Scope of Work For

Project 14-017
Incorporating Space-borne Observations to Improve Biogenic Emission Estimates in Texas

Prepared for

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

by

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ABSTRACT

This proposal is in response to the call by the State of Texas Air Quality Research Program (AQRP) seeking studies to support Texas Air Quality by utilizing the data from the recent Discover-AQ field campaign. The work proposed here is a modeling study to improve our understanding of Texas Air Quality by utilizing satellite observations to improve biogenic emission estimates, surface incident short-wave radiation, and simulated clouds. The work also employs a new soil NO emissions scheme. This work specifically addresses two priority areas; namely improving biogenic emission estimates and improving the simulation of clouds in air quality models. The project also contributes to several other priority areas as the improvements in radiation field not only impacts the biogenic emissions, it also improves the overall photochemical simulation and leads to better understanding of ozone and PM formation.

The University of Alabama in Huntsville (UAH) currently generates a set of products from the Geostationary Operational Environmental Satellite (GOES) that includes surface incident short-wave radiation as well as cloud albedo and cloud top temperature. Under this proposed activity, UAH will produce the Photosynthetically Active Radiation (PAR) needed in the estimation of biogenic hydrocarbon emissions. Satellite-derived PAR will be evaluated against previous satellite-based products as well as surface observations during Texas Discover-AQ campaign. Furthermore, the new PAR retrievals will be used in MEGAN (the Model of Emissions of Gases and Aerosols from Nature) to generate biogenic volatile organic compounds (BVOC) emissions. We will also implement Berkeley-Dalhousie Soil NOx Parameterization (BDSNP) within MEGAN. BDSNP provides a more mechanistic representation of how emissions respond to nitrogen deposition, fertilizer application, and changing meteorology. A series of sensitivity simulations will be performed and evaluated against Discover-AQ observations to test the impact of satellite-derived PAR and the new soil NOx emission model on air quality simulations.

The Weather Research and Forecasting (WRF) Model and the Comprehensive Air Quality Model with Extensions (CAMx) will be targeted for air quality simulations. WRF simulations will take advantage of improved cloud simulation by applying a technique developed at UAH under a previous TCEQ funded project. The technique uses GOES cloud observations to dynamically correct cloud fields in WRF. Additionally, a modified version of CAMx that can utilize satellite-based photolysis rates will be provided to TCEQ and the other AQRP researchers for air quality simulations. This technique was also developed and implemented in CAMx by UAH under a previous TCEQ funding.

As stated in the AQRP 2012 State of the Science report, BVOCs play a critical role in formation of ozone and secondary organic aerosols in east Texas. Previous studies have shown that isoprene is the dominant BVOC in southeast Texas. However, due to high reactivity of isoprene, indirect evaluations of emissions estimates through comparing the simulated isoprene concentration with measurements have proven to be a challenging task. This proposal attempts to assimilate satellite observations that directly impact photochemical activity as well as BVOC emissions and thereby creates a simulated atmosphere that is more compatible with the measurements during Discover-AQ.

UAH will be collaborating with Rice University on this project. Arastoo Pour-Biazar and Richard McNider from UAH will be responsible for retrieval of satellite PAR, insolation, cloud albedo, and cloud top temperature. UAH team also will be performing WRF simulations. Daniel Cohan of Rice University will be responsible for implementing BDSNP in MEGAN and creating biogenic emissions estimates to be used in the modeling. Both UAH and Rice will participate in analysis of Discover-AQ data and in model evaluation tasks.

Technical Work Plan:

1 Technical Approach

One of the challenges in understanding the Texas air quality has been the uncertainties in estimating the biogenic hydrocarbon emissions (Allen et al., AQRP State of the Science 2012 report). Biogenic volatile organic compounds, BVOCs, play a critical role in atmospheric chemistry, particularly in ozone and particulate matter (PM) formation. In southeast Texas, BVOCs (mostly as isoprene) are the dominant summertime source of reactive hydrocarbon (Wiedinmyer et al., 2001). Despite significant efforts by the State of Texas in improving BVOC estimates, the errors in emissions inventories remain a concern. This is partly due to the diversity of the land use/land cover (LU/LC) over southeast Texas coupled with a complex weather pattern (Song et al., 2008), and partly due to the fact that isoprene is highly reactive and relating atmospheric observations of isoprene to the emissions source (vegetation) relies on many meteorological factors that control the emission, chemistry, and atmospheric transport.

