Appendix G.2

Phase 2 HGB Mid Course Review

Estimation of Biogenic Emissions
with Satellite-Derived Land Use and Land Cover Data
for the Air Quality Modeling of Houston-Galveston Ozone
Nonattainment Area

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Estimation of Biogenic Emissions with Satellite-Derived Land Use and Land Cover Data for the Air Quality Modeling of Houston-Galveston Ozone Nonattainment Area

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ABSTRACT

Houston-Galveston area (HGA) is one of the most severe ozone non-attainment regions in the US. To study effectiveness of control strategies of anthropogenic emissions to mitigate regional ozone nonattainment problems, it is necessary to utilize adequate datasets describing the environmental conditions that influence photochemical reactivity of the ambient atmosphere. Compared to the anthropogenic emissions from point and mobile sources, there are large uncertainties in the locations and amount of biogenic emissions. For regional air quality modeling applications, biogenic emissions are not directly measured and instead estimated usually with the meteorological data such as photo-synthetically active solar radiation and surface temperature as well as the land type and vegetation database as inputs. In this paper, we characterize these meteorological input parameters and two different land use/land cover datasets available for HGA: the conventional biogenic vegetation/land use data and the satellite-derived high-resolution land cover data. We describe procedures used for the estimation of biogenic emissions with the satellite derived land cover data. Air quality modeling simulations were performed using the original and new biogenic emissions input. The results showed that there are considerable uncertainties in the biogenic emissions estimates and subsequently the ozone predictions are affected up to 10 ppb, but the magnitudes vary each day depending on the relative to the upwind or downwind positions of the biogenic emission sources relative to the anthropogenic NOx and VOC sources.

Key words: biogenic emissions, land use/land cover, satellite data, air quality, ozone, leaf mass density, photosynthetically active solar radiation, TexAQS experiment

1. Introduction

Development of reliable land use (LU) and land cover (LC) is one of the key activities of environmental management. The LU/LC data is a critical input for environmental modeling, in particular, to characterize the land surface processes in the meteorological modeling and to estimate contributions of the trees in the urban and regional air quality. Different distributions of LU/LC influence meteorological conditions, such as air temperature, moisture, and the height of the planetary boundary layer in which pollutants are dispersed and transformed. Changes in the land use and land cover in a rapidly developing metropolitan area can modify the radiative conditions and thus result in regional climate changes. For example, the LU/LC modification can exacerbate the urban heat island (UHI) effects in a metropolitan area like Houston-Galveston when the vegetation cover is replaced with buildings and pavements. Also, the extended impervious surface may enhance run off of rainfalls, increase the sensible heat flux and air temperature, and thus modify the turbulent mixing conditions in urban areas. There are a few attempts to mitigate such problems by introducing more plants in the urban environment, pave with light color and porous materials, and install reflective roofing materials.

Although the reduced UHI effects have other beneficial consequences, such as reduced summer air conditioning costs in cities, there is a controversy whether these measures will always mitigate local ozone problems. Changes in the land use and land cover will induce further changes in the amount vegetation can eliminate pollutants from the air through dry deposition process. Deciduous trees are well known to generate a significant amount of photochemically sensitive biogenic emissions of volatile organic compounds (VOCs), carbon monoxide (CO) and nitrogen monoxide (NO) as well as terpenes which are precursors of secondary organic aerosols (SOCs). The rates of the biogenic emissions are heavily dependent on the environmental factors that affect tree and vegetation physiology, such as ambient temperature, moisture, and solar radiation, in particular the photosynthetically active solar radiation (PASR) component. For example, the lower temperature would have beneficial effects by reducing the amount of such ozone precursor emissions. However, decreased temperatures could produce lower mixing heights in which precursors and secondary air pollutants can disperse, thus increasing ozone concentrations. Therefore there is a need to perform a thorough assessment of these issues by using advanced computer models to evaluate whether an expanded tree planting program would mitigate ozone problems in an urban area like Houston-Galveston Airshed (HGA)

To disentangle these complicated issues step by step, the present research targets to identify the effects of LU/LC changes on the local biogenic emission estimates without considering the indirect effects on the meteorological conditions. Land-use (or land-cover) data is an essential input for estimation of regional biogenic emissions. The higher the spatial resolution and the larger numbers of plant species available, the better the estimations that can be expected.

