Texas Air Quality Research Program
Strategic Research Plan 2016-2017

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

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

Beginning with the 2010-2011 biennium, and continuing through the 2012-2013 and 2014-2015 biennia, the Texas Commission on Environmental Quality (TCEQ) contracted with the University of Texas at Austin to administer the AQRP. During this period, the AQRP funded more than 50 projects, which have now been completed. This Strategic Research Plan identifies high priority topics for AQRP funded research in the 2016-2017 biennium.

The fifty research projects and two science synthesis projects funded by the AQRP between 2010 and 2015 are listed in the Appendix and are described in more detail in a companion State of the Science document. Primary findings and accomplishments are summarized below, along with recommendations for future research projects. The findings and recommendations are grouped into the areas of emissions inventory development, atmospheric chemistry, meteorology and air quality modeling, and air quality field programs.

Emissions:

Despite improvements in inventory estimates over the past decade, significant discrepancies are still observed between some key estimated emissions used in air quality planning and observed emission rates. Uncertainties in emissions lead to uncertainties in air quality management decisions, and so a number of AQRP projects over the past 6 years have focused on reducing uncertainties in emission inventories, particularly focusing on emission sources that are important in Texas. As documented in the Appendix, the AQRP has funded projects on industrial flaring, industrial sources of highly reactive volatile organic compounds (HRVOCs, which include ethene, propene, butenes, and 1,3-butadiene) and aldehyde emissions, fires, and biogenic volatile organic compounds.

- *Industrial flares* Studies of flaring under controlled operating conditions have demonstrated that at low flow rates, and with low heating value gases, standard emission estimation methods may understate flare emissions if excess steam or air-assist is used. Subsequent air quality modeling demonstrated that these emissions, coupled with the temporal variability in the emissions, can lead to additional ozone formation both locally and over large spatial scales. To reduce these emissions, AQRP studies indicate that minimum levels of steam or air assist, which comply with the flare manufacturer's recommendations, should be used when possible. Further development of remote sensing technologies, which have been assessed in AQRP projects, such as Passive Active Fourier Transform Infrared Spectroscopy and Multivariate Image Analysis, may offer approaches for improving the detection, monitoring, and evaluation of flare operational conditions in the future (AQRP Project 10-009). Parallel projects on flaring, funded by the TCEQ, developed operator training packages to document best flaring practices.

- *Industrial sources of HRVOCs and aldehydes* Aircraft and remote sensing measurements in the Houston Ship Channel and Texas City indicate that HRVOC emissions have decreased compared to emissions observed in the 2000 Texas Air Quality Study, but that emissions still exceed inventory estimates. Mobile ground-based measurements, as well as aircraft based measurements, suggest that both continuous and episodic emissions of HRVOCs continue to contribute to ozone formation (AQRP Projects 10-006, 10-045, 14-020, 14-026). Data emerging from the DISCOVER-AQ field program, conducted in Houston in 2013, is providing some quantification of temporal variability in emission sources and the extent of emission events, but the size and frequency of emission events and the temporal variability in HRVOC emissions remains a significant area of uncertainty. Direct (primary) industrial emissions of aldehydes, especially formaldehyde, also remain uncertain. Focused efforts have led to the identification and quantification of some primary formaldehyde emission sources, such as flares and certain refinery operations (AQRP Project 10-045), however, even when these sources are identified, they are generally episodic in nature and of uncertain frequency. Most of the ambient formaldehyde and acetaldehyde observed during ozone episodes in southeast Texas is secondary (formed due to atmospheric reactions, often from HRVOCs), however, the primary fraction can be significant on an episodic basis (AQRP Projects 14-002, 14-004).

- *Fires* Wildland fires and open burning can be substantial sources of ozone precursors and particulate matter in Texas. AQRP projects (12-018, 14-011) have compared the fire emission estimates from widely used emission estimation tools, and assessed the sensitivity of the estimates to key input parameters. The analyses indicate the need to improve land cover characterization, burned area estimation, fuel loadings, and emissions factors. These needs were particularly pronounced in areas with agricultural burning. Ongoing work by AQRP is using data products from U.S. and European satellite missions as well as crop data from the US Department of Agriculture to make targeted model improvements.