BVOC estimates depend on LU/LC, the amount of radiation reaching the canopy (Photosynthetically Active Radiation, PAR), and temperature. There have been many efforts in developing high resolution LU/LC data sets to better represent the diversity of vegetation over the State of Texas (Wiedinmyer et al., 2001; Byun et al., 2005). However, the treatment of temperature and PAR is not uniform across emissions models and still poses a problem when evaluating the inventories. Guenther et al., 2012, argue that the largest uncertainty comes from the model solar radiation estimates and that using satellite-based PAR would be preferable.

Warneke et al., 2010, compared several BVOC emission models and showed that they agree within a factor of two. This was partly due to the differences in estimating the impact of light and temperature on emissions. Among the models used in their study, MEGAN (Model of Emissions of Gases and Aerosols from Nature) (Guenther *et al.*, 2006) produced higher estimates compared to measurements. Indirect evaluations of MEGAN by using satellite observation of formaldehyde also indicated that MEGAN over-estimates isoprene emissions (Palmer et al., 2006; Miller et al., 2008). But contrary to the above findings, a model study by Muller et al., 2008, showed that MEGAN under-estimated isoprene flux over Harvard forest site. Karl et al., 2007, also found MEGAN under-predicting isoprene flux when compared to the flux estimates derived from aircraft measurements.

This goes to show the difficulty of evaluating the estimated inventory. This difficulty is mostly due to the high reactivity of isoprene and the need to have a reasonable representation of the physical atmosphere when comparing modeled concentrations of isoprene (or related compounds) to the observations. The emissions model estimate of isoprene is highly dependent on providing the correct PAR and temperature. But, relating the observed isoprene concentration (or derived flux) to the emissions inventory also depends on the atmospheric conditions that are regulated by radiation and temperature.

Song et al., 2008, demonstrate this difficulty when they compare modeled and observed isoprene concentrations in southeast Texas. They note that the vertical gradient of isoprene is highly influenced by the effectiveness of boundary layer mixing. Due to high reactivity of isoprene, less efficient mixing in the model allows for higher surface concentration of isoprene and lower concentrations aloft. Given that the surface heating is a key factor in creating efficient mixing and increased isoprene emissions, it is crucial to correctly specify the surface incident radiation in such studies. In fact their results signified the importance of meteorology when evaluating BVOC emissions.

Therefore, to be able to use the measurements to improve the emissions inventory, it is imperative to recreate the best model representation of the atmospheric condition during the observations. The work proposed here is an attempt to achieve this objective by using geostationary satellite observations to retrieve PAR for direct use in the biogenic emissions model, correct model photolysis rates, and by improving model simulated clouds and surface incident radiation, improve the temperature field used in BVOC estimates.

Emissions from soils also remain one of the most poorly quantified sources of NO_x in most air quality models. Soils can be the largest source of NO_x in rural regions where low-NO_x conditions make ozone production efficiency especially high, contributing to background ozone levels. A new soil NO_x scheme has been developed by UC-Berkeley and Dalhousie University (Hudman *et al.*, 2012), which provides more mechanistic representation of how emissions respond to nitrogen deposition, fertilizer application, and changing meteorology. Previous studies (Hudman *et al.*, 2010; Hudman *et al.*, 2012) have shown the new scheme to more than double soil NO_x emission estimates in many regions and to greatly increase their episodic and interannual variability. We propose to use this model for soil NO estimates in this study.

University of Alabama in Huntsville (UAH) will be collaborating with Rice University on this project. UAH currently retrieves and archives several satellite products from GOES imager such as surface insolation, cloud albedo, and cloud top temperature. For this project UAH also will be using GOES Imager visible data to produce PAR. The PAR products will be evaluated against surface observations over Texas and also against satellite-based PAR previously generated by the University of Maryland (UMD) for 2006. We also will be comparing the new PAR products with model estimates to quantify model errors. We will be targeting WRF for meteorological modeling, CAMx for air quality simulations, and MEGAN for biogenic emission estimates.

MEGAN will be used to generate emissions for different input parameters. We will be testing the impact of satellite PAR vs. model PAR for different simulations and soil NOx parameterization. We will conduct WRF simulations with satellite input for August-September 2013 Discover-AQ period to test model sensitivity to these inputs. Model results will be compared to the Discover-AQ observations and the data obtained from these activities will be provided to TCEQ and other researchers for subsequent air quality simulations.

