHEM 2012 monthly averages; modifications made to increase unrealistically low CO concentrations and reduce impacts from 2012 wildfires in northern Manitoba;
- 2012 day-of-week specific anthropogenic emissions inventory provided by TCEQ;
- MEGAN v2.10 biogenic emissions using WRF forecast cycle meteorology;
- WRFCAMx v4.0 using YSU Kv methodology;
- Kv landuse patch up to 100 m and Kv cloud patch applied;
- O3MAP: 2012 monthly averages from 1 degree TOMS satellite ozone column data;
- Photolysis rates files generated using O3MAP 2012 monthly averages;
- Land use / land cover inputs generated using USGS 24-category dataset; monthly LAI data from MODIS satellite.

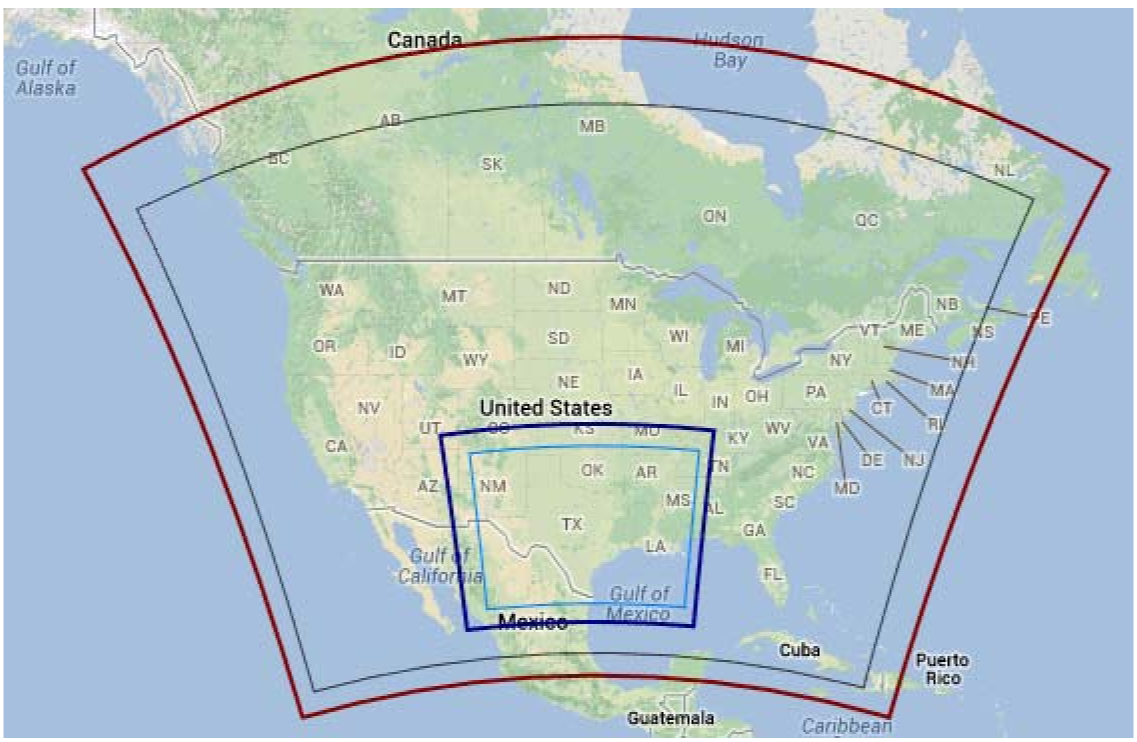
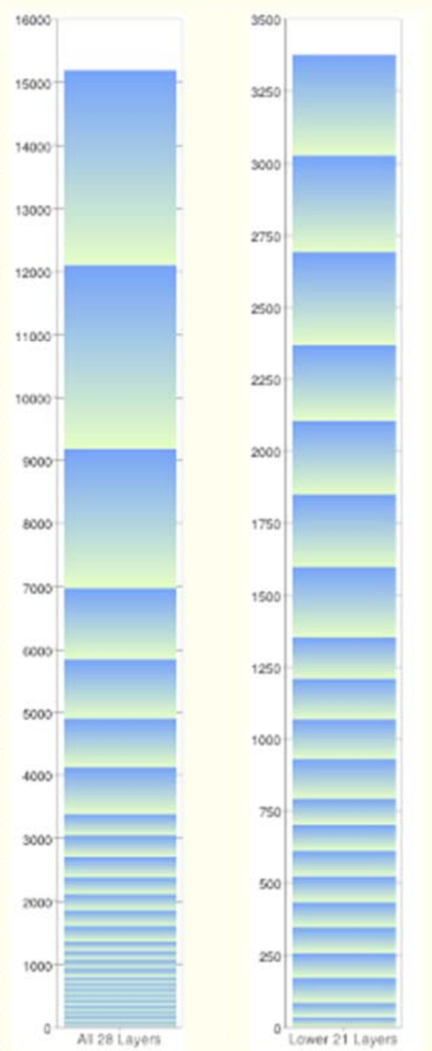