Recently, the Texas Forest Service (TFS), with the support of Texas Commission on Environmental Quality (TCEQ), have compiled a new high-resolution LU/LC dataset for the eight counties surrounding the HGA to characterize regional changes in the vegetation and tree species. The updated map of LU/LC was produced using satellite imagery and ancillary datasets. A supervised classification process using image processing software was employed to define the 8 land cover classes and 15 land use classes (GEM, 2003). The new vegetation and land-use data provides an opportunity to evaluate effects of LU/LC changes on the air quality to support the HGA State Implementation Plan (SIP) preparation efforts. In this study two different biogenic emission datasets are used in air quality simulations to quantify their effects on the predicted ozone concentrations in the HGA.

2. Materials for Analysis

The study area for the land use and land cover is the Houston-Galveston area including the surrounding counties Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller in South East Texas, as shown in Figure 1. The period of modeling analysis is August 22-September 1, 2000, a part of the Texas Air Quality Study 2000 (TexAQS 2000).

2.1 Land cover and land use data

TCEQ biogenic landuse data set

For the HGA SIP modeling purpose, TCEQ is utilizing a specially compiled dataset for land use and vegetation information for the state of Texas and the surrounding states. Compared to other parts of Texas and US, the LU/LC database available for Eastern Texas is up-dated relatively recently. It is a composite land use database that includes a mapping of ground cover, vegetation species, and leaf mass densities for the state of Texas (Weidinmyer, et al., 2001). Land use and vegetation were divided into over 600 classifications at approximately 1 km spatial resolution. Some field surveys were performed to estimate leaf biomass densities of certain tree species. Special emphasis was put in to generate more detailed urban LU/LC classifications. When no recent data were available, the USGS LU/LC database at 1-km resolution was applied to provide spatial distribution of the urban land use types. In addition to the municipal , state, and Federal government land use, land cover, and vegetation data at resolutions from 30 m to 1 km, county-based agricultural LU/LC data were incorporated as well. Although we may consider this LU/LC database has reference year of 2000, the representative years of the different data sources vary widely and in some case uncertain.

For the purpose of creating biogenic emissions, species distributions and biomass densities were associated with each land use type based on the field surveys took place through out the Central and Eastern Texas between 1997-1999 period (Weidinmyer, et al., 2001). Urban land areas, Dallas-Fort Worth, Austin, Beaumont-Port Arthur, and Houston-Galveston were surveyed by automobile and the collected tree size and species distribution information. Biomass density was estimated for each species for each land use type using the empirical relations suggested by Geron et al. (1994). Each LU/LC type was assigned a five -digit code and the biomass densities and species distribution were assigned to each code. According to Weidinmyer, et al. (2001), the total leaf biomass densities associated with these codes for Texas range from 0 to 556 g m^{-2} with highest value in central and eastern Texas where oak species are abundant. This dataset can be considered as a more detailed and up-dated land type distributions than those available from EPA as BELD3 (Kinnee et al., 1997), which is used to estimate biogenic emissions across the conterminous US continent. The data is available from TCEQ's web site (http://www.tnrcc.state.tx.us/air/aqp/airquality_photomod.html#ei4c).

LANDSAT based landuse data set

The GIS shape files from Texas Forest Service (GEM, 2003) covers the eight county areas surrounding Houston (see Figure 1) and consists of 8 land cover classes and 15 Land Use classes.