UAH also will use the techniques developed under previous TCEQ funding that will use satellite observations to improve cloud simulation in WRF and make available a version of CAMx that corrects photolysis fields based on these observations. Rice University will be responsible for biogenic emissions estimates and providing CAMx ready inputs for sensitivity simulations.

1.1 Satellite Products

Currently, UAH collaborates with the IR group at the NASA/MSFC to generate and archive several GOES derived products. The retrieval system, GOES Product Generation System (GPGS), provides routine near real-time retrievals of skin temperature, total precipitable water, cloud top temperature/pressure, cloud albedo, surface albedo and surface insolation for the use in meteorological and air quality models (Haines et al., 2003). Over the years these products have been evaluated and used in many air quality studies (Pour-Biazar et al., 2007; Mackaro et al., 2011; McNider et al., 1998; Haines et al., 2003).

The algorithm used for the retrieval of albedo and surface insolation is the implementation of Gautier et al. (1980) method complemented by the improvements from Diak and Gautier (1983). The method uses the information from GOES Imager visible channel (.52-.72 μm) at 1-km resolution, and employs a clear and a cloudy atmosphere to explain the observed upwelling radiant energy. The model applies the effects of Rayleigh scattering, ozone absorption, water vapor absorption, cloud absorption, and cloud reflection. The effects of Rayleigh scattering are modeled after Coulson (1959) and Allen (1963) for the GOES visible band (radiant flux as viewed by the satellite) and for the bulk solar flux incident at the surface. Ozone absorption is modeled after Lacis and Hansen (1974). Water vapor absorption is assumed to be negligible in both the surface and cloud albedo calculations (explaining the observed radiance in the GOES visible band), but accounted for when applying the total solar flux in the surface insolation calculation. Water vapor absorption coefficients are obtained from Paltridge (1973), and total column water vapor is assumed to be 25 mm and adjusted for solar zenith angle. Cloud absorption is assumed to be a constant 7% of the incident flux at the top of the cloud (Diak and Gautier, 1983). The products are aggregated to 4-km and archived at UAH.

Under this proposed work, UAH will use GOES visible channel observations to generate PAR. PAR is defined as:

$$PAR = \int_{.4}^{.7} I(\lambda)d\lambda \quad (W\,m^{-2}) = \frac{1}{hc}\int_{.4}^{.7} I(\lambda)d\lambda \quad (quanta\,m^{-2}s^{-1}) \qquad (1)$$

Therefore, in principal insolation can be scaled to produce PAR. This means that we can define a conversion factor (*CF*) to convert insolation to PAR:

$$CF = \frac{PAR}{Insolation} \qquad (2)$$

Frouin and Pinker, 1995 and Pinker and Laszelo, 1992, documented the dependency of such conversion factor on several relevant atmospheric parameters such as water vapor, total overhead ozone, optical depth (representing aerosol/cloud impact), and zenith angle. The largest variations are caused by water vapor, optical depth, and solar zenith angle (Figure 1).

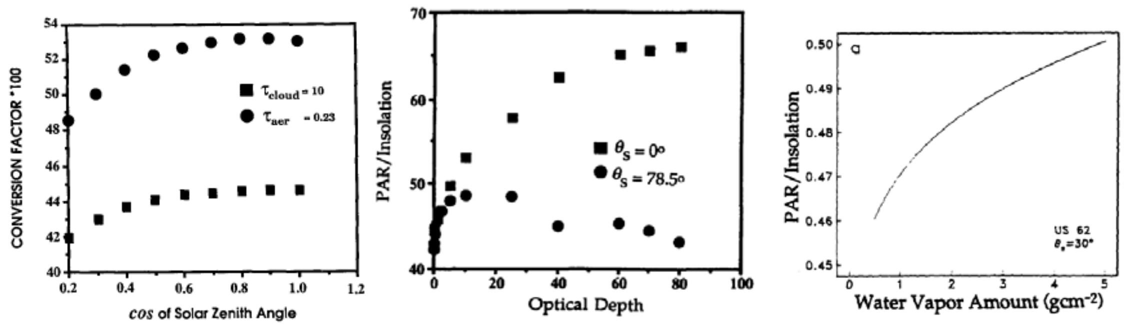


Figure 1. Variation of PAR conversion factor with respect to solar zenith angle, optical depth, and water vapor (adapted from Frouin and Pinker, 1994).