Figure 1. WRF 36-km (red) and 12-km (dark blue) and CAMx 36-km (grey) and 12-km (light blue) modeling domains. Generated from http://www.tceq.texas.gov/airquality/airmod/rider8/modeling/domain.

Vertical Layer Structure

Corresponding WRF Layer	Layer Top (m AGL)	CAMx Layer	Layer Center (m AGL)	Thickness (m)
38	15179.1	28	13637.9	3082.5
36	12096.6	27	10631.6	2930.0
32	9166.6	26	8063.8	2205.7
29	6960.9	25	6398.4	1125.0
27	5835.9	24	5367.0	937.9
25	4898.0	23	4502.2	791.6
23	4106.4	22	3739.9	733.0
21	3373.5	21	3199.9	347.2
20	3026.3	20	2858.3	335.9
19	2690.4	19	2528.3	324.3
18	2366.1	18	2234.7	262.8
17	2103.3	17	1975.2	256.2
16	1847.2	16	1722.2	249.9
15	1597.3	15	1475.3	243.9
14	1353.4	14	1281.6	143.6
13	1209.8	13	1139.0	141.6
12	1068.2	12	998.3	139.7
11	928.5	11	859.5	137.8
10	790.6	10	745.2	90.9
9	699.7	9	654.7	90.1
8	609.7	8	565.0	89.3
7	520.3	7	476.1	88.5
6	431.8	6	387.9	87.8
5	344.0	5	300.5	87.1
4	256.9	4	213.8	86.3
3	170.6	3	127.8	85.6
2	85.0	2	59.4	51.0
1	33.9	1	17.0	33.9



AGL - Above Ground Level.

Figure 2. CAMx Model Layer Structure. TCEQ figure from http://www.tceq.texas.gov/airquality/airmod/rider8/modeling/domain.

The new version of WRF will be re-run for the September 2013 DISCOVER-AQ episode for the 36 and 12 km nested grids shown in Figures 1. WRF will be configured to be consistent with the layer structure (Figure 2), physics options, and data assimilation inputs and specifications employed by TCEQ (Table 1), except that the modified version of the K-F cumulus parameterization will be used to support the CAMx convection model.

Table 1. WRF physics options used in the ozone forecasting system.

WRF Physics Option	Option Selected	Notes
Microphysics	WRF Single-Moment 6-class (WSM6)	A scheme with ice, snow and graupel processes suitable for high-resolution simulations.
Longwave Radiation	RRTM	Rapid Radiative Transfer Model. An accurate scheme using look-up tables for efficiency. Accounts for multiple bands, and microphysics species.
Shortwave Radiation	Dudhia	Two-stream multi-band scheme with ozone from climatology and cloud effects
Surface Layer Physics	MM5 similarity	Based on Monin-Obukhov with Carslon-Boland viscous sub-layer and standard similarity functions from look-up tables
LSM	Noah	NCEP/NCAR land surface model with soil temperature and moisture in four layers, fractional snow cover and frozen soil physics.
PBL scheme	Yonsei University (YSU)	Non-local-K scheme with explicit entrainment layer and parabolic K profile in unstable mixed layer
Cumulus parameterization	Kain-Fritsch scheme	Deep and shallow convection sub-grid scheme using a mass flux approach with downdrafts and CAPE removal time scale

