

Air Toxics Exposure

ATE-1: Personal Exposure Monitoring

(Estimated Cost: \$300,000; Duration: 1 yr)

The RIOPA ("Relationship Among Indoor, Outdoor, and Personal Air Concentrations") study is a research project funded by the Environmental and Occupational Health Sciences Institute, the aim of which is to investigate the correlation between outdoor, indoor (home, in-vehicle, school, office), and personal exposures to PM_{2.5} and toxic air compounds. RIOPA spans 12 cities, including Houston, and is a comprehensive exposure assessment of households across microenvironments and times of day (time-activity patterns), sources (natural and human), and natural variability (meteorology and topography). This project will complement the RIOPA study by focusing on near-source exposure in a specific neighborhood (e.g., Milby Park) in the Houston Ship Channel, whereas RIOPA focuses on broader scale exposures. The goal is to provide data for the development and evaluation of appropriate modeling tools to quantify human exposure to air toxics and PM_{2.5} on neighborhood scales. The project will deploy portable Personal Exposure Monitors (PEMs) to measure both PM_{2.5} and Hazardous Air Pollutant VOC concentrations in both indoor and outdoor microenvironments over a one-year period. The PEMs will be carried by a representative selection of members of appropriate census tracts in the Houston Ship Channel. Volunteers will record their activities in diaries, and the information used to deduce human exposure as a function of microenvironment and time of day during several days of the 2006 TexAQS II intensive. Other data from the field study intensive will be used along with the PEM data to support human exposure modeling, data analysis, and interpretation. The study will enhance the usefulness of the extensive fixed-site ambient measurements in the Houston area by correlating the fixed-site measurements with personal exposure measurements. If the averaging time differences can be normalized, the results will also provide an understanding of the mathematical relationship between ambient measurements and personal measurements.

Proposed by: NUATRC, HARC (co-funding)

Contractor: To be determined

ATE-2: Human Exposure Modeling

(Estimated Cost: \$150,000; Duration: 1 yr)

This project will deploy a contemporary human exposure model such as APEX in conjunction with an appropriate neighborhood scale dispersion model to simulate ambient concentrations of and human exposure to moderately reactive air toxics (so as not to require a sophisticated model chemical mechanism) during the 2006 TexAQS II intensive. Possible neighborhood scale model approaches include semi-empirical meteorological models based on SODAR measurements of wind turbulence, explicit Computational Fluid Dynamics (CFD) models, and Large Eddy Scale prognostic meteorological models. The results of the human exposure model will then be evaluated by comparing the predictions with data from both the RIOPA project and the PEM project described above.

Proposed by: HARC

Contractor: To be determined

ATE-3: Evaluation of Air Toxics Emissions with an Advanced Chemical Mechanism and the CMAQ Air Quality Model

(Estimated Cost: \$200,000; Duration: 2 yrs)

Air toxics are difficult to simulate in the current CAMx model used by TCEQ for SIP applications because of the limitations of the CB-4 chemical mechanism used to represent the by-products and chemical pathways of toxic compound reactions in air. By-products of air toxics may themselves be hazardous pollutants, so it is important to understand the chemistry of air toxics in greater detail than is required for ozone SIP modeling. By applying an advanced chemical mechanism in an air quality model, one can simulate the distribution of air toxics resulting from a given emission inventory, compare the simulated distribution with monitoring observations, and determine the quality of the assumed emission inventory. This project will deploy a specialized version of the SAPRC chemical mechanism with the CMAQ air quality model to examine air toxic emissions. The specific objectives of the project are as follows:

- generate model emissions input based on the current stationary toxics inventory (Texas Toxics Release Inventory),
- develop a mobile air toxics inventory,
- increase chemical species resolution in air toxics modeling, and
- evaluate toxics modeling results with available observations, including all relevant data obtained during the TexAQS II field study.

The specialized version of SAPRC to be used in this project will be based on that developed by the University of Houston, which was used to evaluate the NEI 99 emission inventory. In this SAPRC version, 16 non-aromatic air toxics are explicitly represented, including propene and 1,3-butadiene, chloroform, methylene chloride, perchloro- and trichloro-ethylene, acrolein, formaldehyde and acetaldehyde, acetone, phenyls, cresols, ethylene oxide, vinyl ethylene, ethylene di-chloride, and ethylene di-bromide. Moreover, 18 aromatic compounds have been extracted from their generic surrogates (ARO1 and ARO2) and treated as individual tracers in the CMAQ model. These include benzene, toluene, xylenes, alkyl-, nitro-, and chloro-benzenes, and naphthalenes. Hazardous by-products of aromatic decomposition include 1,4-unsaturated carbonyls, which may be either carcinogenic or mutagenic. Because many aromatics are emitted largely from mobile sources, and because of the need to account for local conditions in Houston, an up-to-date Houston emission inventory for both mobile and stationary sources will be developed. The updated inventory will be assessed to see if major corrections and better reporting are needed to properly account for the observed distributions of toxic species, as measured by auto-GCs in the Houston Ship Channel, and by other instruments deployed during the Second Texas Air Quality Study (TexAQS II).

Proposed by: University of Houston (possible TCEQ SEP funding)

ATE-4: Air Toxics Workshop

(Estimated Cost: \$30,000; Duration: 1 yr)

The purpose of the Air Toxics Workshop is to bring together the air toxic research and toxicology communities in a workshop format to identify the key issues of air toxics research that impact Southeast Texas, with a focus on the entire spectrum of air toxics exposures. The workshop will identify the top unresolved questions that need to be

answered to obtain the best possible understanding of human exposures to air toxics in our area. Questions to be addressed include:

1. What is the current status of air toxics research worldwide, and in Southeast Texas?
2. What have been the major impacts of air toxics on human health?
3. How has air toxics research combined with medical research impacted policymakers?
4. What tools have been used or need to be used for monitoring air toxics?
5. What considerations need to be given to the chemistry of toxics including reactivity and production of secondary toxics?
6. How do we develop an accurate air toxics emissions inventory?
7. How do we model air toxic exposures?
8. How do we identify gaps in the research of air toxics?
9. How do we develop collaborative working relationships with air quality researchers and toxicologists, and eventually medical researchers, policy makers and regulators?

Target attendance is 75-100 people. Some possible speakers include:

EPA: Ruben Casso and/or EPA HQ Staff: Residual Risk, MACT, UATS, TRI, NATA (Roy Smith), Monitoring, Source Apportionment, Modeling (Ted Palma)

TCEQ: Permitting (Hyde), Enforcement (Thompson, Air Program Manager R12), Monitoring (Doughty, Carmichael, Brymer, Megbroff), Permit Modeling, Toxicology (Honeycutt, Pechacek, Leopold)

Harris County: Monitoring (Paul Newman)

Proposed by: NUATRC, HARC (co-funding)

ATE-5: Acute and Chronic Hot Spots and the Importance of Emission Events (Estimated Cost: \$100,000; Duration: 1 yr)

We propose to use air quality models to identify the locations of air toxics hot spots in the Houston-Galveston area. Emission inventories and chemical mechanisms in the CAMx model will be modified so that the concentrations of benzene and 1,3-butadiene, and their reaction products, can be tracked during typical photochemical episodes. Examination of benzene and butadiene is proposed since they are emitted by both stationary sources such as chemical plants, and mobile sources such as cars and trucks. Reported event emissions will be simulated to evaluate the relative importance of acute and chronic concentrations. The spatial and temporal distributions of concentrations will be combined with population density maps and population density maps sorted by income to evaluate the distributions of potential exposures.

Proposed by: University of Texas at Austin

ATE-6: Mapping of Air Toxics Hot Spots, Including Indoor/Outdoor Partitioning (Estimated Cost: \$40,000; Duration: 1 yr)

Studies recently conducted by the Mickey Leland National Urban Air Toxics Research Center provide quantitative estimates of indoor/outdoor partitioning of a variety of air toxics in a variety of Houston building types. We could couple air quality modeling of the spatial distribution of a variety of air toxics (above) with indoor/outdoor partitioning

parameters and a mapping of building types to identify potential hot spots for both indoor and outdoor air toxics exposures.

Proposed by: University of Texas at Austin

ATE-7: Diesel Soot Hot Spot Mapping

(Estimated Cost: \$75,000; Duration: 1 yr)

The Electric Power Research Institute plans to develop an improved understanding of public exposures to fine particulate matter in the Dallas-Fort Worth area, using data from the Hinton site as indicative of area wide exposures. We propose to use air quality modeling of fine particulate matter in the Dallas-Fort Worth area to evaluate the extent to which the Hinton site is broadly representative of population exposures to outdoor fine PM. Several air quality modeling episodes would be evaluated.

Proposed by: University of Texas at Austin

Second Texas Air Quality Study (TexAQS II)

PART A: ATMOSPHERIC CHEMISTRY

TEX-CHM-1: Differential Absorption LIDAR and Solar Occultation Flux to Measure VOCs at Sweeney and Toxics in Milby Park

(Estimated Cost: \$600,000; Duration: 1 yr)

Differential Absorption Lidar (DIAL) has been used in Europe for over 20 years to measure VOC flux from petrochemical facilities, ports and other applications. In the past 3-4 years Solar Occultation Flux (SOF), a passive Fourier Transform Infrared (FTIR) technique, has been used in similar applications. The focus of this project will be to compare these two measurement techniques and test their capabilities for calculating the total VOC flux from a petrochemical facility at Sweeney, Texas and for monitoring low ppb levels of critical toxic VOC's at Milby Park in Houston. When measuring VOC flux values, the results will be compared to those obtained using standard emissions estimating techniques as a basis for evaluating point source emissions inventories. So far as is possible, results will be reported by section of the plant, e.g. process, feed tanks, storage tanks, water treatment area, etc. A comparison of DIAL and SOF will be made in terms of their relative abilities in identifying "hot spots", or high VOC concentration areas. (Hot spots have been found in tank farms, where in some cases over 90% of the tank emissions were due to one or two tanks.) DIAL and SOF will also be used in Milby Park to characterize the concentrations of 1,3-butadiene from local petrochemical plants. Comparisons will be made of the relative abilities of DIAL and SOF to map out the 1,3-butadiene concentrations in vertical planes. Concentrations will be checked with ground level readings from canisters and/or auto-GC's. Independent experts in analytical measurements will evaluate the two techniques and the data that they generate for VOC flux measurements as well as toxics.

Proposed by: HARC (possible TCEQ SEP funding) Contractor: To be determined

TEX-CHM-2: Measurement and Modeling of Urban HONO Concentrations

(Estimated Cost: \$70,000; Duration: 1 yr)

Studies in Italy and California have demonstrated the possibility that HONO produced by heterogeneous reactions on building surfaces may be a significant source of radicals throughout the entire day and not just in the early morning hours. This missing source of radicals in urban air quality models may help explain why ozone production in the current SIP model for Houston is relatively low despite large over-predictions of both NO_x and VOC ozone precursors. This project will deploy relatively inexpensive and portable annular denuders to measure ambient daylight-average HONO concentrations in Houston. Air quality modeling will then be performed to determine if heterogeneous formation of HONO in the Houston urban canopy can explain ambient observations of HONO and improve model ozone predictions when compared to surface ozone measurements.

Proposed by: HARC

Contractor: To be determined

TEX-CHM-3: The TexAQS II Radical Measurement Project (TRAMP)

(Estimated Cost: \$400,000; Duration: 1 yr)

This project addresses the determination and quantification of sources and sinks for radicals in the urban atmosphere of Houston during the TexAQS II field campaign 2006, which is important for a better understanding of the formation processes of secondary species in the Houston area. The hydroxyl radical (OH) is the most important oxidant in the atmosphere and controls the atmospheric lifetimes of most trace gases. OH is produced in photolysis processes of ozone (O₃), formaldehyde (HCHO) and nitrous acid (HONO). OH initiates oxidation reactions with NO_x, CO, anthropogenic and biogenic volatile organic compounds (VOC). These reactions form peroxy radicals (RO₂) which in turn will cause the conversion of NO to NO₂ and subsequently the formation of O₃. Within the degradation of VOC also carbonyls will be formed which either may be photolyzed (e.g. formaldehyde) or oxidized by OH and finally contribute to the formation of peroxy-carboxylic nitric anhydrides (PANs). Loss mechanisms for OH involve reactions between peroxy radicals leading to hydrogen peroxide (H₂O₂) and organic peroxides, e.g. methylhydroperoxide (MHP) and hydroxyl-methylhydroperoxide (HMHP), and reactions with NO₂ leading to nitric acid (HNO₃) and PAN. The University of Houston is in the process of setting up an air quality measurement facility at the University main campus on the roof of the 18-story tall North Moody Tower residence hall. This facility will include a 35 ft high sampling tower (200 ft above ground level) and will be equipped with air chemistry measurements including, O₃, CO, NO, NO₂, PAN and online VOC. It will also include measurements of photolysis frequencies for O₃, NO₂, HONO and HCHO and 16 other important photolysis reactions. During the 2006 TexAQS summer campaign UH will be hosting additional photochemistry experiments at the UH-Moody Tower facility that will include OH, HO₂, and RO₂ radical measurements by William Brune of Penn State University. Our study will be accomplished by an analysis of radical sources and sinks (and production and loss rates) as identified by a steady-state time dependant photochemical box model.

For a successful completion of the proposal some additional instrumentation will be needed. The proposed budget includes instrumentation for:

- HONO,
- Formaldehyde,
- H₂O₂, and MHP,
- online GC-MS for oxygenated VOC (C₂-C₆ carbonyls, including MVK and MACR; methanol, ethanol).
- permeation calibration device for oxygenated VOC.