This variation is mostly due to the difference in the impact of direct and diffused light. Meaning that in the presence of water vapor and aerosols, a modest increase in diffused light increases the conversion factor when the sun is overhead. However, one must note that the largest increase in CF is when the insolation is drastically reduced (for optical depths greater than 10-15). This means that in the presence of opaque clouds, the sizeable reduction in surface incident radiation will offset such marginal increases in CF. Therefore, the practical variation of conversion factor hovers around .5. In fact many of the models used in agricultural applications use the .5 factor. A review of the MEGAN code also revealed that MEGAN uses CF=.5 when model estimates of solar radiation is used. Guenther et al., 2012, argue that the largest uncertainty comes from the model solar radiation estimates and that using satellite-based PAR would be preferable.

We propose to use a simple parameterization for calculating a variable conversion factor for generating PAR from the current insolation product at UAH. We devised the following relationship that takes into account the impact of optical depth and zenith angle on conversion factor:

$$
\begin{aligned}
&CF = \frac{PAR}{Insolation} = .48 + .17 * Cfactor * Zfactor \\
&Where \quad Cfactor = \sqrt{1-(\alpha_c - 1)^2} \\
&and \qquad \alpha_c = cloud\ albedo
\end{aligned}
\tag{3}
$$

This relationship assumes a conversion factor of .48 for a completely cloud free atmosphere. Note that in Figure 1, CF=.48 can be obtained for overhead sun when aerosol optical depth is .23. The conversion factor gradually increases for increased clouds.

Figure 2 demonstrates a preliminary attempt in estimating PAR for September 14, 2013, at 19:45 GMT. Note, that the impact of zenith angle is not considered at this time (Zfactor=1) but will be included later. As evident in the figure, for opaque clouds, PAR patterns are identical to the reductions in insolation, meaning that the increase in CF is not enough to compensate for the reduction in direct light. However, in areas with more transparent clouds PAR spatial pattern deviates from insolation as CF increase due to diffused light compensates for the loss of direct sunlight.

Under this proposal, we will be generating satellite PAR for August 2006 and August-September 2013. These periods coincide with TexAQS-2006 and Discover-AQ Texas field campaigns. University of Maryland is no longer generating satellite PAR, but their data for 2006 is available. We will be evaluating our 2006 PAR retrievals against University of Maryland retrievals as well as comparing to surface radiation observations during TexAQS-2006. PAR retrievals for 2013 will be evaluated against available surface observations during Texas Discover-AQ campaign.

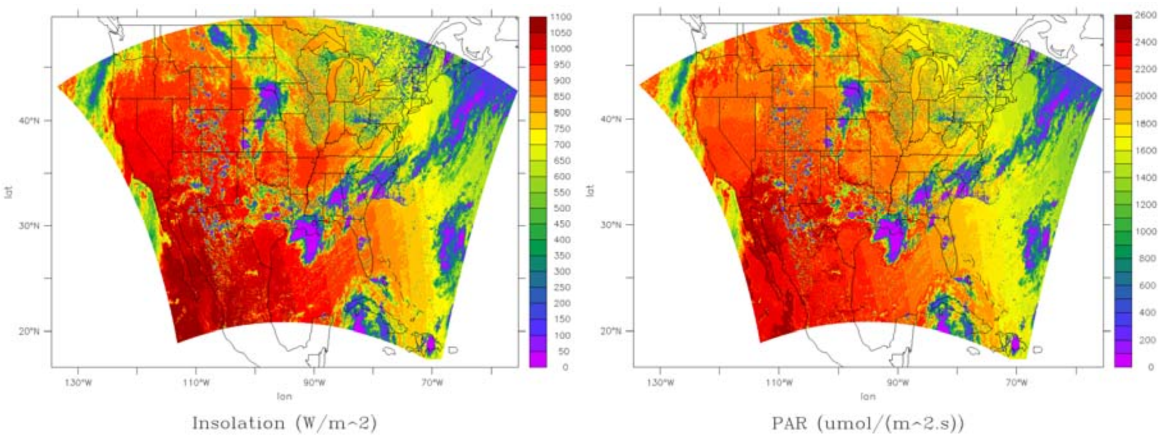


Figure 2. Satellite-derived insolation (left) and PAR (right) for September 14, 2013, at 19:45 GMT.