1.4.4.2 May/June 2008 START08

The next two cases occurred during the Stratosphere-Troposphere Analyses of Regional Transport 2008 (START08). START08 was designed to measure the effects of a wide variety of transport and mixing processes in the upper troposphere and lower stratosphere, including deep convection (Pan et al., 2010). The key platform for START08 was an NCAR/NSF Gulfstream-V aircraft equipped with sensors for measuring O_3, CO, CO_2, NO, NOy, CH_4, N_2O, and 55 other trace species. The first case, on May 6, 2008, featured a squall line over North Texas and has already been simulated with WRF to study the transport effects of explicitly-resolved convection (Bowman 1993, Bowman and Carrie 1992). The second case occurred on June 16, 2008 and was an instance of a multi-day episode of unorganized, diurnally-forced deep convection over the south-central United States. High-altitude and vertical column measurements were made within a triangle bounded by Colorado, the northern Gulf of Mexico, and Missouri.

The project team will employ existing 2008 CAMx modeling datasets used in two prior AQRP projects in 2012/2013 (Emery et al., 2013b; McDonald-Buller et al., 2013). CAMx will be run for the May and June 2008 START08 episodes using a CAMx dataset developed by Alpine Geophysics for the Eight Hour Coalition (a cooperative of Houston petrochemical and refining companies). This dataset is configured with a continental US (CONUS) 36 km grid and a large 12 km nested grid over the central US (Figure 3), includes both ozone and PM precursor emissions chemically speciated for the CB05 chemical mechanism, and uses emissions data from both the TCEQ and EPA (Table 2). Biogenic emissions are available from both MEGAN and GloBEIS, but

Table 2. Configuration and input data for the 2008 CAMx model.

Model Component	Description
Modeling Period	April 1 - October 18, 2008
Modeling Domain	36/12/4 km
Vertical Structure	30 Vertical Layers
Meteorological Model	WRF
Chemical Mechanism	CB05
Boundary Conditions	MOZART
Deposition	Zhang
Emissions	
• Biogenics	MEGAN and GloBEIS
• On-road Motor Vehicles	MOVES
• Off-Road Motor Vehicles	EPA NEI
• Shipping	EPA NEI
• Area Source	EPA NEI
• Point Source	TCEQ
• Wild Fire	BlueSky/EPA SMARTFIRE 2