- *Biogenic volatile organic compounds* On a global scale, biogenic hydrocarbon emissions (primarily isoprene and monoterpenes) are among the largest sources of volatile organic compound emissions to the atmosphere, and these compounds are highly reactive. In the eastern half of Texas, biogenic emissions can have a significant impact on air quality. Texas ranked first in state-wide biogenic hydrocarbon emissions within the continental United States (data from the 2011 National Emission Inventory). Even in urban areas, biogenic hydrocarbon emissions can be significant, with an estimated 29% and 40% of the total VOC inventories in the Dallas/Fort Worth and Houston/Galveston/Brazoria ozone nonattainment areas attributed to biogenics. Understanding the roles of biogenic hydrocarbon emissions in tropospheric ozone and organic aerosol formation has been a topic of multiple AQRP projects and improvements in inventories have been made (AQRP Projects 14-003, 14-008, 14-016, 14-017, 14-030), especially concerning the spatial distribution of the emissions. Nevertheless, significant uncertainties remain, particularly with respect to the absolute magnitude of the emissions and the response of the emissions to changes in plant stress (e.g., water and heat stress). Critical data gaps persist for information important in estimating biogenic emissions (e.g., soil moisture data). Focused data collection is still needed, particularly in regions where biogenics have the greatest impact on ozone and particulate matter formation and accumulation (e.g., rural regions with NOx sources and urban regions that are NOx rich).

Recommendations for future emission inventory research AQRP projects have improved emission inventories for industrial flaring, industrial sources of HRVOC and aldehyde emissions, fires, and biogenic volatile organic compounds. Improvements continue to be needed in many of these emission categories, including topics such as reconciliation of existing and emerging satellite-based products and ground reports for fire detection, understanding the magnitude, frequency and causes of flaring emission events, and the ability of biogenic emission estimation tools to better predict emissions of monoterpenes and to better predict responses to short- and long-term drought stress.

A source category that has received significant attention in other TCEQ and private sector initiatives, but not yet in AQRP projects, is oil and gas production. A growing body of evidence indicates that within this diverse source category, there is great variability in emissions from site to site and over time, as production varies and regulations evolve. Several recent studies have focused on hydrocarbon emissions from the oil and gas supply chain, with NOx sources receiving comparatively little attention. Modeling analyses suggest that NOx emissions from oil and gas production in rural regions with high biogenic emissions may be particularly important in ozone formation in Texas and reducing the uncertainties in these emissions should be a focal point for additional research. An additional uncertainty is the performance of flares used in oil and gas production.

Other source categories that are significant in Texas, but that have not yet been the focus of AQRP projects, are on-road and off-road emissions. While much research has already been done on this topic, the recent implementation of new air quality modeling approaches and tools for these sources (e.g., MOVES; models for off-road sources) suggests the need for evaluating the performance of on-road and off-road portions of emission inventories under Texas conditions.

Chemistry:

Atmospheric chemistry in Texas has a number of unique features. The combinations of industrial and urban emissions, and forested and coastal environments, cause certain chemical pathways to become more significant in Texas than in other regions. Specific findings arising from the AQRP program that address ozone formation under Texas conditions include:

- Highly Reactive Volatile Organic Compounds (HRVOCs, ethene, propene, butenes, and 1,3-butadiene) contribute significantly to atmospheric reactivity in Texas air sheds where petroleum refining and chemical manufacturing is significant. With support by AQRP, chemical reaction mechanisms used in photochemical models have been modified to explicitly account for HRVOC reactions and reaction products (AQRP Projects 12-006, 14-026). This has allowed both more accurate understanding of the role of HRVOCs in ozone formation (AQRP Project 14-002) and improvements in the ability to track HRVOC emissions and reactions using unique photochemical reaction products.
- Field studies in southeast Texas (during TEXAQS-II) have demonstrated that certain oxides of nitrogen can react with atmospheric particulate matter containing chloride (for example, from sea salt) to form nitryl chloride. Nitryl chloride can affect tropospheric oxidation capacity and ozone formation in coastal and inland regions. Representation of the chemistry of nitryl chloride formation in CAMx has been implemented and chlorine/chloride sources have been characterized for Texas emissions inventories (AQRP Project 10-015).
- Volatile organic compounds can remove NO_x by forming NO_x reservoir compounds that reduce the availability of NO_x for ozone formation. These NO_x reservoir species may eventually react to return NO_x back to the atmosphere, in a process known as NO_x recycling, potentially causing additional ozone production in NO_x-limited regions. Novel experimental data, describing the NO_x sinks for aromatics and isoprene and NO_x-recycling from photolysis of alkyl nitrates and nitro-cresols, have been obtained and used to develop a revised version of chemical mechanisms (AQRP Projects 10-042, 12-012).
- Recent measurements have indicated that daytime observed HONO mixing ratios are often far larger than the expected photo-stationary state with OH and NO in Houston and other locations throughout the world. Statistically significant vertical gradients of HONO throughout the day, with smaller mixing ratios aloft, have suggested that a likely source of daytime HONO could be photocatalytic conversion of NO_2 on the ground. Although daytime mechanisms for HONO formation have been a subject of exploration, it is evident uncertainty remains (AQRP Project 12-028).

Recommendations for future atmospheric chemistry research Most AQRP projects have focused on gas phase chemistry that influences ozone formation. Increasingly, however, scientific evidence suggests that gas-particle interactions can influence ozone formation, and these chemistries are, in general, poorly understood. In addition to continuing to improve understanding of gas phase chemistry, future AQRP projects could focus on chemistries involving fine particulate matter interactions with gas phase chemistry, and partitioning of species between gas and particle phases with and without chemical reactions (e.g., intermediate volatility organic compounds). In addition, a variety of halogen chemistries have been shown to be important in Texas, but uncertainties remain in understanding their contribution to ozone formation.

Meteorology and Air Quality Modeling

Photochemical air quality models take data on meteorology and emissions, couple the data with descriptions of the physical and chemical processes that occur in the atmosphere, and mathematically and numerically process the information to yield predictions of air pollutant concentrations. The models provide predictions of air pollutant concentrations in a gridded representation of the area being modeled, where the grid cells are typically no smaller than 1 to 4 km by 1 to 4 km in horizontal dimension. The models are used to quantitatively assess the potential effectiveness of air quality management strategies. Model performance is assessed by comparing model predictions of pollutant concentrations to ambient data. In Texas, modeling used to assess regulatory strategies has often focused on periods during which large air quality field studies have been conducted. This has allowed for robust model performance evaluations, using measurements that are not routinely available.

AQRP projects directed at improving model performance have focused on improving the description of emissions and atmospheric chemistry (described in previous sections), models of physical pollutant loss mechanisms, as well as improvements in cloud characterizations, cloud processes, and models of wind fields.

- The production, transport, and fate of tropospheric ozone are highly dynamic processes with contributions from a multitude of anthropogenic and natural sources spanning spatial scales from local to global. Regional models used for regulatory assessments now routinely address worldwide contributions by deriving chemical boundary conditions from global models. The TCEQ uses the Comprehensive Air Quality Model with extensions (CAMx) for research and regulatory photochemical modeling. Assessments of the coupling of CAMx to multiple global models, including GEOS-Chem, MOZART, and AM3, to provide chemical boundary conditions for its continental-scale grid system have been conducted. Continued evaluation of processes involved in the formation and transport of ozone and the performance of evolving global models will be highly relevant to air quality management and planning in the state.

- The most important loss mechanism for air pollutants in Texas is deposition of pollutants onto surfaces. The AQRP has funded research on the magnitude of losses to building surfaces (AQRP Project 10-021), and parallel research, funded from other sources, has examined the effect of drought on the loss of pollutants to leaf surfaces. This research has demonstrated that accurate quantification of deposition losses is important in accounting for air pollutant persistence and fate in Texas, but the work is frustrated by an almost complete lack of measurements of dry deposition rates. Comprehensive field programs aimed at measuring deposition are beyond the scope of AQRP funding, but strategic and targeted measurement campaigns could help reduce uncertainties on this important set of processes.