1.2 ***Biogenic Emissions Estimates***

TCEQ has historically simulated biogenic emissions with the Global Biosphere Emissions and Interactions System (GLOBEIS), a model based on the BEIS family of models developed by Alex Guenther and others in the 1980s and 1990s. TCEQ is now switching to MEGAN model, which applies more sophisticated algorithms to represent the responsiveness of biogenic emissions to changing conditions and which continues to be updated in ongoing model development efforts by Guenther and others. Recent modeling by TCEQ has shown MEGAN isoprene emission to provide better model performance than GLOBEIS (Mark Estes, personal communication).

MEGAN will first be applied with the WRF simulations from the episodes of interest in 2006 and with 8-day MODIS-based leaf area index data to replicate the baseline approach used by TCEQ. We will then repeat the simulations for several sensitivity scenarios in 2013. MEGAN will be applied with photosynthetically active radiation (PAR) data from two satellite-based retrievals: the product developed by Dr. Rachel Pinker of University of Maryland, and the new PAR data created by University of Alabama-Huntsville. We will also test the influence of using vegetation phenology reanalysis data (Stockli *et al.*, 2011) in place of the currently used MODIS retrievals to represent leaf area index (LAI). Modeling in the Cohan group has shown significant differences both in the magnitude and interannual variability of these LAI estimates. We will also explore the feasibility of using high-resolution land use-land cover data developed by Texas A&M for TCEQ to represent vegetation in the MEGAN runs (Popescu *et al.*, 2013). In addition, we will be taking advantage of an ongoing research under this call that will produce improved land cover and emission factor inputs for the MEGAN biogenic emission model. Upon the timely availability of such product, we will be testing the impact of this new product.

We also will implement the new Berkeley-Dalhousie soil NO scheme into MEGAN so that soil NO_x emissions can be estimated for use in the CAMx model. The implementation of this scheme in CMAQ (by Dan Cohan from Rice University) utilized its inline biogenic emissions module, which allowed nitrogen deposition within the model to influence soil NO_x emission rates. Since the approach with MEGAN will be offline, two approaches can be used to incorporate the influence of N deposition: using the deposition-influenced component of soil NO_x emissions computed in CMAQ and adding it to the MEGAN-computed components, or using N deposition fields from CAMx as inputs to the MEGAN calculations. We will also explore the influence of using temperature data from the satellite retrievals to influence the soil NO_x emission rates. All of the MEGAN estimates of biogenic VOCs and soil NO_x will be converted into a CAMx ready format and substituted for the biogenic emissions component of the base CAMx runs.

1.3 Meteorological Modeling

Clouds play a critical role in the production and destruction of pollutants and yet the models have difficulty in creating clouds in the right place and time compared to observed clouds. This is especially the case when synoptic-scale forcing is weak (e.g. Stensrud and Fritsch 1994). Weak synoptic-scale forcing is often associated with air pollution events. Errors in model cloud not only impact radiative fluxes and subsequently surface temperature and boundary layer evolution, they also alter the boundary layer photochemistry, aerosol formation and recycling, heterogeneous chemistry, and wet deposition.

Under a previous TCEQ funded project (Pour-Biazar et al., 2011) UAH has developed a technique to assimilate GOES cloud observations in the WRF model that dynamically adjusts cloud fields (Allen et al., AQRP State of the Science 2012 Report). This technique has proven to improve cloud simulation in WRF. In this project, we will be using this technique in WRF to test the sensitivity of biogenic emission estimates and air quality simulations to improved cloud simulations.

1.4 Air Quality Modeling

The Comprehensive Air Quality Model with extensions (CAMx) has been one of the preferred models in Texas for air quality simulations. Since TCEQ prefers to use CAMx for their air quality simulations, our work can benefit from TCEQ simulations during Discover-AQ. Furthermore, our results can readily be incorporated in TCEQ simulations. We will be using model inputs and model configuration similar to TCEQ setup whenever possible. We will also provide a modified version of CAMx modeling system that can benefit from GOES cloud observations.