Proposed by: University of Houston

TEX-CHM-4: Continuation of Aircraft Measurements of Highly Reactive Volatile Organic Compounds using Proton Transfer Reaction Mass Spectrometry (PTR-MS) During TexAQS II – 2006

(Estimated Cost: \$210,000; Duration: 1 yr)

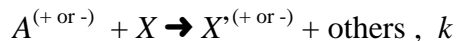
Texas A&M University (TAMU) proposes to conduct continued aircraft measurements of highly reactive volatile organic compounds (HRVOCs) using proton-transfer reaction mass spectrometry (PTR-MS) during TexAQS II - 2006. A commercial compact PTR-MS (Ionicon Analytik Ges.m.b.H, Innsbruck, AUSTRIA) has been purchased for

measurements of pre-selected HRVOCs during TexAQS II – 2005; selected biogenic and anthropogenic VOCs and their degradation products will be measured using the PTR-MS in conjunction with the 2005 - Tetroon Study. The compact PTR-MS instrument has a light weight (about 120 lb) and compact volume (22 x 25 x 17 inches) suitable for airborne measurements, with an estimated sensitivity of about 100 ppt and a response time of less than 200 ms. In situ VOC monitoring by aircraft is essential to distinguish which chemical plants and refineries are contributing to the VOCs that cause rapid ozone formation and high ozone concentrations in the industrial areas. The aircraft PTR-MS measurements also will allow for *in-situ* investigation of plume transport and chemical transformation, and will allow for identification of emission sources and improvements of the current estimate of emission inventory and evaluation of simulations of ozone and its precursors using chemical transport models. Our proposed efforts include deployment, operation and calibration of the PTR-MS instrument on the aircraft and analysis and interpretation of the data during the period of TexAQS II - 2006.

Proposed by: Texas A& M

TEX-CHM-5: Measurements of Nitrogen Reservoir Species Using Ion-Drift Chemical Ionization Mass spectrometry (ID-CIMS) during TexAQS II – 2006 (Estimated Cost: \$150,000; Duration: 1 yr)

The purpose of this research is to conduct field measurements of several nitrogen reservoir species during TexAQS II - 2006. Nitric acid (HNO₃), dinitrogen pentoxide (N₂O₅), and nitrous acid (HONO) will be measured *in situ* using ion-drift chemical ionization mass spectrometry (ID-CIMS). Measurements of the nitrogen containing compounds will be essential to elucidate the nighttime chemistry and quantify the impact of NO_y on ozone formation on the subsequent day. The ID-CIMS technique detects atmospheric neutral molecule X according to the ion-molecule reaction (Fortner et al., 2004),



where *k* is the ion-molecule reaction rate constant. The abundance of the species X can then be determined by:

$$[X'] = k [A][X] dt$$

where *dt* = *l/U*, *l* is the length of the drift tube, and *U* is the reagent ion drift velocity. (If *A* = H₃O⁺, the method is often referred to as proton-transfer reaction mass spectrometry, PTR-MS). The chemical ionization detection schemes for HONO, HNO₃, and N₂O₅ will be similar to those described in previous laboratory and field operations (Zhang et al., 1995; Huey et al., 1998; Wisthaler et al., 2002). The ID-CIMS instrument has been recently constructed at TAMU and deployed for limited measurements of HNO₃ and N₂O₅ in Houston during the summer 2004. We propose to deploy the ID-CIMS instrument either on the Williams Tower or a TAMU trailer. Our proposed efforts include deployment, operation and calibration of the ID-CIMS instrument on the aircraft and analysis and interpretation of the data during the period of TexAQS II - 2006.

Proposed by: Texas A& M

TEX-CHM-6: Downwind Aging of the Houston Ozone Plume (Estimated Cost: \$120,000; Duration: 2 yrs)

Ozone production in air pollution plumes from single or large area sources such as major cities is dependent on both NO_x and Volatile Organic Compound (VOC) emissions within and downwind of the source. Two decades of air pollution research have shown that biogenic VOC emissions not only provide ample "fuel" for ozone production downwind of cities, but also sequester primary NO_x emissions into secondary atmospheric NO_z (= NO_y - NO_x). Plume air chemistry leads to various O₃ to NO_z ratios depending on the primary emissions composition and downwind VOC injection and NO_y deposition. Earlier works have attempted to assign a uniform ozone production efficiency inside plumes to the measured O₃ to NO_z ratio, however, that efficiency changes not only with distance from the primary source but also with the atmospheric lifetime of individual NO_y components during transport. To characterize the Houston city air pollution plume in this respect, we propose to build a portable, speciated NO_y flux system based on two fast-response NO₂ analyzers (luminol technique). A sequentially heated inlet system will allow us to quantify the four most important component groups of NO_y (HNO₃, alkyl nitrates, peroxyalkyl nitrates, and NO₂) and their fluxes between the biosphere and atmosphere with an automated eddy covariance system. Field measurements would be taken at the Texas A&M air quality tower or other appropriate sites during summer 2006 and analyzed during the following months.

Proposed by: Texas A&M

**TEX-CHM-7: Evaluating Gas Phase Photochemical Mechanisms in Houston
(Estimated Cost: \$75,000; Duration: 1 yr)**

Project H12.8HRB demonstrated that ozone concentrations predicted by the Carbon Bond and SAPRC chemical mechanisms, under current Houston conditions, can be different by as much as 40 ppb. The differences have been attributed to a variety of factors including different handling of the reaction products of aromatic hydrocarbons, differences in the representation of nitrogen chemistry (especially the photolysis of organonitrates) and differences in radical termination rates. Determining which of the mechanisms more accurately represents Houston conditions will be important to resolve before air quality planning begins for the new ozone standard, with concentrations averaged over 8 hours, since the two mechanisms predict very different relative reductions in ozone. We propose a combined modeling and experimental program that will distinguish between the mechanisms. Approximate budget for modeling component: \$75,000; experimental measurements to be conducted as part of TexAQS II field program.

Proposed by: University of Texas at Austin

**TEX-CHM-8: Evaluating Halogen Cycling
(Estimated Cost: To be determined)**

Previous work has demonstrated that reactive halogen cycling is a significant, but not dominating, source of atmospheric reactivity along the Gulf Coast. Improvements in our understanding of halogen cycling will require a concerted sampling effort that is not currently part of the planning for the Second Texas Air Quality Study. We propose augmenting measurements planned for TexAQS II to examine reactive halogen cycling in urban atmospheres along the Gulf Coast.

Proposed by: University of Texas at Austin

TEX-CHM-9: Participation in the TexAQS II (2006) Study Aimed at Top-down Emissions Verification and Ozone Impact of Industrial Emissions
(Estimated Cost: \$200,000; Duration: 2 yrs)

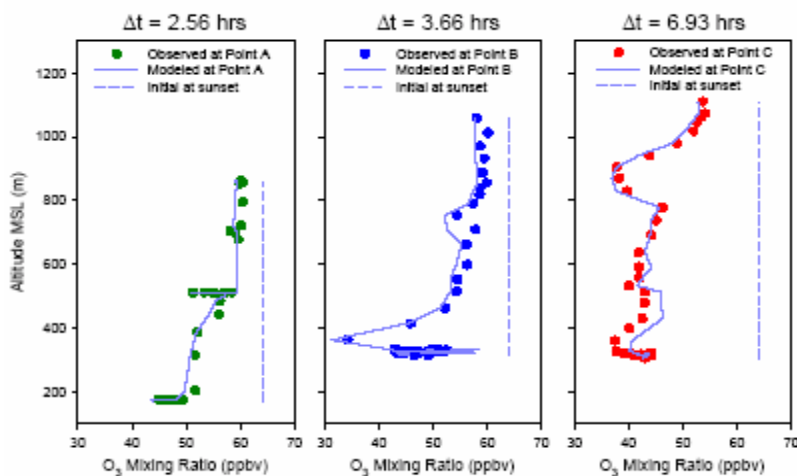
Considerable uncertainty remains concerning reactive alkene emission rates in the Houston Ship Channel (HSC), because of the very sparse nature of the near-source primary species measurements (in TexAQS I) in a regime of large spatial concentration gradients. To reduce this uncertainty, it is necessary to make high-resolution (spatial-temporal) speciated measurements of the VOC primary emissions close to the source(s) within the context of an appropriate experimental design related to a pre-determined data analysis plan. The best way to accurately estimate the reactive alkene emissions from a source complex such as the HSC is by the so-called mass-flux method, in which the emissions are captured in full as close to the source(s) as possible. The approach we propose is a combination of near-source mass-flux measurements of speciated primary VOC to infer the emissions, and farther downwind cross-plume measurements of appropriate product species (e.g., O₃ and CH₂O) to evaluate the inferred emissions (by mass-flux analysis). Aircraft chemical measurements (in combination with wind field measurements) in the near-source field, particularly in an urban environment such as that of the HSC, are not best suited for mass-flux analysis because they cannot capture the full emissions. It is better to make horizontally-continuous, column-integrated species measurements from a mobile platform such as a ground-based vehicle with an instrument such as the FTIR deployed as in the Solar Occultation Flux technique, SOF. Importantly, such an FTIR can satisfactorily measure the species of most interest --- ethene and propene (the aircraft PTRMS cannot measure ethene). Such surface-based measurements cannot provide information about the nature of the vertical species distribution. Thus, supplemental continuous aircraft measurements by the PTRMS can be useful in obtaining supplemental vertical information so that the column measurements (FTIR) can be meaningfully weighted by the wind data to obtain the mass fluxes. There is one important complication in applying the SOF technique to estimate emissions: the FTIR measurements must not be made too close to the source, because there, the plume is highly fluctuating in space and time in response to the large turbulent eddies; also, the O₃-forming chemistry is most rapid (hence VOC depleting) in this near field. LES modeling has been shown (data analyses for Sweeny Tracer Study, Nov. 2003) to provide very useful guidance in determining the optimum downwind location for mass-flux measurements, and LESchem modeling can provide the most accurate estimate of O₃ chemistry and VOC depletion between emission and sampling. Such considerations are important in optimum experimental design and in data analyses. We propose to join a team of field-study scientists in optimally designing the intensive field study for mass-flux analysis (based on surface and aircraft measurements, then participating in the intensive field measurement program (particularly the aircraft component) to facilitate optimum measurements. Finally, UAH will perform data analyses of the field data, (a) to infer the primary emissions of target species such as NO_x, ethene and propene by mass-flux analysis using the SOF, aircraft and wind data and applying the LESchem model to correct for the VOC depletion, and (b) to evaluate the inferred emissions using diagnostic farther-field modeling based on the application of the LPDM/LRPM system in conjunction with data of product species such as ozone and formaldehyde.

Proposed by: University of Alabama at Huntsville

TEX-CHM-10: Nighttime Chemistry and Transport: a 2-Year Study Using Smart Balloons and Aircraft

(Estimated Cost: Year 1: \$300,000; Year 2: \$200,000)

During the past two decades, significant progress has been made in understanding the complex photochemistry of VOCs and NO_x that leads to the formation of secondary pollutants such as ozone, nitrogen acids, and other oxidants. However, a large source of uncertainty stems from the chemistry and meteorology at night. Nighttime chemistry can result in a significant change to the composition of the atmosphere in many ways, including the removal of hydrocarbons and NO_x, and the formation of precursors for daytime radicals. Many chemical reactions at night occur on surfaces (e.g., the ground or on aerosols) and are poorly understood. The planetary boundary layer at night is also poorly understood, involving vertical mixing through layers of stable air and low level jets. Past observations and supporting modeling studies at two other major urban areas suggests a heterogeneous loss rate of ozone in the presence of aerosols of up to several percent per hour throughout the night. We propose to evaluate the loss rates and the proposed mechanism within the Houston/Galveston plume during the Texas 2006 campaign. However, to clearly detect the effects of postulated nocturnal chemistry and transport on the long-lived nighttime species (O₃, NO₂, HONO, HNO₃, etc.), we must obtain the time evolution of these and other trace-gas concentrations in the same air parcel throughout the night. The only way we know to make such observations is through



the use of smart balloons, as will be tested during the Texas 2005 Air Quality Study. The type of measurements and analysis we propose to carry out during the 2006 campaign, when more complete airborne observations will be available than are anticipated in 2005, are illustrated in the figures

below, showing ozone profiles made within a plume segment tagged with a balloon released near Boston, Massachusetts at night. The top of each panel identifies hours after local sunset when airborne chemical profiles were made in the vicinity of the balloons (shown by circles). The initial conditions for the modeling system were assumed to be well mixed (shown by vertical lines on the right side of each panel). By including the heterogeneous uptake of both N₂O₅ and O₃ on (measured) aerosol surface area, we were able to produce the observed profiles. Note that the simulated and observed O₃ loss rate is of order 10's of ppbs of O₃. *Simulations based only on standard gas-phase chemistry could not capture this information*, and similar measurements made near Portland, Oregon suggested a comparable rate of ozone loss in the presence of fine aerosols. We

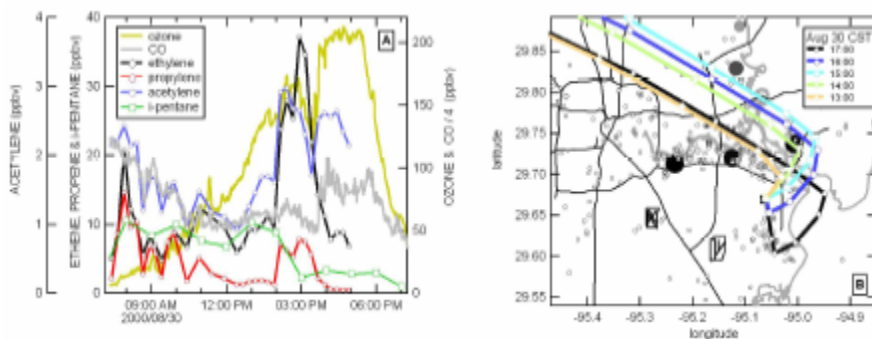
propose to launch and follow at least 10 ‘smart’ balloons carrying GPS units that will allow aircraft to make detailed measurements within the vicinity of moving parcels of air tagged by the balloons. The proposed launch location will be within emissions from the Houston/Galveston area. The resulting measurements and analysis will provide SIP-relevant information on transport patterns and O₃ nighttime chemistry.