- Meteorological simulations in support of air quality modeling must capture both large-scale and local atmospheric circulation features. Observational studies that utilize output from national-scale models are currently being used to investigate the large-scale circulation patterns most common when high ozone concentrations are measured in eastern Texas (AQRP Project 14-010). Because large-scale influences are often weak during conditions of poor air quality, the potential impacts from local-scale circulations (such as terrain flows, sea/land breezes, nocturnal jets) become especially important. These local phenomena can be highly sensitive to processes that affect the development of the planetary boundary layer, including land/atmosphere interactions. AQRP has supported studies using the Weather Research and Forecasting model (WRF) to diagnose and evaluate the impact of simulated fluxes of heat, moisture, and momentum between the ground surface and lower atmosphere on predictions of low-level winds (AQRP Project 12-TN1).

- Clouds play important roles in a number of atmospheric processes, notably attenuation of solar radiation, vertical mixing and aqueous chemistry. Locating the position of clouds and the extent of cloud cover is therefore important and the AQRP has funded the development of modeling tools that allow cloud processes to be modeled when a grid cell is partially cloud covered (neither completely clear nor completely cloud covered). These cloud in grid (CiG) tools are currently being tested (AQRP Project 14-025).

Recommendations for future meteorology and air quality modeling research Future work on air quality meteorology should extend current projects on the treatment of clouds and solar radiation, boundary layer dynamics, and simulation of winds in state-of-the-science meteorological models.

In air quality modeling, research continues to be needed on the performance of land surface models used in air quality models. Differences in the structures and physics employed in various land surface models should be investigated and model performance should be evaluated against emerging data, such as soil moisture observations. Continued research is also needed on how global chemical transport models can best be used to predict boundary conditions in regional photochemical models and to predict international transport of air pollutants.

Finally, a new research area for the AQRP could be the development of photochemical model performance evaluation tools and diagnostic tools for identifying causes of model over- or under-predictions.

Air Quality Field Studies

One of the ways in which air quality models are improved is by collecting detailed field measurements that can be used to evaluate the performance of the air quality models. Prior to 2010, large field measurement campaigns in the state were primarily focused on southeast Texas. In 2010-2012, a field measurement program in the Barnett Shale oil and gas production region, near Dallas-Fort Worth, was funded by AQRP (AQRP Projects 10-DFW, 11-DFW, 10-024, 10-034, 10-044). The measurements led to a number of significant findings and insights. In 2013, field studies returned to southeast Texas and AQRP researchers participated in the Houston measurement campaign of NASA's DISCOVER-AQ program (AQRP Projects 12-004, 13-005, 13-016, 13-022, 13-024, 12-032, 14-002, 14-004, 14-005, 14-006, 14-007, 14-009, 14-014, 14-020, 14-024, 14-026, 14-029), continuing to improve scientific understanding of emissions and chemistry in that region.

- Aircraft flights over portions of the Barnett Shale did not find enhancements in ozone concentrations clearly associated with oil and gas emissions. The Measurement of Ozone Production Sensor (MOPS) indicated that the air masses in the Barnett Shale had relatively low potential ozone productivities, compared to measurements in nearby DFW urban/suburban locations. While low overall ozone productivities were observed in the Barnett Shale oil and gas production region, on some occasions, elevated concentrations of reactive alkenes (up to 10 ppbv) and formaldehyde (4-6 ppbv compared to background concentrations of 2-3 ppbv) were measured over the Barnett Shale (AQRP Projects 10-034, 10-044).

- The largest point sources of methane and other hydrocarbon species at oil and gas locations near Fort Worth were gas treatment facilities combined with large compressor stations. Emissions were an order of magnitude lower from smaller compressor stations and single well pads; however, collectively, the large number of well pads constitutes a significant source and this source can be intermittent. Hydrocarbon emissions as high as 150 kg/hr from a condensate tank were estimated, suggesting further study for this potentially important intermittent source. More recent field studies of hydrocarbon emission sources in the Barnett Shale have confirmed that a relatively small proportion of oil and gas sites (high emitting well pads, gas compression and treatment) contribute a majority of the emissions, and that the emissions from these large sources can be intermittent (AQRP Project 10-024).