Pour-Biazar et al., 2007, implemented a technique in CMAQ that used GOES satellite data to correct the photolysis rates. Their air quality simulations for TexAQS-2000 demonstrated alterations in ozone precursor lifetime and significant improvements in model prediction of ozone (Allen et al., AQRP State of the Science 2012 Report). Later, under another TCEQ funded project, UAH implemented a similar technique in CAMx. Recently UAH has made additional changes and has ported the technique to the newer version of CAMx with online photolysis calculation. The technique has been implemented in

CAMx-V5.32, but can easily be adapted for other versions since the modifications only impact the meteorological pre-processor (MM5CAMx). The technique uses GOES retrieved cloud albedo and cloud top temperature to derive a satellite-based cloud transmissivity. In MM5CAMx satellite-based transmissivity is converted into cloud optical depth which is part of the standard input for CAMx. Basically, the technique replaces model calculations of cloud optical depth with satellite-based optical depth. Since this work is accomplished in CAMx pre-processor, no modification to CAMx is necessary.

2 Research Experience

2.1 Participating Organizations and Key Personnel

Arastoo Pour Biazar and Richard T. McNider from the University of Alabama in Huntsville will be collaborating with Dan Cohan of Rice University to accomplish the objectives of this project. Both of these organizations have been working with the State of Texas on numerous air quality related projects. UAH investigators have been involved in both TexAQS-I and TexAQS-II field campaigns and the subsequent modeling and data analysis efforts.

Dr. Pour-Biazar , PI, started his career investigating the impact of natural sources of ozone precursors, soil and lightning NOx and hydrocarbons, on ozone formation in the southeast United States. He participated in the development of CMAQ and has since worked on utilizing satellite data in air quality models (especially for retrospective simulations). He has a long history of working with the State of Texas. As listed in the previous sections, this project will benefit from the research results that were produced by Dr. Pour-Biazar under previous funded projects by the State of Texas.

Dr. McNider, Co-I, has a long history in mesoscale modeling and air quality. He served as an air pollution meteorologist with the State of Alabama. He was one of the five principals in the Southern Oxidant Study (SOS). He has also been a leader in the use of satellite data in mesoscale models and air quality models including developing techniques for using satellites to provide photolysis and surface energy budgets. He is currently a member of NASA's Applied Science Air Quality Team.

Dr. Cohan, **Co-I**, has led numerous atmospheric modeling studies, including an AQRP study that investigated uncertainties in pollution response to emissions reductions and a NASA-funded collaboration with UAH that incorporated satellite observations of clouds and NO2 into CAMx modeling of Texas. He is a recipient of an NSF CAREER award and a member of NASA's Air Quality Applied Sciences Team.

3 Project Management, Task Descriptions, and Deliverables

Dr. Pour-Biazar from UAH will be leading this project and will be responsible for coordinating all aspects of the work. Dr. McNider will help in data analysis and model evaluation. They will be assisted by a research associate and a graduate research assistant who will be helping the team in data preparation and model simulations. Dr. Cohan will be responsible for coordinating the work performed at Rice University. He will be responsible for incorporating UC-Berkeley and Dalhousie University Soil NOx parameterization in MEGAN and performing emissions modeling and sensitivity calculations for biogenic emissions.

3.1 Task Descriptions

The following tasks will be accomplished under this project:

Task 1. Generation of Satellite-Based Photosynthetically Active Radiation:

UAH will examine the satellite data archives for August-September 2006 and 2013 (Discover-AQ field campaign) to ensure its completeness and will prepare the necessary GOES raw images for reprocessing if necessary. Retrieval codes will be developed to produce PAR. Rice University will obtain satellite-based PAR from the University of Maryland (UMD) and surface observations for 2006 to be used in evaluation efforts. This task will be accomplished within the first two months.

Deliverable 1.1: Description of the technique used in the generation of satellite-based PAR in the appropriate monthly reports as listed in section 3.2.

Deliverable Date: July 31, 2014

Task 2. Evaluation of PAR Products:

The PAR generated for August-September 2006 at UAH will be compared with the satellite-based PAR generated by the University of Maryland (UMD) for the same period. Both of these satellite-based products along with PAR generated from model simulations performed at TCEQ for 2006 will be evaluated against surface observations. The evaluation will rely on standard quantitative metrics (such as absolute/normalized bias, root mean square error (RMSE), correlation, standard deviation…) as well as graphical comparisons. First, UAH product will be compared to UMD's PAR to discern geographical differences and any overall bias. Second, both products will be compared to surface observations to determine which one is closer to the observation. UAH product has higher spatial resolution (4-km) and might be able to resolve the spatial variations better. The evaluation will focus on Texas and surrounding region (with an emphasis on east/southeast Texas) and will consider overall statistics as well as temporal variability of the two products. Based on this evaluation, we will make necessary adjustments to UAH algorithm and remove any systematic bias if any. Furthermore, UAH will generate satellite-based PAR for 2013. The data will be evaluated against surface observations during Discover-AQ. Finally, PAR generated from WRF insolation field will be compared to satellite-based PAR and surface observations for the Discover-AQ period. This task will be accomplished within 5 months from the start of project.