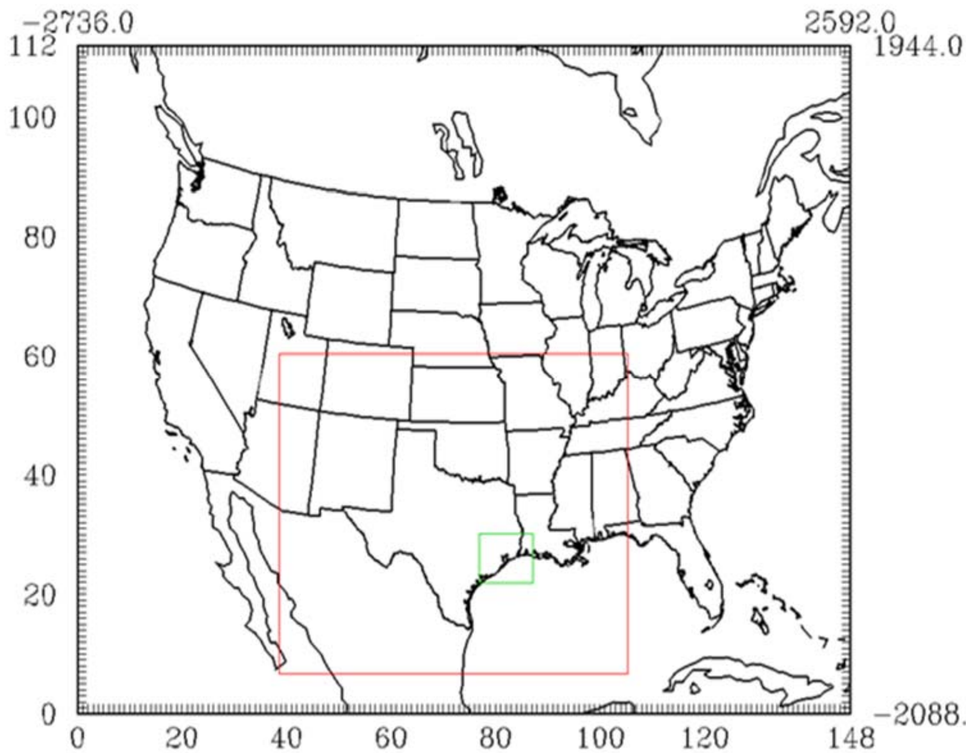


Figure 3. CAMx modeling grids developed by Alpine Geophysics for the 2008 modeling application: outer 36 km grid (full extent of map), 12 km nest (red), 4 km nest (green; not used).

only GloBEIS emissions will be used in this project. The 36 and 12 km grids are run in 2-way interactive nested mode; the 4-km grid shown in Figure 3 will not be used. Boundary conditions have been developed for the 36 km CONUS grid using 6-hourly output from MOZART.

The new version of WRF will be re-run for the May-June START08 episodes for 36 and 12 km nested grids that align with, and are slightly larger than, the CAMx grids shown in Figure 3. WRF will be configured to be consistent with the layer structure (Figure 2), physics options, and data assimilation inputs and specifications employed by TCEQ (Table 1), except that the modified version of the K-F cumulus parameterization will be used to support the CAMx convection model.

1.4.4.3 CAMx Evaluation

The project team will conduct a detailed evaluation of the CAMx results against ambient measurements. TAMU will develop graphical and statistical products with which to facilitate the evaluation, specifically including surface concentration measurements from the TCEQ monitoring system, and in situ concentration measurements and remotely-sensed tropospheric column profiles from the START08 and DISCOVER-AQ databases. The team will collaborate on evaluating these products and identifying any clear problems in the modeling results. Solutions will be developed to improve certain details within the CAMx CiG framework or to fix bugs or performance issues not caught during the code development and testing tasks. Additional model runs will be performed and evaluated as necessary. Particular focus will be placed on how well CAMx captures or evolves features in the profiles of NOx, ozone and other key tracers during monitored convective periods, and how the WRF/CAMx modeling system performs overall in characterizing convection and its impacts to spatial and temporal pollutant distributions.

Deliverables: Monthly and quarterly progress reports documenting evaluation results in the form of plots and tables, and discussion of technical issues and solutions.

1.4.5 Task 5: Project Reporting and Presentation

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

1.4.5.1 Executive Summary

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

Due Date: Friday, May 30, 2014

1.4.5.2 Quarterly Reports

The Quarterly Report will provide a summary of the project status for each reporting period. It will be submitted to the Project Manager as a Word doc 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.

Due Dates:

Report	Period Covered	Due Date
Quarterly Report #1	March, April, May 2014	Friday, May 30, 2014
Quarterly Report #2	June, July, August 2014	Friday, August 30, 2014
Quarterly Report #3	September, October, November 2014	Monday, December 1, 2014
Quarterly Report #4	December 2015, January & February 2015	Friday, February 27, 2015
Quarterly Report #5	March, April, May 2015	Friday, May 29, 2015
Quarterly Report #6	June, July, August 2015	Monday, August 31, 2015
Quarterly Report #7	September, October, November 2015	Monday, November 30, 2015

1.4.5.3 Technical Reports

Technical Reports will be submitted monthly to the Project Manager and TCEQ Liaison as a Word doc using the AQRP FY14-15 MTR Template found on the AQRP website.