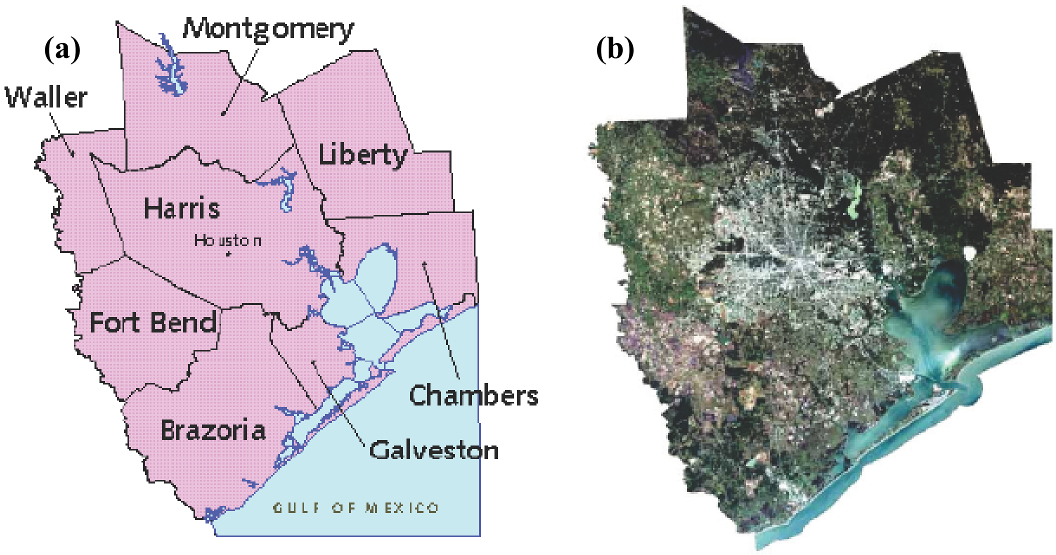

Figure 1. (a) The study area consists of the eight counties around Houston, Texas, including Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller. (b) The LANSDAT image of the corresponding area. (from GEM, 2003).

An updated map of Land Use and Cover Type conditions within the eight counties surrounding Houston, Texas was produced using satellite imagery and ancillary data sets. A supervised classification process using image processing software was employed to define the classes described below:

Land Use:	forest, range, agriculture, urban/developed
Land Cover:	forest composition (coniferous, broadleaf, mixed), grass, wet land, water, barren (e.g., beach, bare soil), impervious (roads, parking lots, buildings)

The separation between urban and non-urban areas was identified by year 2000 census data. Land use conditions within the urban areas were further classified as residential, commercial, industrial, transportation corridors, and parks. Surface properties including albedo, surface roughness, emissivity and thermal inertia were mapped through direct measurement when possible and, otherwise, through the use of look-up-tables that assign a value according to cover type. Several data sources were utilized to enhance feature identification and improve the classification process. The data sources included LANDSAT satellite imagery, digital aerial photography, aerial LIDAR data, USGS elevation data, a variety of vector based GIS data, and extensive ground-truth information obtained from more than three hundred field plots.

The multi-resolution and multi-temporal data sets were correlated to develop unique class parameters for optimal recognition of land use and cover type features. The higher resolution data sets were used to perform a sub-pixel analysis of the LANDSAT imagery over selected field plot locations in order to produce spectral signatures for the associated cover types. The spectral signatures were then extrapolated across the entire study area to assign a land cover type to each picture element (pixel) in the satellite imagery using the Spectral Angle Mapper algorithm within the ENVI software package by Research Systems, Inc.