Deliverable 2.1: Description of the results from evaluation of satellite-based PAR in the appropriate monthly reports as listed in section 3.2. Also, the data products will be made available for TCEQ and other AQRP researchers.

Deliverable Date: October 31, 2014

Task 3. BVOC and Soil NOx Emission Estimates in MEGAN:

Rice University will implement the UC-Berkeley and Dalhousie University Soil NOx parameterization in MEGAN and will perform BVOC emissions calculations for different PAR inputs to the model and evaluate the results for 2006. Previous studies have shown that east Texas is the dominant region of the state for biogenic VOC emissions, but the spatial distribution of east Texas BVOC emission estimates has varied widely across studies and even within studies as assumptions of land use/land cover and other conditions are varied (see, for example, Figure 6 of Gulden and Yang, Atmos. Envt 2006, at http://www.geo.utexas.edu/climate/Research/Reprints/GuldenYang.pdf). Comparisons will be made based on the emissions rate per unit surface area (for example, in ug C per m2 per hour). We will quantify both how the magnitudes of emissions rates vary with different assumptions in the MEGAN biogenic model, and also how temporal and spatial heterogeneity depend on those assumptions. Different PAR inputs include model-based PAR as well as those prepared under task 2. BVOC and soil NOx emissions will be prepared in CAMx ready format for use in the air quality simulations. This task will be accomplished within the first 6 months.

Deliverable 3.1: A summary of the results from evaluation of BVOC and soil NOx emission estimates will be provided in the appropriate monthly reports as listed in section 3.2. Also, the data products will be made available for TCEQ and other AQRP researchers to be used in subsequent CAMx simulations. The modified MEGAN model will be documented for final delivery to TCEQ.
Deliverable Date: November 30, 2014

Task 4. Performing WRF Simulations:

UAH will conduct a series of WRF simulations for August-September 2013 employing satellite cloud assimilation. Two sets of simulations will be performed: a base case in which WRF will be configured similar to the TCEQ simulations and an assimilation run in which UAH technique will be employed. This task will be accomplished within 8 months from the start of the project.

Deliverable 4.1: A summary describing the results from UAH WRF simulations in the appropriate monthly reports as listed in section 3.2. Also, WRF outputs will be made available for TCEQ and other AQRP researchers.
Deliverable Date: January 31, 2015

Task 5. Emission Estimates for 2013 Simulations:

Rice University will prepare BVOC and soil NOx emissions in CAMx ready format for use in the 2013 CAMx simulations. The emissions will reflect the impact of different WRF inputs generated in task 4. We will also explore the feasibility of using high-resolution land use-land cover data developed by Texas A&M for TCEQ to represent vegetation in the MEGAN runs. In addition, we will be taking advantage of an ongoing research under this call that will produce improved land cover and emission factor inputs for the MEGAN model. Upon the timely availability of such product, we will be testing the impact of this new product. This task will be accomplished within 10 months.

Deliverable 5.1: A summary describing the new emissions estimates in the appropriate monthly reports as listed in section 3.2. Also, CAMx ready emission inputs will be made available for TCEQ and other AQRP researchers.

Deliverable Date: March 31, 2015

Task 6. Preparation of the Data and model to Be Shared:

UAH and Rice University will document and prepare the data and the modified MEGAN model from this project to be shared with other AQRP researchers and TCEQ. The documentation will serve as a metadata explaining the important aspects of each dataset. The datasets are a collection of the data generated in the previous tasks. This task will be accomplished within 11 months.

Deliverable 6.1: A summary describing this activity will be included in the appropriate monthly reports as listed in section 3.2. The metadata and data files will be included in the final deliverables.