In addition to field measurements, AQRP projects also included data analysis of previously conducted field programs. Among these were flights examining the long range transport, overnight, of urban, industrial and power plant plumes. Results from laboratory and field studies of pollutant loss mechanisms (dry deposition) were also incorporated into air quality models.

- Overnight transport of plumes from urban, petrochemical, and coal-fired power plant plumes can affect regional air quality the following day. Aircraft flights in the Houston area have shown NO_3 to be 3 to 5 times more important than O_3 as a nighttime oxidant of VOCs. Net NO_3 radical productions rates can be large (1–2 ppbv h^{-1}) within NO_x-containing plumes of industrial origin from Houston. Nighttime NO_x loss through N_2O_5 heterogeneous uptake is modest, but should be an area of continued study (AQRP Project 10-020).

- Analysis of nighttime aircraft intercepts from two different Texas power plants resulted in improvements to the plume-in-grid formulation in CAMx version 5.40, released in October 2011. Plume-in-grid puff growth rates were modified to ignore growth contributions from horizontal and vertical shear during stable/nighttime conditions. Shear effects remain during neutral/unstable/daytime conditions. Minimum limits on vertical diffusivity, turbulent flux moments, and nighttime planetary boundary layer depths were reduced. With these improvements, plume-in-grid puff behavior will change potentially significantly at night and above the boundary layer, usually leading to longer lifetimes (AQRP Project 10-020).

- The heterogeneity of the urban environment is typically not represented in the dry deposition algorithms used for photochemical modeling. Refined characterization of the urban built environment on the dry deposition of ozone in Austin, Texas resulted in decreases in predicted daily maximum 8-hour average ozone concentrations of 0.2 to 1.3 ppb. The results were primarily attributed to deposition to urban vegetation and highlighted the importance of characterizing Texas urban landscapes undergoing rapid development (AQRP Project 10-021).

Recommendations for future air quality field studies Highly successful air quality field campaigns have focused on the Houston and Dallas-Fort Worth metropolitan areas; Central Texas, in particular San Antonio and Austin, face new challenges associated with activities in the Eagle Ford Shale, continued population growth, land use/land cover change, congestion, and more stringent federal ozone standards, and could be the focus of future larger-scale campaigns.

Additional field studies could also focus on land surface characterization and land-atmosphere exchanges in eastern Texas under varying climatic conditions. These field studies might include long-term ecosystem-level measurements of biogenic emissions, measurement of dry deposition velocities/fluxes, and land cover and fire fuel validation to support fire emissions estimates.

Finally, additional field study activities funded by the AQRP could focus on assessing new technologies for monitoring emissions and atmospheric chemistry, with an emphasis on miniaturized pollutant sensors, drone technology, infrared imaging, and active and passive remote sensing, as well as strategically augmenting future air quality measurement studies in Texas that are largely funded by other organizations.

Research Priorities

This strategic research plan has identified multiple topics for future AQRP research; the following topics will be emphasized in the 2016-2017 biennium, based on their relevancy to air quality management in Texas:

- An overall research need that crosses many individual research areas is improving the understanding of ozone and particulate matter (PM) formation, the interaction of ozone and PM precursors, and quantifying the characteristics of emissions of ozone and PM precursors through analysis of data collected during air quality field studies conducted in Texas.
- Investigating global, international, and regional transport of pollutants (both inter- and intra-state) using data and modeling analyses. These analyses could be used to establish baselines and examine deviations from those baselines, so that high concentration events originating outside of Texas (e.g., wildfires) could be identified and quantified.
- Investigating emissions of non-methane hydrocarbons (NMHC), nitrogen oxides (NOx), and radical precursors from on-road and area sources using data from mobile monitoring, aircraft measurements during field campaigns, satellite data, and routine monitoring, and comparisons to modeling estimates of these emissions. On-road emission projects should focus on the accuracy of current MOVES emission estimates. Area source projects should focus on source types that potentially emit significant NOx, HRVOC, or radical precursors and have not been extensively monitored or evaluated to date. The studies should aim at quantifying all emissions from a source category, rather than simply identifying high emitters. Analyses could include long-term trend analyses of tracer species ratios, recent on-road monitoring, remote sensing results, and/or near-roadway monitoring.
- Performing sensitivity analyses of photochemical grid modeling to diagnose and quantify the impacts of different sources of uncertainty. These sources of uncertainty could include, but are not limited to, emissions, the treatment of atmospheric physical processes such as deposition, the treatment of atmospheric chemical processes such as condensed photochemical models, and the treatment of meteorology such as land surface interactions. The purpose of these sensitivity analyses will be to help decide which modeling issues to solve first and could include the development of model performance analysis tools.
- Incorporating biogenic emission findings from previous Texas projects into a version of a biogenic model appropriate for Texas air quality applications.
- Improving the simulation of clouds in air quality modeling, especially sub-grid-scale convective clouds.
- Assessing new technologies for monitoring emissions and atmospheric chemistry, with emphasis upon miniaturized pollutant sensors, drone technology, infrared imaging, and active and passive remote sensing.
- Analyzing Houston-area HRVOC and radical precursor measurements in an effort to create top-down emissions estimates suitable for air quality modeling. Analyses of emission magnitudes, temporal variations, and the locations of the most-frequently-occurring high emission rates are of particular interest.
- Investigating land surface modeling and the most effective methods for incorporating these models into air quality modeling.
- Quantifying the local ozone production that impacts the design value (DV) monitors in *any* Texas areas that exceed the NAAQS (based on current DVs; see design values in Appendix). The studies can include new measurements, and analysis of existing data.

Appendix

AQRP Research Projects 2010-2015

The projects are listed, by category, in the Table below. Full project reports are available at the AQRP web site (http://aqrp.ceer.utexas.edu/reports.cfm).

Project Number	Title
	Dallas-Fort Worth Area Studies
10-DFW, 11-DFW	Logistical Support for Dallas-Fort Worth (Barnett Shale) Measurement Study
10-024	Surface Measurements and One-Dimensional Modeling Related to Ozone Formation in the Suburban Dallas-Fort Worth Area
10-034	Dallas Measurements of Ozone Production
10-044	Airborne Measurements to Investigate Ozone Production and Transport in the Dallas/Fort Worth (DFW) Area During the 2011 Ozone Season
	Houston Area Studies
10-032	SHARP Data Analysis: Radical Budget and Ozone Production
10-045	Quantification of Hydrocarbon, NOx and SO_2 Emissions from Petrochemical Facilities in Houston: Interpretation of the 2009 FLAIR Dataset
12-013	Development of Transformation Rate of SO_2 to Sulfate for the Houston Ship Channel using the TexAQS 2006 Field Study Data
14-010	Impact of large-scale circulation patterns on surface ozone concentrations in HGB
	DISCOVER-AQ (Houston measurement campaign) Studies
12-004	Logistical Support for DICOVER-AQ Measurement Study
13-005	Quantification of industrial emissions of VOCs, NO_2 and SO_2 by SOF and mobile DOAS during DISCOVER AQ
13-016	Ozonesonde launches from the University of Houston and Smith Point, Texas in Support of DISCOVER AQ
13-022	Surface Measurements of PM, VOCs, and Photochemically Relevant Gases in Support of DISCOVER-AQ
13-024	Surface Measurement of Trace Gases in Support of DISCOVER-AQ in Houston in Summer 2013
12-032	Collect, Analyze, and Archive Filters at two DISCOVER-AQ Houston Focus Areas
14-002	Analysis of Airborne Formaldehyde Data Over Houston Texas Acquired During the 2013 DISCOVER-AQ and SEAC4RS Campaigns
14-004	Emission Source region contributions to a high surface ozone episode during DISCOVER-AQ
14-005	Sources and Properties of Atmospheric Aerosol in Texas: DISCOVER-AQ Measurements and Validation
14-006	Characterization of Boundary-Layer Meteorology during DISCOVER-AQ Using Radar Wind Profiler and Balloon Sounding Measurements
14-007	Improved Analysis of VOC, NO_2, SO_2 and HCHO data from SOF, mobile DOAS and MW-DOAS during DISCOVER-AQ