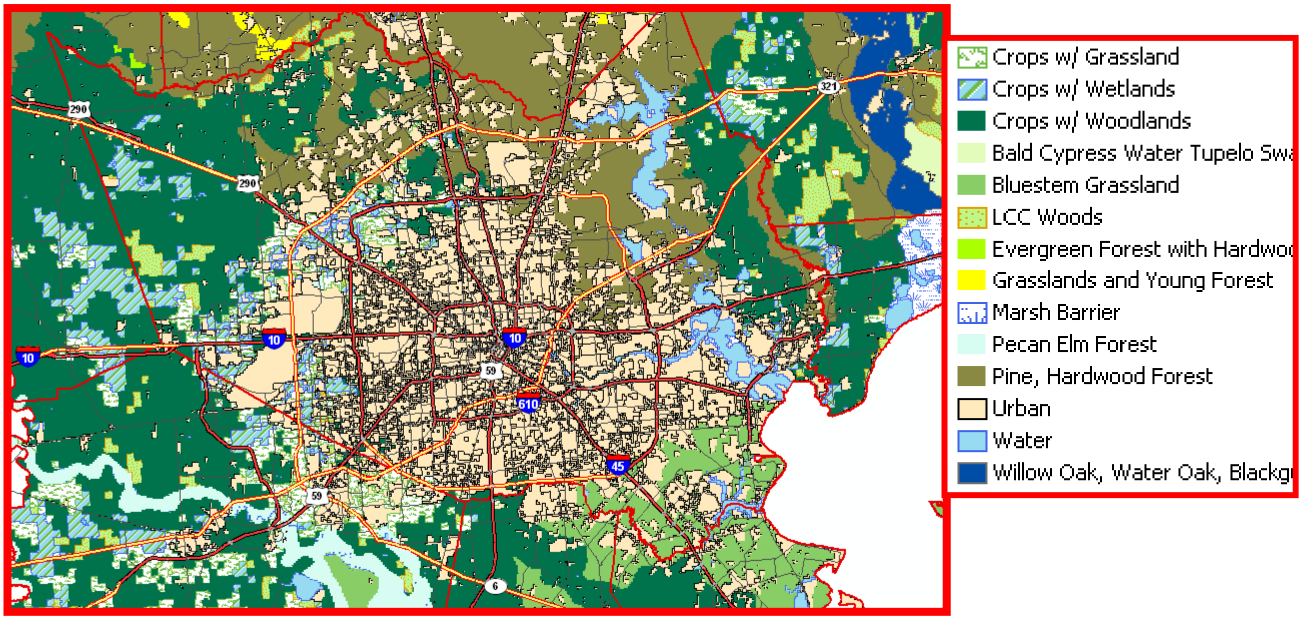

Figure 2. TCEQ biogenic land use dataset used for the modeling of the TexAQS 2000 episode. The original land cover classification of 600 types is aggregated to 14 vegetation and land cover types for readability.

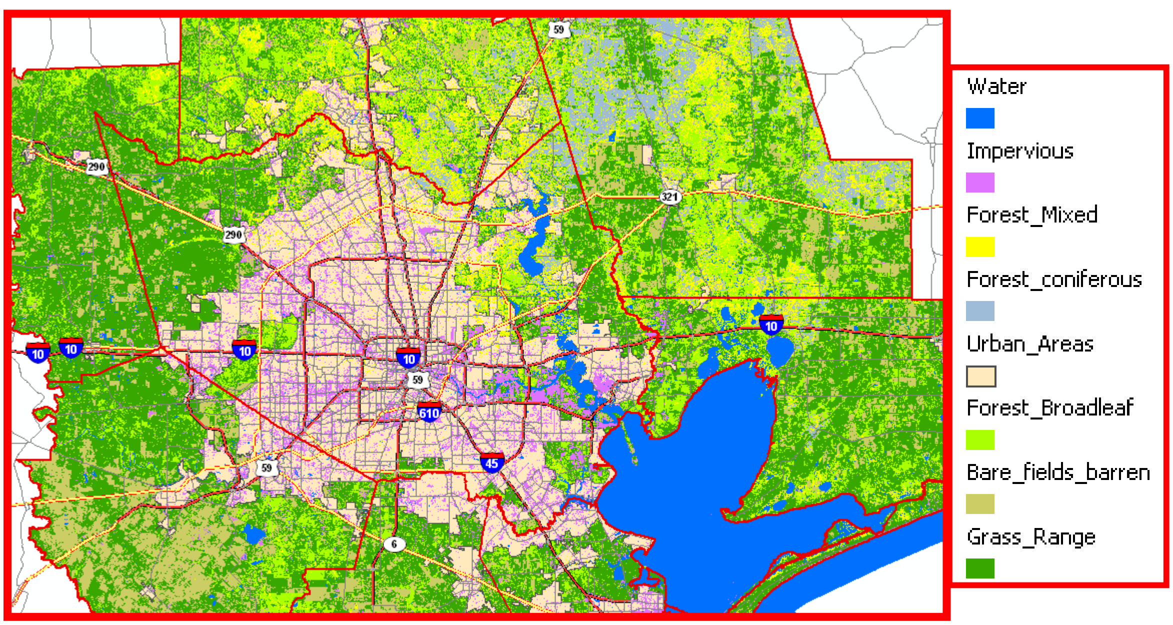

Figure 3. A composite map of land cover and urban land use classification derived from the LANDSAT data. The urban category here includes urban commercial and residential areas.