Proposed by: Battelle

TEX-CHM-11: VOC Precursors – High Time Resolution Measurements for Dispersion Modeling

(Estimated Cost: Year 1: \$200,000; Year 2: \$100,000)

It is known that alkene emissions from the Houston Ship Channel (HSC) make a substantial contribution to O₃ formation rates on the local urban scale. Our measurements made at La Porte during TexAQS 2000 showed that light alkene mixing ratios, principally ethene and propene, were highly variable and often exceeded 100’s of ppbv. We also found that emissions of the light alkanes and alkenes were clearly dominated by industrial emissions [see Jobson et al., 2004]. The highest observed O₃ mixing ratios (> 200 ppbv) at La Porte were likely due to refinery emission from the Baytown complex based on back trajectory calculations *yet the alkenes and other hydrocarbons were not dramatically elevated* in these plumes. This is illustrated below, taken from Jobson et al., 2004. The data suggest that the alkenes had been rapidly been oxidized from the plume. A clear implication of this observation is that subsequent O₃ production in downwind plumes may be driven by longer lived species such as light alkanes, methanol, and aromatics co-emitted from the HSC.



Left: Time series of O₃ and VOC precursors at La Porte, August 30, 2000. Right: back trajectories at the indicated times. Elevated

ozone between 4-5 PM is not associated with elevated ethene and propene.

The goal of this study is to make measurements of selected VOCs downwind of the HSC (possibly in the vicinity of HRM Site 10) for comparison with models to assess the importance of HSC emissions of alkenes, alkanes, aromatics and methanol on ozone formation. Our pre-field campaign work will be to identify longer lived tracers of alkene emissions that can serve as a fingerprint for “older” plumes that have oxidized away the ethene and propene. The figure above suggests acetylene may be a tracer of such compounds, and other tracers will be considered. Measurements will of these tracer compounds will be made and compared with values derived from TCEQ emission rates and simulated chemical loss rates to come from a coupled meteorological-chemistry model (PEGASUS) run in a very high-resolution mode and using a chemical mechanism

designed to explicitly resolve specific hydrocarbons of interest (rather than using a lumped mechanism). This will allow a more detailed comparison of between measured and modeled VOC precursors to evaluate emission inventories. We will use a Proton Transfer Reaction Mass Spectrometer (PTR-MS) to make high time resolution measurements of methanol, acetaldehyde, and aromatic species. The PTR-MS measurements will be made with a time resolution fast enough to resolve individual plumes. Speciated measurements of C2-C5 alkanes and C2-C4 alkenes and acetylene will be made with a custom *in-situ* gas-chromatograph previously deployed at La Porte during TexAQS 2000. GC samples will be collected every 20-30 minutes. Instruments will be deployed in the summer of 2006, with data analysis and modeling done in subsequent years.

Proposed by: Battelle

TEX-CHM-12: Houston Ozone Monitoring Interferences

(Estimated Cost: To be determined; co-funding from American Petroleum Institute and EPA possible; Duration: 1 yr)

Recent studies indicate that non-attainment of the ozone standards in many areas may be the result of interferences to the Federal Equivalent Method (FEM) for ozone (Leston et al., 2005). Such network monitors appear susceptible to high interference bias during hot, humid, stagnant meteorological conditions typical of design value days (Leston and Ollison, 1993). Smog chamber comparisons of conventional ultraviolet (UV) monitors with manganese dioxide (MnO₂) ozone scrubbers, UV monitors with alternative heated metal (e.g., silver wool) scrubbers, and ethylene-chemiluminescence Federal Reference Method (FRM) ozone monitors indicate that higher ozone levels (20-40 ppb O₃) are reported by the conventional units. Ambient studies (e.g., Mexico City) also demonstrate significant differences between UV-FEM instruments and chemiluminescence FRM units (Leston et al., 2005). Trailing vehicle studies have shown very large apparent ozone values (100s of ppbs) in roadways where exhaust NO emissions were expected to titrate ambient O₃ to low levels (Molina et al., 2004). Given the breadth and magnitude of these findings it may be prudent to establish collocated monitoring sites to determine whether such monitoring errors are affecting ozone compliance monitoring in the Houston region.

1. Collocated sites should be established at existing State ozone design value sites (e.g., Aldine & Deer Park) in the Houston area to minimize set-up costs (TCEQ staff indicate that this probably can be worked out). State or University of Houston staff that may wish to operate and maintain the added monitors should be approached. Deployment of turnkey units (sampling line, monitor, calibrator, data logger) would minimize TCEQ impact. A third collocated site should be established and operated at the UH campus elevated tower. The collocated sites should be operated over the Houston smog season.
2. Up to four additional ozone monitors (depending on availability) should be collocated along with the existing conventional MnO₂-scrubbed FEM instruments: an ethylene-chemiluminescence FRM; an Horiba APOA-360 UV FEM monitor with heated silver wool scrubber; a TAPI 400E UV FEM monitor with heated metal scrubber; and a TAPI 265A NO-chemiluminescence monitor (for comparison to NO-CL units on aircraft). Manufacturers of the supplemental

units may wish to loan out instruments for use during the project and should be contacted to reduce costs (Horiba is interested).

3. Appropriate research staff should collect the quality-assured data (40 CRF 58), compile and integrate the findings, and assess any associations of monitor differences with meteorological parameters or ozone model output that might serve to explain and eventually correct biased measures of ozone compliance.

Proposed by: API, EPA, HARC

Contractor: To be determined

TEX-CHM-13: Ethylene Monitor for Aircraft to Complement the PTRMS

(Estimated Cost: \$40,000; Duration: 1 yr)

Deploy an olefin-ozone reactor with a filter to allow mainly or exclusively the photons from ethylene reaction with ozone so that a monitor will be available for ethylene to use with the PTRMS to monitor a wide variety of VOCs important in ozone formation. Development work remains to be conducted.

Proposed by: TCEQ (SCC Project # 223)

Contractor: To be determined

TEX-CHM-14: Use of Aircraft Measurements to Observe Ozone and Aerosol Plume Transport

(Estimated Cost: \$96,000; Duration: 1 yr)

Use airborne ozone/aerosol LIDAR to provide information on plume transport and mixing within, as well as upwind and downwind of, the Houston area. Internal NOAA Health of the Atmosphere funds will be available for 4 weeks of flights, 24 flight hours per week; TexAQS II funds would support an additional 2 weeks of data collection. Data would be analyzed the following fiscal year.

Proposed by: NOAA (SCC Project # 188)

TEX-CHM-15: Aircraft for FY 2006 Flights

(Estimated Cost: \$700,000; Duration: 1 yr)

This project would ensure the availability of DOE aircraft equipped with basic or standard air monitoring instrumentation during TexAQS II.

Proposed by: TCEQ (cost sharing may be necessary)

TEX-CHM: - Measurement of VOCs by Aircraft to Study Spatial Distribution of Isoprene and Other Biogenic VOCs and Regional Emission Modeling

(Estimated Cost: \$150,000)

Regional emission modeling and measurement activities that will substantially improve biogenic VOC emission estimates for eastern Texas and establish uncertainty levels will be conducted. Modeling: combine the most recent Texas land cover data with a biogenic emission model (Model of Exchange of Gases between the Atmosphere and Nature: MEGAN) that has recently been developed at NCAR. Measurement: directly measure trace gas fluxes (e.g., eddy covariance using Proton Transfer Reaction Mass Spectroscopy (PTR-MS) and disjunct eddy accumulation with analysis by GC-MS) using an aircraft platform that will enable investigators to examine both a large number of land cover types and replicate sites for each land cover class. Investigators could add other flux and concentration measurements to the aircraft (e.g., O₃, CO, CO₂, H₂O, NO_y, particles) with other funding. ***Proposed by: NCAR (SCC Project # 129)***

PART B: METEOROLOGY, MODELING AND TRANSPORT

TEX-MET-1: PBL - Free Troposphere Coupling

(Estimated Cost: \$30,000; Duration: 1 yr)

This project will consist of a workshop to survey the current scientific literature and ongoing research efforts on transport mechanisms coupling the PBL and free troposphere and their implications for both intra- and extra-continental long-range transport of pollution into Texas. Relevant results of various field studies over the last two decades, such as AEROCE and ICARTT, will be summarized. Recommendations will be made for specific measurements and modeling studies to be implemented in Texas during the 2006 TexAQS II intensive.

Proposed by: HARC

TEX-MET-2: Mexican Emissions and Transport Impacts

(Estimated Cost: \$30,000; Duration: 1 yr)

TERC and SEMARNAT (Mexico's equivalent to EPA) will conduct a joint workshop to identify issues of common concern regarding Mexico's emissions inventory and the impact via transport of Mexican emissions on air quality in Texas, as well as Texas pollution impacts on Mexico. The workshop will identify: 1) research necessary to improve and evaluate Mexico's emissions inventory and to assess bi-national transport impacts, especially during the 2006 TexAQS II intensive, 2) sources of research funding, and 3) potential control measures, such as a bi-national emissions trading scheme.

Proposed by: HARC

TEX-MET-3: Application and Tracer Validation of an Inverse Method for Source Apportionment

(Estimated Cost: \$300,000; Duration: 1 yr)

The Kalman Filter is a data assimilation and inverse modeling technique that has been used in atmospheric chemistry models for more than a decade. It can be used to deduce and apportion emission sources using monitoring information. The Kalman Filter will be applied to a semi-empirical micro-meteorological model for neighborhood scales (~1 km) and tested using controlled emissions of SF₆ from an isolated facility (to make siting of measurements easier) such as the Sweeney complex in Brazoria County. Portable sodars will provide appropriate wind measurements, whereas ambient measurements of SF₆ will be made using an appropriate analytical method. The resulting source apportionment tool will be made available over the Web as an interactive model using a GIS interface. The tool can be used to validate and/or correct reported emissions of moderately reactive VOCs (also known as Other VOCs as distinct from Highly Reactive VOCs) and air toxics from industrial facilities

Proposed by: HARC (possible TCEQ SEP funding) Contractor: To be determined

TEX-MET-4: The Nocturnal Boundary Layer in the Houston Area and its Impact on the Vertical Ozone Distribution

(Estimated Cost: \$110,000; Duration: 1 yr)

The goal of this project is to characterize the ozone residual layers aloft in the nocturnal boundary layer (NBL) over the urban area of Houston as well as its surrounding urban-

rural transition zones during the TexAQS II field campaign. The nocturnal boundary layer is formed by the cooling of the earth's surface during night. The NBL typically forms to depths of 200 m above ground level (AGL) over rural areas while over urban regions it is not as well defined. Since the NBL is stable and stagnant it effectively leads to the accumulation of primarily emitted pollutants close to the surface while ozone (O_3) for instance will be either depleted by titration with nitrogen monoxide (NO) or by deposition. Aloft in the NBL, however, O_3 may be preserved and elevated layers of O_3 have been documented in many urban environments. During morning hours surface concentrations will be modified by the entrainment of pollutants in the residual layer (RL) by the upward growth of the daytime convective boundary layer (CBL). This process, although not well understood, has been identified as a source of rapid morning ozone increases in urban areas. In the Houston area NBL conditions are superimposed by the diurnal variations of the land-sea breeze system. A better understanding of this complex system will help to identify the fate of presumably re-circulated aged photochemical air masses and their mixing with freshly emitted pollutants. While there are many surface air-quality measurement sites in the Houston area, there are no upper-level measurements of ozone and NBL heights available. To determine the NBL structure including its dynamics during the morning hours and the presence of ozone layers, vertical profiles of meteorological parameters and ozone are needed. We propose both an urban site and a rural site to characterize these layers. The University of Houston is equipped with one tethered balloon system for vertical profiles of temperature, relative humidity, winds, and ozone up to 1000 m AGL. In particular, this system allows detailed studies of the critical transition from nighttime to daytime regimes as multiple soundings are possible and high vertical resolutions can be obtained. In addition to gaining a better understanding of the nocturnal boundary layer structure, this study will also lead to improvements in numerical modeling efforts by allowing comparisons of model boundary layer depths and those that will be measured. For a successful completion of this proposal some additional instrumentation will be needed, including a balloon winch and ozonesonde receiver station.