14-009	Analysis of Surface Particulate Matter and Trace Gas Data Generated during the Houston Operations of DISCOVER-AQ
14-014	Constraining NO_X Emissions Using Satellite NO_2 and HCHO Column Measurements over Southeast Texas
14-020	Analysis of Ozone Formation Sensitivity in Houston Using the Data Collected during DISCOVER-AQ and SEAC4RS
14-024	Sources of Organic Particulate Matter in Houston: Evidence from DISCOVER-AQ Data, Modeling and Experiments
14-026	Quantifying ozone production from light alkenes using novel measurements of hydroxynitrate reaction products in Houston during the NASA SEAC4RS project
14-029	Spatial and temporal resolution of primary and secondary particulate matter in Houston during DISCOVER-AQ
Flares and Emission Inventories	
10-006	Quantification of Industrial Emissions of VOCs, NO_2 and SO_2 by SOF and Mobile DOAS
10-009	Additional Flare Test Days for TCEQ Comprehensive Flare Study
10-022	Development of Speciated Industrial Flare Emission Inventories for Air Quality Modeling in Texas
12-011	Investigation of Global Modeling and Lightning NOx Emissions as Sources of Regional Background Ozone in Texas
12-018	The Effects of Uncertainties in Fire Emissions Estimates on Predictions of Texas Air Quality
14-011	Targeted Improvements in the Fire Inventory from NCAR (FINN) Model for Texas Air Quality Planning
14-023	Assessment of Two Remote Sensing Technologies to Control Flare Performance
Emissions and Chemistry of Biogenic Volatile Organic Compounds	
14-003	Update and evaluation of model algorithms needed to predict Particulate Matter from Isoprene
14-008	Investigation of Input Parameters for Biogenic Emissions Modeling in Texas during Drought Years
14-016	Improved Land Cover and Emission Factor Inputs for Estimating Biogenic Isoprene and Monoterpene Emissions for Texas Air Quality Simulations
14-017	Incorporating Space-borne Observations to Improve Biogenic Emission Estimates in Texas
14-030	Improving Modeled Biogenic Isoprene Emissions under Drought Conditions and Evaluating Their Impact on Ozone Formation
Modeling and Atmospheric Chemistry	
10-008	Factors Influencing Ozone-Precursor Response in Texas Attainment Modeling
10-015	An Assessment of Nitryl Chloride Formation Chemistry and its Importance in Ozone Non-Attainment Areas in Texas
10-020	NOx Reactions and Transport in Nighttime Plumes and Impact on Next-Day Ozone
10-021	Dry Deposition of Ozone to Built Environment Surfaces
10-029	Wind Modeling Improvements with the Ensemble Kalman Filter
10-042	Environmental Chamber Experiments to Evaluate NOx Sinks and Recycling in Atmospheric Chemical Mechanisms

12-006	Environmental chamber experiments and CMAQ modeling to improve mechanisms to model ozone formation from HRVOCs
12-012	Interactions Between Organic Aerosol and NOy: Influence on Oxidant Production
12-028	Implementation and evaluation of new HONO mechanisms in a 3-D Chemical Transport Model for Spring 2009 in Houston
12-TN1	Investigation of surface layer parameterization of the WRF model and its impact on the observed nocturnal wind speed bias
12-TN2	Development of IDL-based geospatial data processing framework for meteorology and air quality modeling
14-022	Use of satellite data to improve specifications of land surface parameters
14-025	Development and Evaluation of an Interactive Sub-Grid Cloud Framework for the CAMx Photochemical Model
State of the Science Evaluations	
10-SSA	State of the Science Synthesis, 2012
	State of the Science Synthesis, 2015