Due Dates:

Report	Period Covered	Due Date
Technical Report #1	Project Start - May 31	Monday, June 9, 2014
Technical Report #2	June 1 - 30, 2014	Tuesday, July 8, 2014
Technical Report #3	July 1 - 31, 2014	Friday, August 8, 2014
Technical Report #4	August 1 - 31, 2014	Monday, September 8, 2014
Technical Report #5	September 1 - 30, 2014	Wednesday, October 8, 2014
Technical Report #6	October 1 - 31, 2014	Monday, November 10, 2014
Technical Report #7	November 1 - 30 2014	Monday, December 8, 2014
Technical Report #8	December 1 - 31, 2014	Thursday, January 8, 2015
Technical Report #9	January 1 - 31, 2015	Monday, February 9, 2015
Technical Report #10	February 1 - 28, 2015	Monday, March 9, 2015
Technical Report #11	March 1 - 31, 2015	Wednesday, April 8, 2015

Technical Report #12	April 1 - 28, 2015	Friday, May 8, 2015
Technical Report #13	May 1 - 31, 2015	Monday, June 8, 2015

1.4.5.4 Financial Status Reports

Financial Status Reports will be submitted monthly to the AQRP Grant Manager (Maria Stanzione) by each institution on the project using the AQRP FY14-15 FSR Template found on the AQRP website.

Due Dates:

Report	Period Covered	Due Date
FSR #1	Project Start - May 31	Monday, June 16, 2014
FSR #2	June 1 - 30, 2014	Tuesday, July 15, 2014
FSR #3	July 1 - 31, 2014	Friday, August 15, 2014
FSR #4	August 1 - 31, 2014	Monday, September 15, 2014
FSR #5	September 1 - 30, 2014	Wednesday, October 15, 2014
FSR #6	October 1 - 31, 2014	Monday, November 17, 2014
FSR #7	November 1 - 30 2014	Monday, December 15, 2014
FSR #8	December 1 - 31, 2014	Thursday, January 15, 2015
FSR #9	January 1 - 31, 2015	Monday, February 16, 2015
FSR #10	February 1 - 28, 2015	Monday, March 16, 2015
FSR #11	March 1 - 31, 2015	Wednesday, April 15, 2015
FSR #12	April 1 - 28, 2015	Friday, May 15, 2015
FSR #13	May 1 - 31, 2015	Monday, June 15, 2015
FSR #14	June 1 - 30, 2015	Wednesday, July 15, 2015
FSR #15	Final FSR	Wednesday, August 15, 2015

1.4.5.5 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. The report will be developed during the course of the work that fully documents the methodology, assumptions, and evaluation results from Tasks 1 through 4. Conclusions will include recommendations to address near-term issues associated with the new CAMx cloud treatment, as well as recommendations for longer-term research.

Due Date: Monday, May 18, 2015

1.4.5.6 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.

Due Date: Tuesday, June 30, 2015

1.4.5.7 Project Data

All project data including but not limited to QA/QC measurement data, databases, modeling inputs and outputs, etc., will be submitted to the AQRP Project Manager within 30 days of project completion. The WRF, WRFCAMx, CAMx and other pre-processor codes, associated scripts, and all input/output data and analysis products generated under Task 4 will be delivered to the AQRP and TCEQ at the completion of the project via high-volume disk media. The data will be submitted in a format that will allow AQRP or TCEQ or other outside parties to utilize the information.

1.4.5.8 AQRP Workshop

A representative from the project will present at the AQRP Workshop in June 2015. The project approach and results will be summarized in presentation format.

1.4.5.9 Journal Manuscript

After completion of the project, if warranted on the basis of our modeling results, the project team will collaborate on developing a manuscript from the project report for submission to an appropriate and mutually-agreed scientific journal. A draft will first be submitted to AQRP and TCEQ for review. A final draft will be submitted to an appropriate journal for peer review.