Proposed by: University of Houston

**TEX-MET-5: East Texas Air Quality (ETAQ) Forecasting Project
(Estimated Cost: \$240,000; Duration: 1 yr)**

The objective of this project is to operate real-time ozone and haze forecasts in support of the TexAQS II field study. It includes four separate operational components; (1) Eulerian air quality forecasting, (2) Web interface and data archives (3) Real-time trajectory/particle dispersion systems, and (4) Common real-time emissions input for other air quality forecasting projects. Through TERC Project H45, TAMU and UH developed a prototype air quality forecasting system to link real-time meteorological data to photochemical modeling for East Texas. The continuous improvement and operation of the air quality forecasting system is required to provide high resolution meteorological, ozone and haze forecasts during the TexAQS II study. The linked system will make available routine and special meteorological and photochemical outputs to the TexAQS II study participants via internet/web access in both gridded and image form as well as access to the digital data. The MM5 output from TAMU will be utilized and UH-MM5/NOAH simulations will be provided to TAMU to support the ensemble forecasting

activities. We made significant progress with the initial web design. Further linkage of the web interface with the Oracle database to allow access of modeled and observation data are planned in this second year project. The continuous improvement of web contents and presentation methods are necessary to serve TexAQS-II participants. The air quality forecasting system would run every day for the additional 15 month duration of the TexAQS II field program, producing optimal wind fields for prediction of plume locations and ozone and haze predictions. In addition to the ozone and PM forecasting we will provide the real-time trajectory analysis both through the Real-Time Trajectory Analysis System (RTAS), linked to the past and forecast meteorology data, to generate a set number of predefined forward/backward trajectories, and the Real-Time Interactive Trajectory System (RITS) to allow individual researchers to construct trajectories of their own project interests. A real-time particle trajectory model will be operated as well. Further, this project will provide common, real-time model-ready emissions inputs based on the most up-to-dated Texas and national inventories to support other air quality forecasting operations to be performed by other TexAQS II participants. The emissions output will include data for CB-4, SAPRC, and RADM (or RACM) depending on the need of the participating institutions.

Proposed by: University of Houston

TEX-MET-6: Real-Time Meteorological Modeling and Forecasting for TexAQS II (Estimated Cost: \$240,000; Duration: 1 yr)

This project is a continuation of the existing project for forecasting support and real-time meteorological modeling of the TexAQS II domain in support of TexAQS II field operations and objectives for the period Sept. 2005-Oct. 2006. It encompasses:

- (1) Daily 48h+ high-resolution (4 km) forecasts of the meteorology over the entire state of Texas, and coarser resolution in surrounding areas;
- (2) Generation of forecast graphics, including time series, horizontal and vertical sections, etc., as requested by TexAQS-II scientists;
- (3) Validation of numerical forecasts through statistical comparison with surface and tropospheric observations;
- (4) Assimilation of selected observations into the forecast model to produce a first-cut dynamically consistent analysis/simulation for initialization of forecasts and driving of near-real-time photochemical models;
- (5) Archival and generation of products from standard and special meteorological observations;
- (6) Archival of meteorological model forecasts and analyses;
- (7) Transmission of meteorological forecast grids as they are generated to other entities for photochemical simulation, trajectory analysis, and other purposes;
- (8) Daily forecasting, including posted forecasts and forecast discussions, as well as on-site forecasting support and discussions following a schedule to be determined to satisfy needs of TexAQS-II project scientists.
- (9) Inclusion of GOES satellite data assimilation, pending availability of data and software from UAH.

Proposed by: Texas A& M

TEX-MET-7: Implementation, Evaluation and Application of Meteorological and Photochemical Ensemble Forecasts

(Estimated Cost: \$180,000; Duration: 2 yrs)

This project will select historical time periods to model, based on recent ozone episodes that include a wide range of meteorology and photochemistry associated with high ozone episodes in Houston and Dallas. The project will implement moderate-resolution (~10km, 20-50-member) ensemble forecasts for meteorology, using appropriate perturbations including realistic initial/boundary condition uncertainties as well as model errors. Two types of initial condition uncertainties will be tested: (1) deriving the random but balanced initial perturbations from the WRF/3Dvar background error covariance as implemented in Zhang (2005, MWR, in press); (2) deriving the random perturbations directly from climatological uncertainties as implemented in Zhang et al. (2005, GRL, submitted). Two types of model errors will be considered: (3) a multi-model (multi-parameterization) approach that uses different combination of physical parameterization schemes in MM5; (4) randomly perturbed key parameters of a given physical parameterization scheme (such as the mixing coefficient and critical Richardson number in MRF PBL scheme). Ensemble forecasts with one or more sources of meteorological uncertainties described above will be verified against observations in comparison to the standard deterministic high-resolution (1-5-km) forecasts/simulations. The best-performing meteorological ensemble forecast will be interpolated to a high-resolution nested domain and then used to drive the ensemble forecasts for photochemistry. Two types of photochemical ensemble forecasts will be tested: (1) only meteorological uncertainties derived from the meteorological ensemble forecast; (2) combination with uncertainties in the emission inventory. The photochemical ensemble forecast are then verified with observations in comparison to deterministic high-resolution photochemical forecasts/simulations. The meteorological and photochemical ensemble forecasts will help to understand the major source of uncertainties in predicting and simulating air (ozone) pollution (meteorology initial condition or model error, or chemical emission). These ensemble forecasts can also be used to identify what contributes most to the enhanced air pollution in a given area at a given time. These ensemble forecasts can also provide key information in where to deploy the observations during a field experiment for maximum gains in the state (targeting observations) through the ensemble-Kaman filter framework. The second phase of the ensemble forecasts will include errors in the photochemical models and evaluate the potential for real-time probabilistic/ensemble forecast of air pollution.

Proposed by: Texas A& M

TEX-MET-8: Doppler Radar Observations of Boundary Layer Winds over Houston and Dallas-Ft. Worth in Support of TexAQS II

(Estimated Cost: \$41,000/radar/mo.)

The objective of the proposed work is to provide near real-time three-dimensional winds in the boundary layer, which are estimated from the synthesis of dual-Doppler radar observations, over the cities of Houston and Fort Worth, Texas during high ozone events between May and September 2006. To accomplish this task, a single SMART (Shared Mobile Atmospheric Research and Teaching) radar (mobile, C-band, Doppler) will be deployed to a fixed location in both Houston and Fort Worth within approximately 20 -

25 km of the respective National Weather Service (NWS) WSR-88D (Weather Surveillance Radar – 1988 Doppler) (i.e., KHGX and KFWS, respectively), where it will conduct continuous Doppler radar observations of “clear air” boundary layer winds. The SMART-R and WSR-88D data will be sent via high speed communication lines to a central computer at Texas A&M University where they will be quality controlled, gridded, and analyzed using customized multi-Doppler software. Boundary layer winds over each urban zone will then be available in near real time for comparison with and assimilation into numerical models for the purpose of improving ozone forecasts.

Proposed by: Texas A& M

TEX-MET-9: Assimilation of Radar Observations with an Ensemble-Kalman Filter (EnKF) for the Modeling of Houston-Area Air Pollution Meteorology (Estimated Cost: \$160,000; Duration: 2 yrs)

The goal of this project is to expand the capability of the current MM5/WRF EnKF system to directly assimilate the radial velocity and reflectivity for improving the simulations of the Houston-area air-pollution meteorology. First, we will select historical time periods to model, based on recent ozone episodes that include a wide range of meteorology and photochemistry associated with high ozone episodes in Houston and Dallas. We will then apply the EnKF to the upcoming TexAQS II field experiment including the SMART radar observations. The EnKF has been recently implemented in MM5 and WRF for mesoscale data assimilation (Zhang et al. 2005, MWR, submitted). Data to be assimilated include radial velocity and reflectivity from WSR88D and SMART radars, profiler observations in addition to standard sounding and surface observations. The feasibility of the EnKF for assimilating radar observations has been previously demonstrated in Snyder and Zhang (2003, MWR) and Zhang et al. (2004, MWR) for simulated observations and for real radar data in Dowell et al. (2004, MWR). The EnKF analysis will be compared against independent observations as well as other assimilation techniques such as nudging. The EnKF analysis and its associated uncertainties can also be used to initialize ensemble forecasts.

Proposed by: Texas A& M

TEX-MET-10: Ensemble-Kalman Filter for Improvement of Land-Surface and Vertical Mixing Parameters (Estimated Cost: \$200,000; Duration: 2 yrs)

The goal of this research is to use regular and supplemental observations from the TexAQS II field program to improve aspects of the internal model physics, particularly the vertical mixing parameterization and soil characteristics. Photochemical modeling is particularly sensitive to these aspects of the meteorological model. Vertical mixing directly affects surface concentrations of ozone and its precursors and indirectly affects regional concentrations through transport by vertically-sheared winds. Land surface characteristics, such as soil moisture, directly drive the local circulations such as the sea breeze and urban heat island effects that govern the distribution of pollution within an urban area under light large-scale wind conditions. Conventional data assimilation, such as nudging, will never be able to overcome model shortcomings caused by these two sources of error. To date, we have completed two-dimensional idealized proof-of-concept tests (papers submitted to JGR) and have made initial tests (with some success) with

MM5 simulations of an ozone episode. Under this project, we would continue this work. We would focus first on the parameters governing vertical mixing, through assimilation of profiler and radar observations of winds within and above the boundary layer during daytime and nighttime. We would then use assimilation to tune the model's land surface characteristics, initially using in situ measurements. If time permits, we would investigate the use of this technique with GOES satellite data as an improvement over the current brute-force technique for inferring land-surface characteristics.

Proposed by: Texas A& M

TEX-MET-11: Model-Integrated Air Trajectories

(Estimated Cost: \$30,000; Duration: 1 yr)

Most model trajectories are computed using periodic model output, often hourly to six-hourly, with some form of time interpolation between output times. This technique introduces an error in the trajectory estimation, such that the trajectories computed from the model are not consistent with the transport simulated by the model. To eliminate this source of error, we propose to compute air parcel trajectories during the numerical model integration. By doing this, the winds *at every time step* can be used to advect air parcels. This approach is particularly advantageous in the vicinity of sea breezes or other such small-scale wind features that vary in space and/or time. Under this project, trajectories would be computed from pre-selected source locations at pre-selected times, and the set of trajectories would be immediately available for real-time and chemical data analysis applications.

Proposed by: Texas A& M

TEX-MET-12: Frontal Dead Zones

(Estimated Cost: \$200,000; Duration: 1 yr)

Previous research under the Southern Oxidant Study (SOS) had shown that a predominance of ozone design days for urban areas occurred under conditions where synoptic stationary fronts or analyzed trough lines (often representing old air mass boundaries) were present in the area. In an analysis of synoptic structures associated with high one hour and eight hour ozone in the DFW area it was also found that stationary fronts were associated with the three highest ozone events in the summer of 1999. In response to this finding Texas A&M and UAH carried out a preliminary analysis of these events examining the synoptic structure and air quality structure associated with two of the events (August 4-6, 1999 and August 12-17). The major findings of this study were:

1. The deformed flows characteristic of synoptic stationary fronts give rise to narrow zones of light winds without vertical lifting. The result is an area of reduced dilution that if located over even modest emission source regions could produce high precursor and ozone concentrations.
2. Trajectories into DFW under these events show relatively short trajectories over 24-48 hours indicating local influences rather than long range transport. However, the longer trajectories showed considerable descent from the mid-troposphere to the surface.
3. Considerable moist deep convection (thunderstorms) was present in both episodes. As a result of this study a pilot program was developed and proposed to use aircraft during TexAQS 2005 to sample in the vicinity of a stationary front if one presented itself

while the aircraft was available. The goal of this study is to take a broad look at ozone and precursor distributions both horizontally and vertically in the vicinity of the fronts. TAMU and UH will also be involved through their real-time modeling for selecting the episode and planning flight tracks. The new study would:

1. Carry out detailed modeling of the August 4-6, August 12-17 and August 23-25 high ozone events during 1999. Modeling will be carried out using MM5 and CMAQ and will be coordinated with TAMU and UH.
2. Examine the physical structure of the atmosphere both modeled and observed (from the 2005 pilot study) with particular attention given to the vertical structure especially the sloped frontal surfaces and potential for transport of mid-tropospheric air to the surface.
3. Examine the role of moist convection in redistributing boundary layer air and producing free troposphere ozone. This will include the potential for the moist convection over several days in conjunction with the partial tropopause folds to provide a conduit for stratospheric ozone to enrich the lower troposphere. The enrichment of free tropospheric air with boundary layer derived ozone or stratospheric ozone (or both) may be a part of why stationary fronts are associated with extreme events.
4. Develop flight plan strategies and other observations for investigating frontal structure under TEXAQS2006. This will include coordination with NOAA, DOE and TCEQ and on-site participation.

Proposed by: University of Alabama at Huntsville

**TEX-MET-13: Lagrangian Particle Modeling in Support of TEXAQS 2005-2006
(Estimated Cost: \$45,000; Duration: 1 yr)**

UAH has continued to use its Lagrangian Particle Model (LPM) tied to MM5 output as a tool to help investigators in TexAQS2000, TexAQS2005-2006. It has provided simulation of single and multiple tetroon trajectories in support of the TexAQS2005 of DOE PNL planned balloon releases from the Houston area. Multiple simulations have been made comparing the balloon trajectories to both plume and puff releases. UAH has also been developing a web-based version of its Lagrangian Particle model that can be used by TEXAQS investigators and flight planners in both retrospective and forecast modes. For Fiscal Year 2006:

1. UAH will continue to support PNL in simulations of balloon releases.
2. UAH will continue development of the web based model including improved background mapping and graphics. This will include super-imposing emission maps and sources under the particle model output. It will also respond to users request in improving and refining the model.