The land use classification was conducted following the cover type analysis by means of a manual interpretation of all the data, including the Cover Type classification, the LANDSAT imagery and the ancillary data sets. On screen digitizing of land use class boundaries was performed for the urban sub-classes of residential, commercial, industrial and parks. The total volume of data for the project exceeded a terabyte of information. Data sets in raster format included LANDSAT 7 satellite data, aerial photography, LIDAR data and USGS elevation data. Data sets in vector format included field plot data, county boundaries, Census 2000 urban boundaries, transportation routes, hydrology, wetlands, parks (City, County, State and National), and grid domains for air quality modeling activities.

It should be noted that the new LANDSAT based LU/LC may represent nether the identical reference year nor changes in the forest cover in Houston because the original TCEQ LU/LC data is a composite of several different data sets completed during different years. The differences we see between the two may be due to things other than the changes in forest density, though that is probably one of the major factors.

2.2 Meteorological Data

Meteorology plays an important role in air quality simulations. Nowadays, meteorological data needed for air quality assessment studies are usually prepared using a sophisticated numerical weather model, often with some kind of measurement data assimilation techniques to best characterize past meteorological conditions. Data from meteorological models are used in photochemical models to characterize advection, dispersion, cloud mixing, and dry and wet deposition processes. Recent studies suggests that the peculiar meteorological conditions in HGA, such as the land and sea breezes, development of the coastal internal boundary layer, urban heat island phenomena, and convergent influx of humid and warm Gulf air mass into the region, all affect formation, accumulation, and transport of ozone and other pollutants in very complex ways. Further, our preliminary modeling study indicates that meteorological simulation results for the HGA are very sensitive to the land surface characterization (e.g., land use and soil moisture) data, model vertical grid structure, and algorithms used for parameterization of the planetary boundary layer (e.g., Byun et al., 2003).

Use of the different land use inputs produces distinctively different meteorological simulation results. In addition to the direct impact of the leaf mass density and vegetation type information pertaining to the LU/LC inputs, changes in the temperature, cloudiness, and radiation conditions also affect the biogenic emissions rate estimates. Therefore, to fully account for the effects of the LU/LC on the air quality, the new LU/LC data must be used to characterize the land surface processes in the meteorological model, the new meteorological model output must be used to provide inputs for the biogenic and anthropogenic emission estimates, and then air quality model simulation be done using all these new inputs. While the research is continuing to assess these cascading impacts of land use change on the air quality, in this study, we have utilized the observation based temperature and PASR inputs for estimating biogenic emissions. This practice allows estimation of the biogenic emissions more realistically and also helps studying the direct effects of using the new land use data in isolation. However, air quality model simulations are performed with the MM5 simulations results, which is described below.

Observation based temperature data

Temperature measurements were obtained from several different monitoring networks. Networks were chosen if they had acceptable QA procedures in place, and data were available for the time period of interest. Differences in sensor height among the temperature networks are usually not an issue during hot summer days, when vigorous mixing leads to small temperature gradients, but they might be an issue during dry, cool, still conditions when larger temperature gradients might occur near the ground. Data from the following networks were used: Texas Commission on Environmental Quality network, Aerometric Information Retrieval System network, National Weather Service network, Texas Crop Weather Program, Conrad Blucher Institute Texas Coastal Observation Network, and National Automated Buoy Data network. Overall, data from over 100 stations were used.