1.5 References

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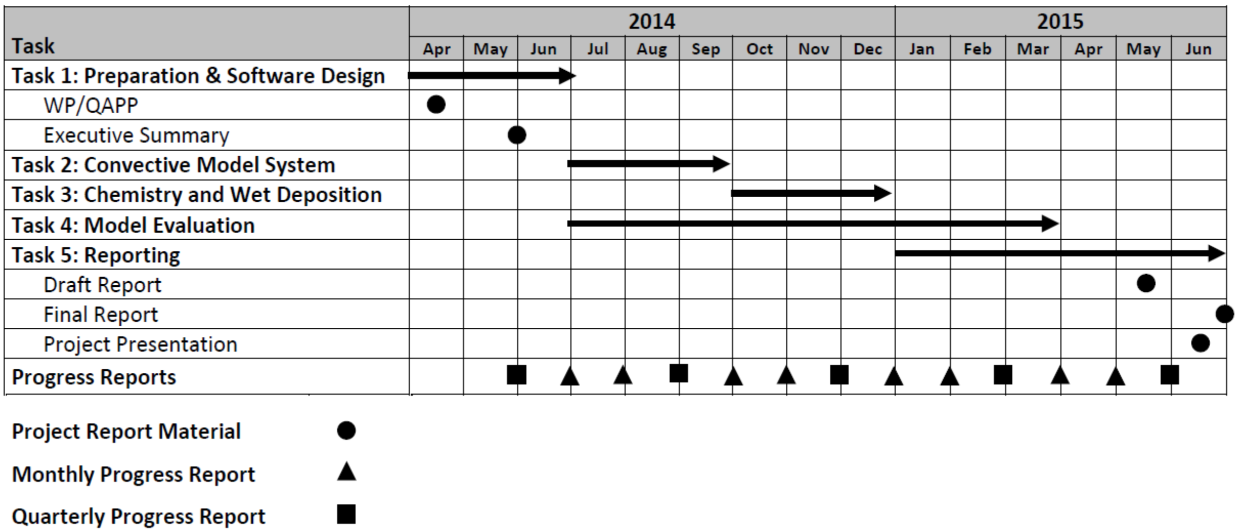
2.0 TIMELINE

The project schedule by task is presented below with associated deliverables. The project start date is assumed to be May 1, 2014. Technical work will not begin until final funding authorization by TCEQ and AQRP. The entire project is expected to be completed in 14 months with an end date of June 30, 2015.



ENVIRON and TAMU will prepare a work plan (this document) and a project Quality Assurance Project Plan (QAPP) upon contract award. Technical work will begin after TCEQ and AQRP review and approve these documents and issue final authorization of project funding. The QAPP will comply with Category III projects and EPA QA/R-5 guidance.

ENVIRON and TAMU will prepare monthly technical and financial progress reports in the format provided by AQRP. Deliverables for this project include draft and final project reports documenting all work from Tasks 1 through 4, and a project summary presentation to AQRP. Data generated for this project, including model inputs and final model outputs, will be securely archived during the project and stored for a period of at least three years following the completion of the project. All data obtained for this project will be stored in electronic format. If data are provided on paper, the paper documents will be scanned to electronic PDF files for storage. The University of Texas will receive an electronic copy of all data sets.

3.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

This project is being conducted by ENVIRON and TAMU under a grant from the Texas Air Quality Research Program. Mr. Emery of ENVIRON and Dr. John Nielsen-Gammon of TAMU will serve as co-Principal Investigators on this project with overall responsibility for the research and associated quality assurance. Other co-Principal Investigators include Dr. Bowman and Dr. Zhang of TAMU. The project will be overseen by AQRP Project Manager Mr. Gary McGaughey and TCEQ Project Liaison Dr. Khalid Al-Wali. The scientists working on this project and their specific responsibilities are listed in the Table below.

Participant	Project Responsibility
Mr. Christopher Emery (ENVIRON)	Co-Principal Investigator: project oversight; lead model design, development and testing; lead CAMx applications; lead reporting
Dr. Sue Kemball-Cook (ENVIRON)	Assistance with convective model design
Mr. Jeremiah Johnson (ENVIRON)	Code development and testing
Dr. John Nielsen-Gammon (TAMU)	Co-Principal Investigator: TAMU oversight; lead WRF meteorological modeling; reporting
Dr. Kenneth Bowman (TAMU)	Co-Principal Investigator: Model comparisons to field study data
Dr. Renyi Zhang (TAMU)	Co-Principal Investigator: CAMx application to field study periods