Proposed by: University of Alabama at Huntsville

**TEX-MET-14: Satellite Data Assimilation
(Estimated Cost: \$45,000; Duration: 1 yr)**

UAH has carried out satellite data assimilation into MM5 and CMAQ for TexAQS2000 modeling periods. In fact the satellite assimilation version of MM5 was selected by TCEQ and TAMU as the preferred model based on performance characteristics for Houston SIP runs. UAH has continued to test and improve the satellite assimilation

system and correct problems. Professor Greg Carmichael under NOAA/TERC support may test its chemical data assimilation in the TexAQS II environment. We will coordinate our satellite assimilation in this regard. It is our hypothesis that chemical data assimilation will work best if full data assimilation of the physical atmosphere especially satellite observed photolysis fields are done prior to the chemical assimilation step.

1. UAH will continue to test and improve its satellite assimilation techniques under TexAQS data sets this will be coordinated with TAMU and UH. Specifically UAH will examine problems with performance relevant to over estimating sensible heat fluxes and under estimating moisture fluxes.
2. UAH will coordinate with Professor Carmichael on using satellite assimilation into the chemical assimilation with particular attention to including satellite derived photolysis fields.
3. Carry out real-time MM5 forecasts using satellite assimilation in support of TexAQS2006 field activities.

Proposed by: University of Alabama at Huntsville

TEX-MET-15 Diagnostic Modeling and Data Analyses of the Summer 2005 Data of the NETPS and SETTS Field Studies

(Estimated cost: \$160,000; Duration: 18 mos)

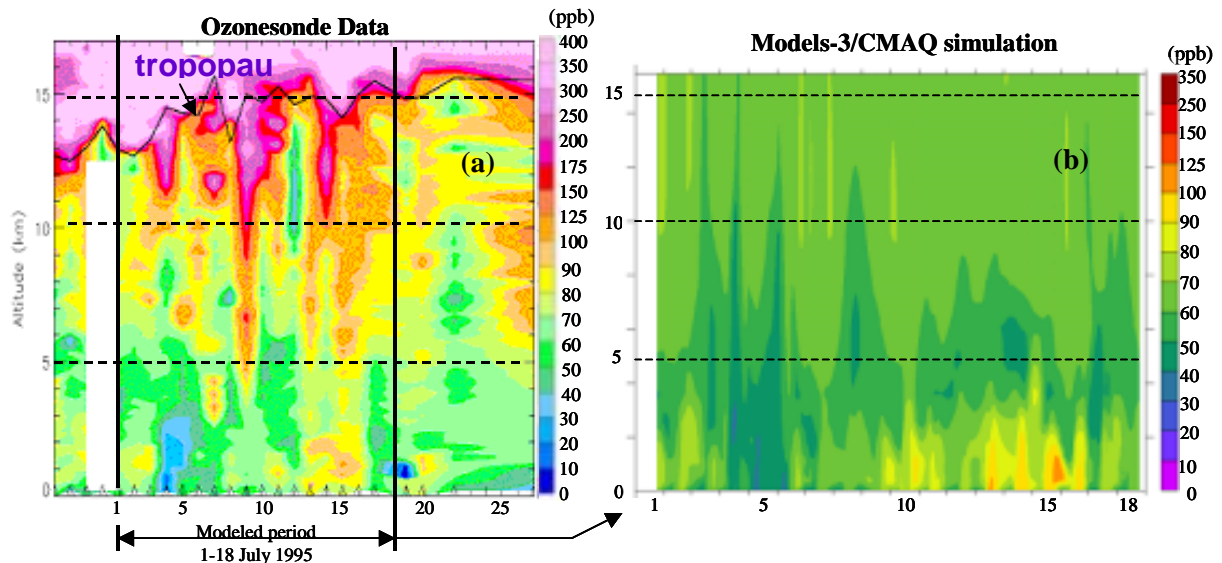
TCEQ and TERC are collaborating in the performance of two field studies in Summer 2005, viz., the NE Texas Plume Study (NETPS) and the SE Texas Transport Study (SETTS). Dr. Noor Gillani is the lead scientist of NETPS and a collaborator in SETTS. This project concept pertains to analyses of the data of these two studies, including diagnostic modeling based on applications of the UAH-LPDM (Lagrangian Plume Dynamics model) and the UAH-LRPM (Lagrangian Reactive Plume Model). He will perform diagnostic modeling analyses of the NETPS data of individual days using the UAH-LPDM/LRPM system, which has been similarly applied to transport-chemistry analyses of single and multiple Major Point Source (MPS) emissions in other major recent field studies (e.g., TexAQS I and SOS-Nashville 1995 and 1999). LPDM will be constrained to assimilate the observed plume widths. LRPM will use the updated CB4-2003 chemical mechanism which has performed particularly well for the simulation of both ozone and HNO₃ production in power plant plumes (PPPs). Whereas NETPS aircraft measurements will provide snapshots of plume and background information, the diagnostic modeling will provide a continuous picture in time and space of the prevailing plume and background chemistry, and will also help in quantifying important related quantities such as the ozone production efficiency (OPE), and in performing practical impact assessment studies. For example, there has been a substantial reduction of NO_x from the emissions of a number of the target sources since TexAQS I, so the modeling of before-after scenarios will permit us to explore the improvement in ozone impact resulting from the NO_x reductions. Since the aircraft measurements will not include nitrates (particularly HNO₃), Dr. Gillani also proposes to perform analyses of TexAQS I NOAA-AL aircraft sampling of the higher NO_x emissions (from the same power plants impacting DFW), because they include reliable measurements of nitrates also. This will permit us to explore not only the before-emissions-reduction ozone scenarios, but also such matters as the OPE and NO_y loss. Dr. Gillani will also perform diagnostic LPDM/LRPM modeling of the SETTS data (tetron and aircraft) of the transport and

chemistry of daytime and nighttime emissions from the Houston Ship Channel complex. Since the aircraft measurements, particularly of the nighttime emissions, will be close to the source at night and then much farther downwind just before and after plume fumigation the next morning, the modeling will provide continuous transport and chemistry information for the full nighttime, as well as for the subsequent fumigation and daytime CBL transport periods. Since the daytime chemistry of concentrated co-emissions of VOC and NO_x from such industrial sources has substantial contribution from microscale turbulent concentration fluctuations, such contribution will also be incorporated through simulations based on the UAH-LESchem (Large Eddy Simulation with detailed chemistry). It is anticipated that SETTS will include one mission aimed at the daytime emissions and another at the nighttime emissions. This project will involve diagnostic modeling and analyses of the data of between 10 and 14 individual day missions (6-8 NETPS, 2-4 TexAQS I, and 2 SETTS).

Proposed by: University of Alabama at Huntsville

TEX-MET-16: Development of the Lightning-NO_x Emissions Inventory for the USA for Summer 2000, and Regional Tropospheric Modeling of Ozone to Assess the Impact of Free-Tropospheric Chemistry on 8-hour Surface Ozone in E. Texas (Estimated Cost: \$200,000; Duration: 2 yrs)

It has been estimated that 20-45 ppb of surface ozone over the USA in summer may represent a background that either subsides (from the free troposphere) or is advected into the US boundary layer (possibly related to Asian emissions). This project is aimed at major improvement in the quantification of the vertical exchange processes impacting 8-h surface ozone in E. Texas, and an evaluation of the same. The figure below shows a comparison of CMAQ simulation of tropospheric ozone over Nashville TN for the period 1-18 July 1995 with local ozonesonde data collected every day at noon.



The tropopause is shown in the ozonesonde plot. Observe that: (a) quite high concentrations of ozone prevail in the free troposphere (FT), particularly in the mid and upper FT, and (b) the simulation is most inaccurate in the FT, and increasingly inaccurate with height. The factors shaping FT ozone are mainly lightning NO_x (LNO_x, peaking at

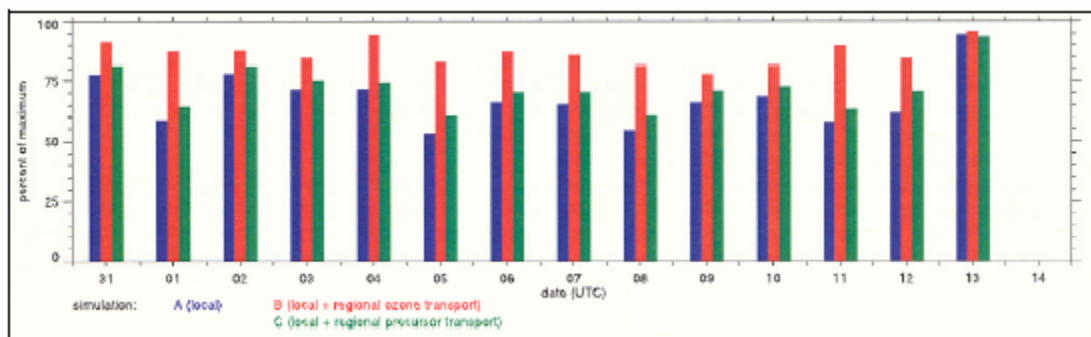
~ 8km), PBL-FT exchange (PFTE), stratosphere-troposphere exchange (STE), in situ chemistry, and advection. Of these, the simulation of LNO_x is the worst in CMAQ, because CMAQ totally ignores it, since it is totally absent in the emissions inventory (EI); PFTE is closely related in space-time to LNO_x, and has large simulation uncertainty too, largely related to uncertainty in modeling of deep convection; STE is partly due to very deep convection in summer, and partly due to dramatic and transient tropopause folding events, which are most common in spring and winter --- its simulation in CMAQ is poor. Based on the ozonesonde data of humidity, we have ruled out the occurrence of any significant tropopause folding events in the data shown above, and most of the high ozone in the FT, particularly in the mid FT (~5-10 km), is due to PFTE and LNO_x, with indications of large contribution from LNO_x, which has a relatively long lifetime and ozone production efficiency in the FT (compared to the PBL). Last year, UAH (in conjunction with NASA and NCAR) received an NSF grant to develop and apply pioneering techniques (a) to improve the simulation of LNO_x, PFTE and STE in MM5-CMAQ, (b) to develop a gridded LNO_x-EI of the USA for one year (April 1999 – March 2000), based on use of observed lightning as much as possible (both cloud-to-ground and intra-cloud), (c) to apply the above in MM5/CMAQ to simulate episodic tropospheric ozone in E. USA during selected periods of SOS-1999, and evaluate it against the corresponding daily ozonesonde data of SOS99, and finally, (d) to assess the impact of LNO_x, PFTE and STE on surface ozone for those 1999 episodes. We believe that our NSF project will result in substantial improvement in regional (E. USA) tropospheric ozone simulation. We are proposing here to use the techniques being developed in our NSF grant to extend the period of the LNO_x-EI by six months (to 30 September 2000), and perform analyses similar to those of our NSF project for selected periods of TexAQS I, with particular focus on estimating the impact of subsidence on the 8-h surface ozone background in E. Texas. This project will capitalize substantially on the much larger collective investments of NSF, NASA and NCAR than what we are seeking here.

Proposed by: University of Alabama at Huntsville

TEX-MET-17: Development of a Summertime Climatology of Locally Produced vs. Imported Ozone and Precursors During 2000, 2005 and 2006 Air Quality Studies (Estimated Cost: \$240,000; Duration: 2 yrs)

The modeling study of Fast et al. (2002) showed that on some days, a large fraction of the ozone in Philadelphia can be attributed to ozone and ozone precursors from upwind sources (see figure). Similarly, contributions to the ozone in Houston and Dallas/Ft. Worth can be attributed to both nearby sources, including the petrochemical facilities in the vicinity of Beaumont and other major cities (e.g. San Antonio), and more distant sources, including the southeastern U.S. and Mexico. Easterly winds can transport ozone and ozone precursors from the Beaumont area to Houston in a matter of hours, and over longer periods of time, ozone and more aged ozone precursors from the southeastern U.S. can be transported into the area in the presence of persistent high-pressure systems. In this study, we propose to use a set of nested grids within our coupled meteorology-chemistry model, PEGASUS, to simulate the evolution of ozone in Houston and Dallas/Ft. Worth resulting from local and upwind anthropogenic and biogenic precursor emissions during the summers of 2000, 2005 and 2006, and to ground the model's performance using observations from the field campaigns during these years. Data

assimilation on the large-scale meteorological fields will be employed so that the predictions closely follow the synoptic conditions over several months (as was done by Fast and Heilman (2005) for the summers of 1999 and 2001 to determine ozone exposure in the Great Lakes region). Sensitivity simulations will be performed that remove the local anthropogenic or biogenic emissions to quantify the impact of those sources compared to the upwind anthropogenic and biogenic emission sources. A Fourier analysis will be performed to determine the intra-day, diurnal, and multi-day components of the surface ozone time series. Changes in the multi-day component correspond to the variations in the background ozone concentrations that are likely the result of regional and large-scale ozone transport. We will determine the relationship of synoptic-scale meteorology associated with the background ozone concentrations that affect the SIPs. The project will provide a climatology for SIPs that have to quantitatively address the relative importance of transport vs. local production within the Houston and DFW areas.



Ratio of the peak daytime ozone mixing ratio from sensitivity simulations A (local), B (local + regional ozone transport) and C (local plus regional precursor transport) and the control simulation. From Fast et al., 2002.