Deliverable Date: April 30, 2015

Task 7. Evaluation, Data Analysis, and Final Report:

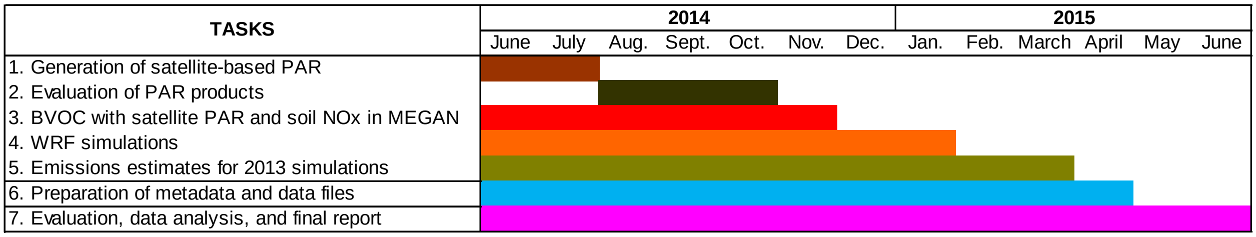
UAH and Rice will collaborate on evaluation of the modeling results against Discover-AQ data and will prepare the results for publication and the final report.

Deliverable 7.1: Draft final report, final report, modified MEGAN model and data.
Deliverable Date: Draft final report by May 18, 2015. Metadata, data, and final report by June 30, 2015.

3.2 Deliverables and Schedule

In addition to deliverables listed in the previous section, we will be adhering to the timelines for monthly and quarterly reports as indicated in the following section, the accompanying QAPP and the tables therein. The following is a graphical representation of the schedule listed in the previous section.

Schedule: The following timeline adheres to the priorities set for different tasks as described above.



3.2.1 Detailed Project Deliverables

The project software deliverable will include a new version of MEGAN that includes BDSNP and satellite PAR input options. The documentation, data, and training deliverables are described in tasks 6 and 7. The schedule for major deliverables is presented in the above table. Here we present a detailed schedule of specific tasks and associated interim reports.

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. UAH will be responsible to submit the reports for this project (as a collaborator, Rice University will not submit separate reports). However, both UAH and Rice U. will submit the Financial Status Reports (FSRs). The lead PI (Dr. Pour-Biazar) 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.

3.2.2 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

3.2.3 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	June, July, August 2014	Friday, August 30, 2014
Quarterly Report #2	September, October, November 2014	Monday, December 1, 2014
Quarterly Report #3	December 2015, January & February 2015	Friday, February 27, 2015
Quarterly Report #4	March, April, May 2015	Friday, May 29, 2015

3.2.4 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 – August 31, 2014	Monday, September 8, 2014
Technical Report #2	September 1 - 30, 2014	Wednesday, October 8, 2014
Technical Report #3	October 1 - 31, 2014	Monday, November 10, 2014
Technical Report #4	November 1 - 30 2014	Monday, December 8, 2014
Technical Report #5	December 1 - 31, 2014	Thursday, January 8, 2015
Technical Report #6	January 1 - 31, 2015	Monday, February 9, 2015
Technical Report #7	February 1 - 28, 2015	Monday, March 9, 2015
Technical Report #8	March 1 - 31, 2015	Wednesday, April 8, 2015
Technical Report #9	April 1 - 28, 2015	Friday, May 8, 2015
Technical Report #10	May 1 - 31, 2015	Monday, June 8, 2015

3.2.5 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 – August 31, 2014	Monday, September 15, 2014
FSR #2	September 1 - 30, 2014	Wednesday, October 15, 2014
FSR #3	October 1 - 31, 2014	Monday, November 17, 2014
FSR #4	November 1 - 30 2014	Monday, December 15, 2014
FSR #5	December 1 - 31, 2014	Thursday, January 15, 2015
FSR #6	January 1 - 31, 2015	Monday, February 16, 2015
FSR #7	February 1 - 28, 2015	Monday, March 16, 2015
FSR #8	March 1 - 31, 2015	Wednesday, April 15, 2015
FSR #9	April 1 - 28, 2015	Friday, May 15, 2015
FSR #10	May 1 - 31, 2015	Monday, June 15, 2015
FSR #11	June 1 - 30, 2015	Wednesday, July 15, 2015
FSR #12	Final FSR	Wednesday, August 15, 2015

3.2.6 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.

Due Date: Monday, May 18, 2015

3.2.7 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

3.2.8 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 data will be submitted in a format that will allow AQRP or TCEQ or other outside parties to utilize the information.

3.2.9 AQRP Workshop

A representative from the project will present at the AQRP Workshop in June 2015.

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