The statistical technique of kriging was used to interpolate temperature measurements, thus creating a temperature field for each hour of the chosen episode. Vizuete et al. (2002) found that kriging is one of the most effective temperature interpolation methods for the purpose of creating biogenic emission model inputs. Kriging takes into account the tendency of neighboring observations to be more alike than those that are far apart. The function that describes the average similarity of any two observations as a function of distance is called the semivariogram. Because there was considerable variability in the semivariograms calculated for different times of day, unique semivariograms were estimated for each hour. Specifically, a power function was fitted to each hourly semivariogram, and the fitted power function was used in the kriging algorithm. Therefore, each hour had a different semivariogram as the basis of the interpolation. The SAS© software kriging algorithm was used in this application. Temperature fields were calculated for each hour at three different spatial resolutions: 4 km x 4 km grid cells, 12 km x 12 km, and 36 km x 36 km. The different grids were nested within each other, and were configured to exactly match the photochemical modeling domains.

Data from a temperature site not used in the interpolations were compared to the temperature field values at that location. The Soil Climate Analysis Network (SCAN) data site was located at Prairie View A&M University, in Waller County, Texas. Figure 4 shows a time series of the interpolated temperatures and the measured temperatures. The time series indicates in general, the interpolated temperatures generally depict the diurnal variation of temperature at the site reasonably well. It also shows that the overnight temperatures were generally overestimated, and the maximum temperatures, especially on very hot days, were sometimes underestimated. A scatter plot of the same data (Figure 5) shows a high degree of correlation ($r^2 = 0.94$) between the measured and modeled values. The 1:1 line indicates that the interpolation overestimates temperatures on the low end, but generally depicts the higher temperatures (i.e., >30° C) relatively well. Since the higher temperatures are more important in biogenic emissions, the temperature interpolation seems to be a sound method for estimating temperatures for biogenic emissions modeling.