Proposed by: Battelle

TEX-MET-18: Inline Photolysis Rate Calculations in Texas Modeling Simulations (Estimated Cost: \$20,000; Duration: 1 yr)

The UNC/CEP Environmental Modeling for Policy Development (EMPD) science team has developed a new fast in-line code for computing chemical species photolysis rates spatially and temporally in the EPA's CMAQ model. This code is a hybrid of TUV and Fast-J. It also puts out the surface fluxes from 290 to 850 nm and can be used to estimate fluxes for outdoor smog chambers and ground based monitoring sites. This project will compare the ozone and photolytic species predictions of CMAQ operated with the older off-line photolysis rates with those predicted with the new in-line system for several modeling episodes in Texas. These episodes will come from existing or new projects. Process Analysis will be used to show how differences in photolysis rates impact the entire chemical system.

Proposed by: University of North Carolina at Chapel Hill

TEX-MET-19: Using Satellite-Derived Sea Surface Temperatures in Texas Modeling Simulations

(Estimated Cost: \$38,000; Duration: 1yr)

To successfully simulate land-sea breeze circulations, improved predictions of the ground/soil temperature alone are not sufficient. One also needs to improve the

representation of temperature gradients across the water-land continuum, resulting in more accurate representation of sea surface temperatures (SSTs). For this purpose, we have acquired satellite measurements from NOAA at very high spatial (1 km) and temporal (1 h) resolutions (<http://www.mslabs.noaa.gov/cwatch/>) over the Gulf of Mexico region. These satellite observations are ingested into the MM5 inputs in place of the typical analyzed SSTs obtained at 40-km resolution (i.e., the NCEP approach). In this project we will:

- Develop an annual simulation of the MM5 for the Houston area to examine the effect of using satellite SST on land-sea breeze circulation and quantify changes on: a) winds; b) temperature gradients; c) boundary layer heights and d) clouds and precipitation.
- Analyze the seasonal characteristics of sensitivity of the above parameters.
- Examine specific ozone pollution episodes to quantify the effect on the ozone predictions.
- Prepare recommendations of modeling protocols using satellite SST.

Proposed by: University of North Carolina at Chapel Hill

TEX-MET-21: Test Smoothly Varying Grid Resolution Model for Treating Highly Variable Spatial and Temporal Varying VOC Emissions
(Estimated Cost: \$20,000; Duration: 1 yr)

CEP scientists have developed a smoothly varying Variable-Grid-Resolution (VGR) model based on MAQSIP/CMAQ framework. This is not a nested model, but instead permits the grid resolution to vary spatially over as many locations as needed. Inputs are pre-processed for each particular grid definition. The VGR model will be evaluated for its ability to simulate the highly competitive interactions among the horizontal and vertical transport processes and the chemical oxidation processes that were determined to be vital in the accurate simulation of ozone production from HRVOC events. The investigation will include various treatments of the horizontal and vertical diffusion rates as well as investigating the horizontal advection relative to the vertical mixing scheme. The input files for existing HGA 1-h and 8-h simulations being done in other non-HARC projects will be reprocessed for use with the VGR model and a series of tests will be conducted and Process Analysis will be performed to determine how the relative rates of the competing processes affects ozone production from emission events.

Proposed by: University of North Carolina at Chapel Hill

TEX-MET-22: Continued Creation, Improvement, and Application of Model Evaluation Tools in Collaboration with UH and HARC Data Center
(Estimated Cost: \$40,000; Duration: 1 yr)

The UNC portion of the H12 project showed the importance of being able to conduct an integrated meteorological and chemical model evaluation on a site-by-site basis and to have the documentation of the evaluation produced automatically using freely available software. The UH modeling in H12 was performed with CMAQ and gave a different results than CAMx with respect to NOx bias. Support is needed to extend the Python-based graphical evaluation to operate with any model outputs and to apply the tools to UH's CMAQ outputs. UH is also doing a large number of model simulations for HGB and is doing a daily forecast runs for Summer 2005. Further work is needed to

incorporate aircraft and LIDAR data along with ground monitor data. Further work is needed to refine the statistical metrics and to find ways to present and understand how the statistical results are achieved. HARC is also developing a Data Archiving Center and our Python based tools can be readily integrated to allow web-based operation of these tools against a large body of archived model outputs and to create readily downloadable pdf files of results.

Proposed by: University of North Carolina at Chapel Hill

TEX-MET: Flux Measurements for TexAQS II

- Focus on the vertical exchange of highly ozone and reactive hydrocarbons (especially isoprene)
- Collaboration with NCAR - NCAR Tethered Balloon Sampling Platform
- Vertical structure of modeled isoprene concentrations
 - o Model predicts very little isoprene above 200 m AGL
- Implications for ozone formation of changing vertical mixing parameters in model
 - o Changing vertical mixing parameters can change ozone concentrations by +/- 20 ppb

Proposed by: University of Texas at Austin

State Implementation Plan

SIP-1: VOC Emission Stack Parameters

(Estimated Cost: \$100,000; Duration: 1 yr)

Among the significant results of TERC Project H12.8HRB was the determination by the University of Houston that direct emissions of VOCs into layers aloft (i.e., above the lowest model layer) are likely to be seriously underestimated based on comparison of CMAQ model results and aircraft observations. This implies that better information is required for stack parameters (e.g., stack heights and gas exit velocities) associated with VOC emissions processes such as flares. This project will collect appropriate data available from State permits and industry surveys and entered into an electronic database.

Proposed by: HARC

Contractor: To be determined

SIP-2: Forecasting EGU Emissions Growth with the ENERGY 2020 Model

(Estimated Cost: \$150,000; Duration: 1 yr)

Regional energy models can be used to produce forecasts of point source emissions from Electric Generating Utilities (EGUs) and other fuel combustion sectors. An example of such a model is ENERGY 2020, a system dynamics model developed by Systematic Solutions, Inc. (SSI), and designed especially for comprehensive regional planning. The complete ENERGY 2020 model simulates regulated electric and gas utilities, other energy supply sources, and the major components of energy demand, including transportation demand, in a single comprehensive framework, allowing policy analyses to be performed. ENERGY 2020 simulates decision-making by participants in an energy system. While it is calibrated to replicate history, it also simulates how decision makers act when faced with conditions for which there is no historical precedent. The scenario framework of ENERGY 2020 integrates the economy of a county or utility service area with corresponding energy supply and demand, as represented by one or more sectors. Demand modules can be linked with the REMI econometric model and to explicitly modeled electric utility, bottled gas, and utility-gas sectors. An attractive feature of ENERGY 2020 is its ability to track pollution generation by end-use and fuel type from the demand sector, and from the utility sector by supply and plant type. It also tracks energy-related pollution in the industrial sector by SIC code. Pollution levels are fed back to the supply sectors, which allows policies to be introduced that adjust production to meet environmental constraints. This project will make use of ENERGY 2020 to improve forecasts of NO_x emissions for the DFW and Houston 8-hour ozone SIPs.

Proposed by: HARC

Contractor: To be determined

SIP-3: Evaluation of Potential New Episodes for the Houston 8-Hour Ozone SIP

(Estimated Cost: \$50,000; Duration: 1 yr)

This project will assess the feasibility of developing new episodes for use in the Houston-Galveston-Brazoria 8-hour ozone SIP. The project will account for the new EPA guidance and determine both data availability and gaps for emissions, meteorology, and chemistry information required for SIP model production runs. Specific episodes will be recommended, as well as a prospective timetable for new episode development compatible with regulatory requirements and options (e.g., a Mid Course Review).

Proposed by: HARC

Contractor: To be determined

SIP-4: Land Use/Land Cover (LULC) Projections for 2010 and Impacts on Eight-Hour Standard for the Houston and DFW Regions

(Estimated Cost: \$135,000; Duration: 1 yr)

The H17.2003 and H17.A.2004 studies demonstrated that land use/land cover changes (LULC) have a measurable impact on temperatures and air quality in the Houston region. They improved the methods by which such changes are modeled and demonstrated the scope and extent of ozone formation due to such changes. The heat island effects in the Houston region are likely different from those found in the DFW region, and the potential for effects are expected to be greater in the less humid DFW climate. This project would perform analysis needed to extend the findings in the Houston region, as well as prepare for analysis of LULC air quality effects in the DFW region. The difficulties in compiling comparable satellite image datasets in the H17 projects detracted significantly from LULC scenario development and from projections of future LULC in 2010 and beyond. This project would include (1) revision of the 2010 LULC projections, (2) development of forest and albedo change scenarios, (3) compilation of 2005 benchmark LULC, (4) meteorological and air chemistry modeling of these datasets, scenarios, and projections, and (5) preparation of LULC datasets and procedures for modeling the DFW region. This project would take advantage of the East Texas LULC datasets being developed by UT's Center for Space Research (H46.2005)

Proposed by: HARC

Contractor: To be determined

SIP-5: Assessment of the Extent of Truck Heavy Duty Idling in the Houston and DFW Regions

(Estimated Cost: \$95,000; Duration: 1 yr)

According to work by the Federal Highway Administration, the "process for estimating regional truck emissions typically ignores long-term truck idling." (ICF Consulting, Assessing the Effects of Freight Movement on Air Quality at the National and Regional Level, FHWA, April 2005. p. 5). Heavy duty truck activities include overnight idling, extended pick-up and drop-off idling, and idling due to access at ports, warehousing and other intermodal facilities. The next generation of EPA mobile source modeling (MOVES) will have provisions to account for such activities, but this modeling will not be available for several years. California has made some modifications to its EMFAC to account for some of the long term idling that occurs. The Texas Transportation Institute (TTI) recently completed a case study in Beaumont. The study projected that extended truck idling emissions results in more than 30 tons per day of NOx) emissions and more than 0.8 tons per day of particulate matter (PM). This suggests that the DFW and Houston regions would account for 15 tons per day or more of NOx emissions, based on regional population and economic shares of the state. This project would use TTI's study and other analyses of truck idling behavior to develop methods to improve heavy duty truck idling emission estimates for the Houston and DFW regions, suitable for inclusion in future SIP modeling.

Proposed by: HARC

Contractor: To be determined

SIP-6: Overestimation of Mobile Source NOx in MOBILE6**(Estimated Cost: \$85,000; Duration: 1 yr)**

Top down analyses of NOx emissions suggest that MOBILE6 overestimates NOx emissions substantially. This project would identify possible sources and extent of such overestimates. One known factor is the inability to set separate average speeds for heavy duty and light duty vehicles within the model. Vehicle speeds are a critical input for mobile source modeling and the emission factors are greatly influenced by the specified average speed (Chatterjee et al. 1997). Field studies have shown that heavy duty trucks generally operate at slower average speeds than light duty vehicles. NOx emissions increase rapidly as speeds increase above 50 miles/hour. MOBILE6 assumes that operating speeds are the same for both vehicle types, which can lead to significant under or over estimates of emissions for heavy duty vehicles. Slower traveling heavy duty vehicles would emit lower NOx levels that MOBILE6 would estimate. Other possible sources of this overestimation would be identified along with recommendations for reducing the overestimations.

Proposed by: HARC***Contractor: To be determined*****SIP-7: Emissions Inventory Verification Study on Small Electric Power Generating Units in the Houston Region****(Estimated Cost: \$35,000; Duration: 1 yr)**

Studies in the Houston and DFW regions identified additional small electric generation units that contribute to non-road emissions in these areas. The DFW project took the additional step of surveying companies that operated these units to gain a better measure of activity levels of these units. Similar analysis was not accomplished in the earlier study of the Houston area. In addition, during the Houston study, it was recommended that the paper-based information on such units that is collected by TCEQ be compiled into a database for both regions. This project would (1) conduct a similar survey in the Houston region as was conducted in the DFW study, (2) compile the TCEQ small generator data into a database, and (3) provide an analysis of the information in the database.

Proposed by: HARC***Contractor: To be determined*****SIP-8: The Impact of Fleet Assumptions in Transition to New Truck Emission Standards in 2007 to 2010****(Estimated Cost: \$45,000; Duration: 1 yr)**

In 2000, EPA signed new emission standards for 2007 and later heavy-duty highway engines (California adopted virtually identical standards in 2001). The new rule includes emission standards and diesel fuel regulation (ultra-low sulfur diesel). The NOx and VOC standards will be phased in for diesel engines between 2007 and 2010. The phase-in will be based on a percent-of-sales: 50% from 2007 to 2009 and 100% in 2010 (gasoline engines are subject to these standards based on a phase-in requiring 50% compliance in 2008 and 100% compliance in 2009). The transition to these new standards will cause significant drops in NOx emissions from the heavy duty vehicle fleet as these engines enter the market. However, vehicle buyers may choose to buy vehicles sooner due to the cost increase and other perceived problems that may occur with the addition of new technologies. Such a spike in early sales will affect current projections

of heavy duty truck emissions, which are expected to occur due to the entry of much cleaner vehicles. This project would examine the impact on heavy duty truck emissions if such sales spikes occur and/or other factors that would change the fleet characteristics for the heavy-duty vehicle fleet. The project would focus on emission impacts of alternative heavy duty fleet assumptions for the Houston and DFW regions. Understanding the sensitivity of these assumptions might help the state and regions to respond starting in 2006 through TERP, CMAQ and other clean vehicle initiatives.