2015 Ozone Design Value
by County by Monitoring Site

County	FIPS	CBSA	Monitoring Site	MonDV
Denton	121	Dallas—Fort Worth—Arlington	Denton Airport South C56/A163/X157	83
Tarrant	439	Dallas—Fort Worth—Arlington	Ft. Worth Northwest C13/AH302	80
Brazoria	039	Houston—the Woodlands—Sugarland	Manvel Croix Park C84	80
Denton	121	Dallas—Fort Worth—Arlington	Pilot Point C1032	79
Harris	201	Houston—the Woodlands—Sugarland	Houston Aldine C8/AF108/X150	79
Tarrant	439	Dallas—Fort Worth—Arlington	Grapevine Fairway C70/A301/X182	78
Harris	201	Houston—the Woodlands—Sugarland	Lang C408	78
Bexar	029	San Antonio—New Braunfels	Camp Bullis C58	78
Harris	201	Houston—the Woodlands—Sugarland	Park Place C416	77
Collin	085	Dallas—Fort Worth—Arlington	Frisco C31/C680	76
Tarrant	439	Dallas—Fort Worth—Arlington	Eagle Mountain Lake C75	76
Tarrant	439	Dallas—Fort Worth—Arlington	Keller C17	76
Harris	201	Houston—the Woodlands—Sugarland	Houston Bayland Park C53/A146	76
Dallas	113	Dallas—Fort Worth—Arlington	Dallas Hinton St. C401/C60/AH161	75
Dallas	113	Dallas—Fort Worth—Arlington	Dallas North No.2 C63/C679	75
Parker	367	Dallas—Fort Worth—Arlington	Parker County C76	75
Harris	201	Houston—the Woodlands—Sugarland	Houston Croquet C409	75
Harris	201	Houston—the Woodlands—Sugarland	Houston Westhollow C410	75
Harris	201	Houston—the Woodlands—Sugarland	Houston East C1/G316	74
Bexar	029	San Antonio—New Braunfels	San Antonio Northwest C23	74
Hood	221	Dallas—Fort Worth—Arlington	Granbury C73/C681	73
Johnson	251	Dallas—Fort Worth—Arlington	Cleburne Airport C77/C682	73
Galveston	167	Houston—the Woodlands—Sugarland	Galveston 99th St. C1034/A320/X183	73
Harris	201	Houston—the Woodlands—Sugarland	Northwest Harris Co. C26/A110/X154	73
Montgomery	339	Houston—the Woodlands—Sugarland	Conroe Relocated C78/A321	73
El Paso	141	El Paso	El Paso UTEP C12/A125/X151	71
Harris	201	Houston—the Woodlands—Sugarland	Houston Texas Avenue C411	71
Harris	201	Houston—the Woodlands—Sugarland	Seabrook Friendship Park C45	71
Rockwall	397	Dallas—Fort Worth—Arlington	Rockwall Heath C69	70
Harris	201	Houston—the Woodlands—Sugarland	Houston Monroe C406	70
Harris	201	Houston—the Woodlands—Sugarland	Houston North Wayside C405	70
Harris	201	Houston—the Woodlands—Sugarland	Clinton C403/C304/AH113	69
Harris	201	Houston—the Woodlands—Sugarland	Hou.DeerPrk2 C35/235/1001/AFH139FP239	69
Bell	027	Killeen-Temple	Killeen Skylark Field C1047	69
Dallas	113	Dallas—Fort Worth—Arlington	Dallas Executive Airport C402	68
Ellis	139	Dallas—Fort Worth—Arlington	Midlothian OFW C52/A137	68
El Paso	141	El Paso	Skyline Park C72	68
Harris	201	Houston—the Woodlands—Sugarland	Baytown Garth C1017	68
Harris	201	Houston—the Woodlands—Sugarland	Channelview C15/AH115	68
Gregg	183	Longview	Longview C19/A127/C644	68
Travis	453	Austin—Round Rock	Audubon C38	68
Travis	453	Austin—Round Rock	Austin Northwest C3/A322	68
Jefferson	245	Beaumont—Port Arthur	Nederland High School C1035	68