Proposed by: HARC

Contractor: To be determined

SIP-9: Reducing Heavy Duty Vehicle Emissions through Non-Engine Technologies and Strategies

(Estimated Cost: \$75,000; Duration: 1 yr)

Heavy duty vehicle emissions can be reduced through non-fuel and non-engine changes, some of which are included in EPA's new voluntary SmartWay program. Technology-based changes include tire pressure tracking devices, oil and lubricant improvements, weight-reductions to vehicles, moving certain engine loads to auxiliary power units (APUs), wide-base tires, and fuel mileage or emission based information devices for drivers. Such technology strategies produce small but additive fuel consumption and emission benefits. Southwest Research Institute has demonstrated some of these on heavy duty vehicles. Another SmartWay strategy is truck driver training for fuel efficiency and emission benefits. Drivers can improve fuel economy using techniques such as cruise control, coasting, limiting use of cab accessories, smoother acceleration, progressive shifting (up shifting at the lowest rpm possible), reducing maximum freeway speeds, and limiting truck idling. This project would assess these technologies and strategies to determine their potential effect on emission reductions for vehicles operating in and around the Houston and DFW regions. Information on application of these technologies by industry or in other locations should be provided along with potential methods for applying these programs in Texas.

Proposed by: HARC

Contractor: To be determined

SIP-10: Using I&M Data and Data Mining to Identify High-Emitting Vehicles

(Estimated Cost: \$65,000; Duration: 1 yr)

Vehicle emissions data are collected as part of Texas on-road remote sensing program to identify smoking or otherwise high-emitting vehicles. Likewise, the State's Inspection and Maintenance (I&M) program collects emissions and repair data on many vehicles in the non-attainment regions. This project would develop methods for mining these and other data identified in the project to target potential high-emitting light duty vehicles. The report "Relationships Between the Repairs and Emissions of Light-Duty Gasoline Vehicles and Technologies" by ERG for the Texas Council on Environmental Technology in 2004 provides an example of such data mining analysis where two different data sets were used to predict repair types for different vehicle types.

Proposed by: HARC

Contractor: To be determined

SIP-11: Analysis of the Status of Reflashing Heavy Duty Diesel Engines Operating in East Texas Non-Attainment Regions

(Estimated Cost: \$25,000; Duration: 1 yr)

U.S. Environmental Protection Agency (EPA) discovered that manufacturers were using dual calibrations on heavy duty engines produced between 1993 and 1998. The engines were equipped with defeat devices on the emission controls that allowed excess emissions of NO_x. As part of a court decree, a low NO_x software upgrade for the electronic control modules in certain heavy-duty diesel engines is required (called reflashing). Trucks with engines manufactured by Caterpillar, Cummins, Detroit Diesel Corporation, Mack/Renault, Volvo and International are required to have this low NO_x software installed according to schedules set in the court decree. The rate of installation of such equipment should keep pace with Texas SIP projections. Otherwise, emissions reductions expected in the heavy duty vehicles will not occur and the effects on ozone will not take place. This project will analyze the rates at which such changes are occurring and their projected emissions impact on Texas non-attainment regions.

Proposed by: HARC

Contractor: *To be determined*

SIP-12: Assessment of Emissions Impacts of LEVII and Tier 2 in the State of Texas (Estimated Cost: \$40,000; Duration: 1 yr)

Phase 1 of a previous TERC project (H37.2005) provided an assessment of possible emissions benefits of adopting California Low Emission Vehicle (LEV-II) emission standards, and discussion of the implications of these findings for the potential analysis and adoption of these standards in Texas. Eastern Research Group, Inc. (ERG), and its subcontractor Cambridge Systematics (CS) were contracted by HARC to conduct this effort. The report concluded that there were sufficient potential emission benefits to warrant analyzing this issue in more detail in a second phase of the project. Since the completion of the project, activities in other states have also increased in regard to this issue.

Proposed by: HARC

Contractor: *To be determined*

SIP-13: Evaluation of Potential Control Strategies for Other VOCs Using a Higher-Order DDM Technique

(Estimated Cost: \$250,000; Duration: 1-2 yrs)

The Houston Mid-Course Review SIP implements controls on Highly Reactive VOCs (HRVOCs), which are known to be responsible for rapid ozone formation events and are grossly underestimated in reported emission inventories. However, other VOCs (OVOCs), such as those associated with solvent usage, are likewise known to be seriously underestimated, and may have a significant impact on attainment of the new 8-hour ozone standard. This project will be a follow-up study to an on-going TERC project examining and correcting the inventory of OVOCs using the Direct Decoupled Method (DDM) and the SAPRC chemical mechanism within the CAMx air quality model. The new project will extend the old one by:

- Using a different air quality model, specifically CMAQ.
- Applying an advanced version of DDM (known as HDDM) that can compute higher order (as opposed to just first order) sensitivities, including cross-derivatives. This will enable rapid and more accurate construction of ozone response curves (i.e., EKMA diagrams), which illustrate and quantify the effect of changes in VOC and NO_x on ozone concentrations.

- Assessing the economic cost and ozone benefits of potential OVOC controls by source category based on generated ozone response curves.

Proposed by: University of Houston/Georgia Tech (possible TCEQ SEP funding)

SIP-14: Event Emission Tracking

(Estimated Cost: \$35,000; Duration: 1 yr)

Project H13 examined the impact on ozone formation of short term releases of hydrocarbons from petrochemical facilities. Limits on these short term releases became an important part of the air quality plan for the Houston-Galveston area, and the analysis methods developed in project H13 were used directly in the development of the plan. Now, public and scientific awareness of the air quality impacts of short term releases has increased significantly, but with existing reporting methods, it is very difficult for the public, companies, air quality researchers, or even regulatory agencies to track the overall magnitude, frequency, duration, location and composition of emission events. Project H13 developed a database system that allowed for event emission tracking and populated that database with event emission data through the first year of event emission reporting (January '03 – January '04). We propose that the emission event tracking begun by the University of Texas be continued and that a UT or TERC web site, providing emission event tracking data, be established. The event emission database would be continued until near real time data on releases detected by continuous emission monitors (CEMs) became widely available. We anticipate that the CEM data will be available by late 2005 or early 2006. Funding of this project will allow for trends in emission events to be tracked from 2003-2005.

Proposed by: University of Texas at Austin

SIP-15: Modeling HRVOC Emissions Trading

(Estimated Cost: \$75,000; Duration: 1 yr)

Project H12EE examined the impact on air quality of trading programs for highly reactive volatile organic compound (HRVOC) emissions. Trading of HRVOC emissions is now a part of the air quality plan for the Houston-Galveston area and the analyses performed in project H12EE were an important part of the evaluation of the trading program. While tentative rules are in place for the trading program, slated to begin in 2007, important questions remain. Should limits be placed on banked credits? Is it possible to include fugitive emissions in the trading program? To what extent should emission reductions of other VOCs be used as credits for HRVOC emission reductions? We propose to perform a more detailed analysis of the HRVOC trading program and proposed modifications to the program. A variety of emission trading scenarios will be evaluated using CAMx.

Proposed by: University of Texas at Austin

SIP-16: Refined Evaluation of Potential for Out-of-State Emission Reductions

(Estimated Cost: \$75,000; Duration: 1 yr)

TERC Project H36 examined current and projected NO_x emission levels for major point source categories in Texas and eight upwind states. Together with the results of source contribution analyses conducted under Project H35, it was concluded that opportunities exist for additional NO_x emission reductions in a number of upwind states which would

result in air quality improvements in the ozone non-attainment and near non-attainment areas of eastern Texas. This follow on effort would provide additional, more detailed analyses to pinpoint the specific NO_x sources or source categories that provide the best opportunities for emission reductions, and to better quantify the expected emissions reduction benefits and cost-effectiveness of any such reductions. Specifically, further work should:

- **Review the response of upwind states to the final CAIR** promulgated on 10 March 2005, the NO_x SIP Call, and other relevant planning requirements. To the extent possible, determine what source categories (EGUs, non-EGUs) these states plan to control to meet their statewide emission reductions obligations. Utilize this information as input to the rest of the project, particularly the setting of priorities in the next bullet.
- **Identify specific point sources in upwind states** for further examination. Prioritize sources and source categories based on 1) states shown in H35 to have the largest contribution to ozone non-attainment in Texas and 2) source categories shown in H36 to have the greatest potential for additional control relative to similar sources in Texas (e.g. natural gas transmission and petroleum refining).
- **Examine a representative sample of major facility and synthetic minor operating permits** (after priorities have been set) within priority source types or source categories for information on allowable limits, existing control equipment and other relevant parameters. Compare actual requirements with the statewide regulatory limits identified in H36 and other control parameters.
- **Identify opportunities for cost-effective and significant NO_x reductions** that could be achieved at these sources by applying “Texas-type” controls to them. Estimate emission reduction based on control potential.

Other related tasks that could be performed for additional funding, including:

- Utilize H36 information to estimate the additional benefits of applying cost-effective controls in priority upwind states on similar NO_x-emitting equipment (e.g. stationary IC engines > “x” HP) regardless of facility size or SIC categories.
- Use the findings of H35 to identify the OCS areas most likely to have a significant impact on Texas. Further examine emission inventories and control measures employed in the offshore oil production platforms and related operations in the Gulf of Mexico and perform an H36 type analysis to obtain a more accurate analysis of potential emissions reductions from the OCS.

Proposed by: Environ

SIP-17: Role of Biogenic Emissions in Dallas-Ft. Worth SIP Modeling (Estimated Cost: \$50,000; Duration: 1 yr)

Biogenic emission estimates are important to DFW control strategy design and could be improved in several ways. Modeling for TCEQ and TERC Project H35 finds that ozone in the DFW urban core is VOC-sensitive, whereas surrounding areas are NO_x sensitive. The implications for ozone control strategies are: (1) Anthropogenic VOC reductions have limited effect because much VOC is biogenic. (2) Anthropogenic NO_x reductions must be relatively deep to overcome NO_x inhibition effects. Improving or substantiating the current biogenic emissions would strengthen these conclusions. Uncertainty in the DFW urban biogenic emissions is particularly important. The current DFW biogenic

emission estimates are based on local land cover data and biomass surveys conducted in the late 90s. However, biogenic emissions are difficult to quantify in urban/suburban DFW and depend upon the extent to which native trees/forests are preserved and influx of non-native (exotic) species. Approaches to improving the biogenic emission inventory include using satellite data to characterize biomass density and/or plant species, leveraging existing tree/landuse surveys, conducting new tree surveys, measuring emission factors for exotic species, specialized ambient VOC measurements to ground-truth biogenic emission levels. On-going studies at UT are analyzing high-resolution satellite data for biogenic emissions modeling. In near term, high-resolution satellite data available from several sources (e.g., UT, the National Center for Atmospheric Research, gap analyses) should be investigated as potential improvements to the DFW biogenic emission inventory for the next SIP revision. The existing biogenic emissions model (GloBEIS) can readily accept new land cover data derived from satellite data.

Proposed by: Environ

**SIP-18: Transient High Ozone Events (THOEs) and 8-Hour Ozone
(Estimated Cost: \$50,000; Duration: 1 yr)**

Document the contribution of transient high ozone events (THOEs) to 8-hour ozone violations and site Design Values and evaluate the effectiveness of existing short-term HRVOC rules on lowering the estimated Relative Reduction Factors for 8-Hour Attainment Demonstrations. Data are from TCEQ and HRM ground-based monitoring network, emissions events reporting system, and industrial on-site emissions monitoring. Develop statistical and graphical methods for determining and illustrating the contribution of observed short duration (transient) high ozone events (e.g., 1-hr ozone increases of +40 ppb) on the running 8-hr ozone, 8-hr ozone exceedances, and the site Design Value. When possible, correlate THOEs with reported event emission data base and with on-site industrial monitoring. In one or more modeling episodes being developed in other projects, impute events emissions consistent with observations and evaluate adequacy of simulating observed 1-hr and 8-hr ozone influenced by THOEs. In future case simulations, apply short-term rules for HRVOCs and evaluate the effectiveness in reducing 1-h and 8-h ozone and the impact on the computed Relative Reduction Factors for monitors that must be applied to observations to demonstrate future attainment.

Proposed by: University of North Carolina at Chapel Hill

**SIP-19: Observation-based Ozone Exceedance Forecasting Tool
(Estimated Cost: \$30,000; Duration: 1 yr)**

Work at UNC has led to an observational-based model of 1-h and 8-h exceedances, and THOE events forecast model. The model's components include certain wind field characteristics in defined spatial domains as well as TCEQ and HRM monitoring data. This model has shown some skill in matching history. It is capable of making 3-day forecasts of the likelihood of having a 1-h or 8-h exceedance and can forecast conditions likely to produce THOEs if large event emissions occur. Thus it could be of use in warning industrial operators of times in which certain operations might lead to high ozone production. In addition to refining the formulation of the model, work is needed to automate the model's operation (e.g., automatically obtaining the weather data), and

imbedding operation in a GIS system using Python scripts. Further operational evaluation is needed.

Proposed by: University of North Carolina at Chapel Hill

SIP-20: Stochastic Emissions Inventory Simulations

(Estimated Cost: \$45,000; Duration: 1 yr)

In TERC Project H13 significant effort was applied to simulating VOC emissions and subsequent ozone based on a Stochastic Emission Inventory. Analyses of emissions distributions for large HRVOC sources were conducted and multi-component probability distribution functions (PDFs) were produced. Preliminary creation of 10,000 instances of HGA emissions inventories were produced and analyzed. These suggested that spatial areas 10 km by 10 km could easily experience 15% hourly variation in VOC concentrations, with smaller spatial domains experiencing 50% or larger variations. Work to fully couple the stochastic driver to the modeling emissions system was curtailed in the H13 project to permit more analysis work to be done on the “events emission database”. Limited resources and time prevented a return to the full stochastic simulation, which would have included the incorporation of the PDFs from analysis of the “events emissions database” along with routinely variable permitted emissions to more rigorously and comprehensively produce likely HGA VOC inventories. This project will complete the formulation and coupling of the stochastic simulator with the emissions inventory modeling system, permitting many instances of variable VOC inventories that include all variable emissions components (including off-permit event emissions) to be created. We will then attempt to reconcile the distributions of the many new ambient VOC hourly measurements with the stochastic predictions, at least on a relative distribution basis. Representative cases of our predicted inventories will be used to operate air quality modeling episodes for 1-h and 8-h ozone (these are being produced in another non-TERC project) to estimate more precisely the impact such variable VOC emissions have on predicted ozone and how the system may respond to short term limits and to evaluate how the extremes in the permitted inventory can affect 1-h and 8-h ozone.

Proposed by: University of North Carolina at Chapel Hill

SIP-21: NOx Emission Factors for Compressor Engines

(Estimated Cost: \$100,000; Duration: 1 yr)

Collect emission rate data from operating engines to be able to statistically evaluate the actual emission rates for East Texas and create estimated inventories on a statistically sound basis.

1. Determine the horsepower capacity installed in Texas.
2. Contact a random sampling of permit holders to determine the load factor appropriate for each category of compressor.
3. Compare the permit database to the Penwell Pipeline database to determine any adjustments needed for covering missing compressors in the TCEQ database.
4. Apply TCEQ emission factors to develop a county level inventory of gathering transmission, distribution and storage compressor stations.
5. Prepare a report and complete NEI forms.

Proposed by: TCEQ (SCC Project # 121E)

Contractor: To be determined

SIP-22: Wastewater Project**(Estimated Cost: 100,000; Duration: 1 yr)**

Use the HAWK camera or other means to identify points of emission in wastewater/process sewer systems. Utilize traditional testing techniques: El Paso Method, VOA samples, VOC hand held analyzers, SUMA canisters, etc. at sample points in the system. Attempt to determine source of VOC. Work with Dr. Richard Corsi of the University of Texas who helped create EPA Water 9 software. The project would require a large amount of sample collection and sample analysis.

Proposed by: University of Texas at Austin (SCC Project # 119W)

SIP-23: Storage Tank Project**(Estimated Cost: \$100,000; Duration: 1 yr)**

European analytical companies using DIAL and Solar Occultation Flux in petrochemical facilities have found that in some cases up to 60% of all refinery emissions can be from storage tanks, and typically only a few storage tanks are responsible for 90% of those emissions. This project would utilize a HAWK camera during TexAQS II activities to identify leaking storage tanks and tank construction blueprints to determine diameters of leaking orifices. The project would also test vents for velocity of plume or make assumptions on the velocity, and bag or otherwise determine volume of plume from non-vent sources. The tanks could be analyzed further with canister samples taken from strategic points around the tank. The analytical results would be used to estimate the emissions rate, which would be compared to the emissions rate predicted using AP-42 and other standard emissions estimating techniques.

Proposed by: TCEQ (SCC Project # 119T)

Contractor: To be determined

SIP-24: Assessing the Effectiveness of Control Strategies for Ozone

Victoria Chen

Department of Industrial & Manufacturing Systems Engineering
Campus Box 19017

UTA

Arlington, TX 76019-0017

Phone: 817-272-2342

Fax: 817-272-3406

Email: vchen@uta.edu

Problem Statement

The objective of the proposed work is to develop a computationally-tractable and rigorous decision-making framework (DMF) for assessing the effectiveness of 8-hour ozone control strategies using the Comprehensive Air quality Model with extensions (CAMx), developed by Environ. CAMx v. 4.0, the latest version released in Dec. 2003, is the photochemical model that TCEQ uses for state implementation plan (SIP) modeling and will be used in this project. In particular, the latest DFW CAMx model for the episode on August 13-22, 1999, which is currently being used to support DFW 8-hour ozone SIP development, will be obtained from TCEQ,

Government decision-makers typically utilize “trial and error” to test control strategies, and typical control strategies involve an overall reduction in emissions and may require exorbitant (and impossible) reductions to maintain the U.S. EPA limits. In addition to traditional across the board control strategies, such as reducing electric utility emissions by a given percent for all plants at all times, the proposed DMF will consider *dynamic* and *focused* control strategies that vary by location and time-of-day. The purpose of the DMF is to comprehensively explore hypothetical “what if” paradigms, subject to technical and societal constraints, and extract key decision information that would otherwise be overlooked using current “trial and error” approaches. Our DMF is based on a rigorous continuous-state stochastic dynamic programming (SDP) optimization approach (Chen et al. 1999, Chen 1999, Tsai et al. 2004) and conducts an intelligent and comprehensive search through the possibilities. By identifying the most critical sources, locations, and time periods to target for control actions, the proposed DMF could play a crucial role in allowing policy makers to identify the options with greatest leverage for a fine-tuned SIP.

The PI has developed a proof-of-concept prototype DMF for studying a one of the worst ozone pollution episodes in metropolitan Atlanta (Yang et al. 2004). In Texas, Dallas/Fort Worth will be used as a test case. The relevant research tasks are as follows:

- A. Work with TCEQ to identify potential DFW SIP control strategies to be evaluated.
- B. Develop the DMF interface with the DFW CAMx model.
- C. Utilize the DMF to systematically implement the desired control strategies in the CAMx model.
- D. Develop statistical metamodels appropriate for the stochastic optimization methodology within the DMF to evaluate the control strategies.
- E. Evaluate the control strategies.

These are each discussed below.

Task A: Work with TCEQ to identify potential DFW SIP control strategies to be evaluated.

TCEQ and other government decision-makers will be consulted to identify a set of DFW control strategies that are relevant to the SIP (e.g., TCEQ 2002, TTI 2003). For each control strategy, emission reductions by time and location must be specified to enable simulation via the CAMx model in Task C. In particular, the DMF can explore the same control strategy in different time periods (e.g., running a power plant at 50% between 10:00 AM and 12:00 noon vs. 10:00 PM and 12:00 midnight). The DMF can provide a ranking of the control strategies by time period. Control strategies that never appear near the top for any time period would clearly be seen as inferior. Both NO_x and VOC controls will be explored.

The DMF can employ various objectives to evaluate the control strategies. Benefit to air quality, measured as reduction in ozone as calculated by the CAMx model, will be of

primary importance. However, an economic cost analysis can also be conducted, as long as the necessary (estimated) economic costs for each control strategy are provided. Uncertainty in both the economic costs and the emission reductions due to the control strategy can be incorporated and is recommended. For example, a range of the emission reductions could be provided instead of a single estimate.

Task B: Develop the DMF interface with the DFW CAMx model.

Together the time periods determined by Task A will define the *time horizon* over which the control strategies will be evaluated. Given the daily cycle of ozone formation, the time periods are expected to be groups of hours or at most a day, and the time horizon will cover several days, specifically the 10-day August 1999 episode. This episode contains a variety of meteorological conditions, including some “worst case” meteorology, and different control strategies may be more effective under different meteorological conditions. The DMF will utilize *statistical experimental designs* (Dean and Voss 1999, Montgomery 2001) to intelligently organize the set of CAMx model runs to execute in Task C.

The latest DFW CAMx model for the 10-day August 1999 episode includes recent improvements, such as the ETA vertical mixing and CB4 chemistry with NO_x recycling. UTA already has experience running a prior version of this CAMx episode model. In order to implement the control strategies in the CAMx model, the appropriate CAMx binary input files must be modified. Thus, a full understanding of CAMx input data relating to emissions must be acquired. To facilitate implementation, programming codes for automatically modifying CAMx input files will be developed and a script file will be set up to assist the CAMx simulation of all scenarios and control strategies to be conducted by Task C.

Task C: Utilize the DMF to systematically implement the desired control strategies in the CAMx model.

Given the control strategy combinations specified from the experimental designs constructed in Task B, a CAMx model run will generate ambient ozone concentrations for a specific control strategy or combinations of control strategies. Because of the heavy computational effort required to execute one CAMx model run, the CAMx model will not be directly implemented within the stochastic optimization methodology of the DMF. Instead, CAMx model output data will be assimilated in Task D, which is an intermediate step prior to executing the evaluation of the control strategies in Task E.

Task D: Develop statistical metamodels appropriate for the stochastic optimization methodology within the DMF to evaluate the control strategies.

Given the CAMx model output from Task C, Task D will conduct a Mining and Metamodeling Process, shown in Figure 1. “Emissions” represents the reductions due to the control strategies, and “Maximum Ozone” represents the maximum 8-hour ozone averages calculated by the CAMx model across the DFW region and over the 10-day

August 1999 episode. The resulting metamodels will be used to efficiently represent how ozone changes over time and space in the DMF optimization in Task E.

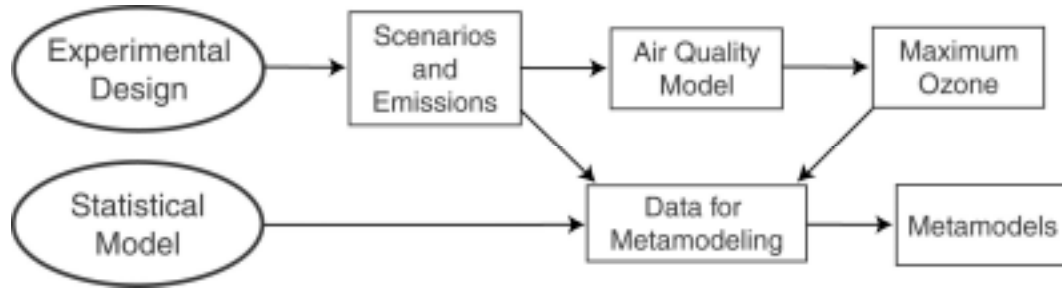


Figure 1: Flow chart describing the Metamodeling Phase for Task D.

Task E: Evaluate the control strategies.

Given the statistical metamodels from Task D, the stochastic optimization of the DMF can now be calibrated and executed. Rankings of the control strategies will be calculated using four measures developed by Tsai (2002).

Facilities

Computation will be conducted using computers in PI Chen’s Linux Lab and UTA’s High Performance Computing facility (hpc.uta.edu). The PI’s Linux Lab currently consists of two Dual 3.06-GHz, three Dual 2.8-GHz and one Dual 2.4-GHz Intel Xeon Workstations. The prototype Atlanta DMF is currently running on one of these workstations.

Project Schedule

Time Period	Tasks
June – December 2005	A and B
January – August 2006	C and D
September – December 2006	E

Estimated Project Costs: \$125,000 (for 19 months)

- 1.75 months summer salary for PI Chen
- One Masters student
- One Doctoral student
- 30% Fringe for faculty, 45% Fringe for students
- Travel
- Material and Supplies
- 48% Indirect costs

References

Chen, V. C. P. (1999). “Application of Orthogonal Arrays and MARS to Inventory Forecasting Stochastic Dynamic Programs.” *Computational Statistics and Data Analysis*, **30**, pp. 317-341.

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- Dean, A. and D. Voss (1999). *Design and Analysis of Experiments*. New York: Springer.
- Montgomery, D. C. (2001). *Design and analysis of experiments*. New York: John Wiley.
- Texas Commission on Environmental Quality (TCEQ 2002). "Dallas-Fort Worth Attainment Demonstration SIP Emission Reduction Control Strategies," October.
- Texas Transportation Institute (TTI 2003), in cooperation with the Texas Department of Transportation. *The Texas Guide to Accepted Mobile Source Emission Reduction Strategies*, August.
- Tsai, J. C. C. (2002). *Statistical Modeling of the Value Function in High-Dimensional, Continuous-State Stochastic Dynamic Programming*. PhD dissertation, Georgia Institute of Technology.
- Tsai, J. C. C., V. C. P. Chen, J. Chen, and M. B. Beck (2004). "Stochastic Dynamic Programming Formulation for a Wastewater Treatment Decision-Making Framework." *Annals of Operations Research*, Special Issue on Applied Optimization under Uncertainty, **132**, pp. 207–221.
- Yang, Z., V. C. P. Chen, M. E. Chang, T. E. Murphy, and J. C. C. Tsai (2004). "Mining and Modeling for a Metropolitan Atlanta Ozone Pollution Decision-Making Framework." *IIE Transactions*, Special Issue on Data Mining, in second review.

SIP-25: Flare Efficiency Investigation

SIP-26: Collaborative Use of New EPA VOC Reactivity Scales and new SMOKE/Reactivity System

UNC PIs: CEP Staff, H. Jeffries

Collaborators: PIs on ATE-3, SIP-13, Carter

Potential Collaborators: PIs on ATE-5, SIP-15

(Est. UNC Budget \$80K)

Overall Goal:

–Integrate the EPA/NARSTO-RRWG new national reactivity scales and the new SMOKE/Reactivity Mechanism/Emissions Processing System (developed at CEP under funding from NARSTO-RRWG) into several of the TERC/HARC projects using CMAQ or CAMx and SAPRC or CB4 mechanisms expanded for reactivity substitutions on OVOCs, HAPs, and Cap and Trade based HRVOCs. Confirm that national scales are appropriate for HGA.

Relevance to Houston:

–Several ongoing efforts in Houston to assess effects of OVOCs, HAPS and HRVOC emissions trading policies. We can leverage these separate parallel efforts and have a unique opportunity to apply the new SMOKE-based reactivity modeling system to provide an integrated assessment of VOC-reactivity based substitution policy for H-G

Solidify EPA Acceptance of SIP use of Reactivity

Proposed by: University of North Carolina