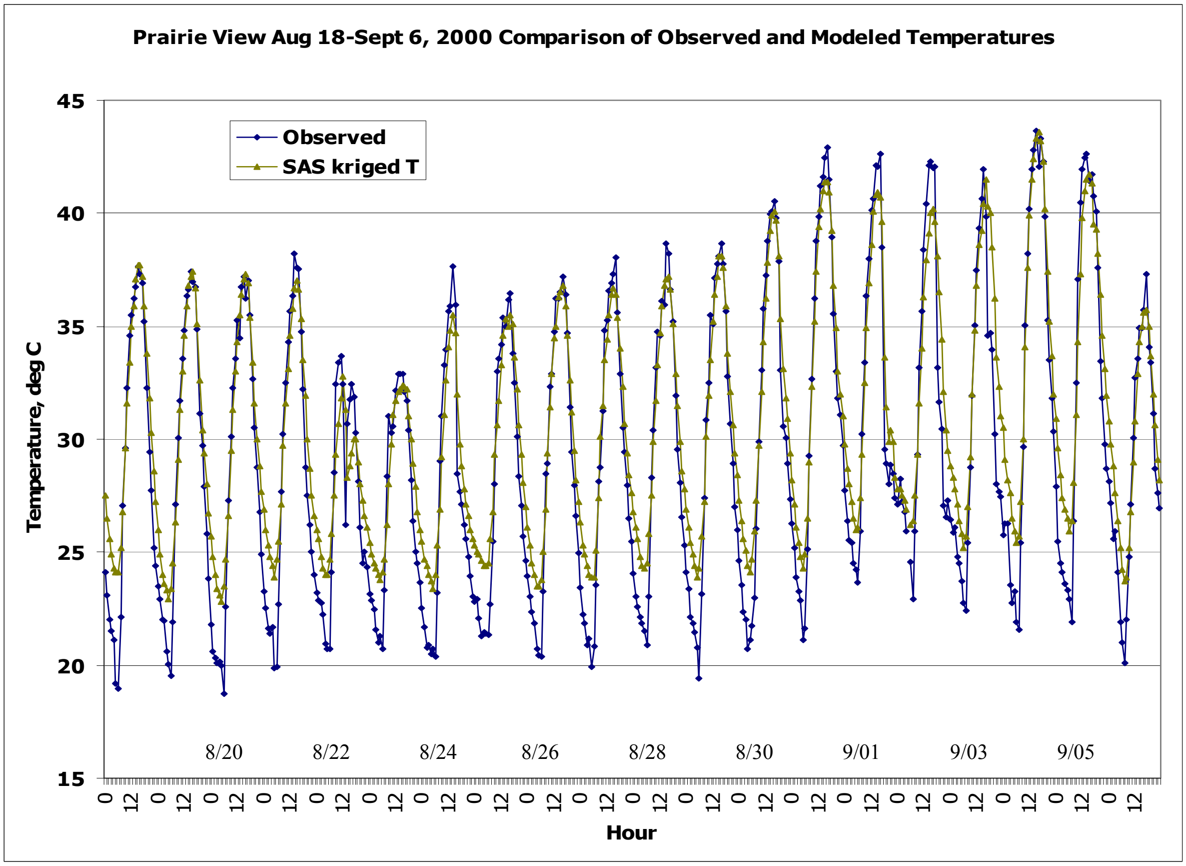

Figure 4. A sample time series of the interpolated temperatures and the measured temperatures at the Prairie View for August 19-September 6, 2000.

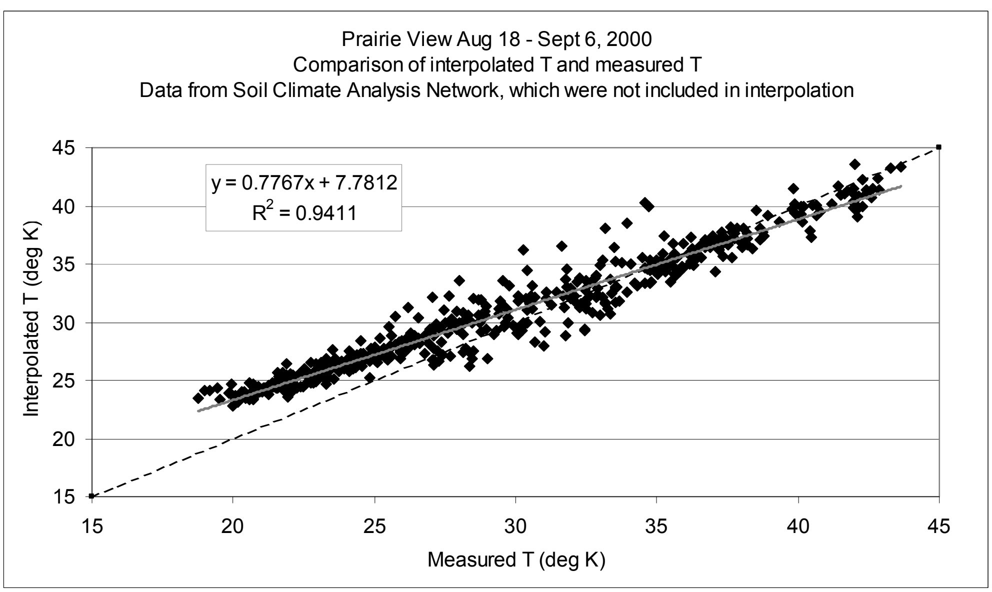

Figure 5. A sample scatter plot of the interpolated temperatures versus the measured temperatures at the Prairie View for August 19-September 6, 2000.

Photosynthetically-active solar radiation data

Photosynthetically-active solar radiation (PASR) is defined as visible radiation with wavelengths between 400 nm - 700 nm. Biogenic emissions modeling requires input of hourly PASR fields that extend over large domains. Interpolation of surface measurements is unlikely to yield a satisfactory field, given the heterogeneous nature of clouds, and the comparative rarity of PASR measurements. Meteorological models can generate PASR fields, but sometimes generate spurious clouds, which would greatly affect the PASR field. Therefore, hourly PASR fields were created using algorithms developed by Pinker et al. (2003), and input data from the GOES8 satellite. Cloud cover estimates from satellite imagery were fed into the radiation balance algorithm(s) to create a large-scale field of PASR. High resolution PASR fields were created from 1/16 degree solar field data.

Comparisons between GOES-derived PASR fields and ground-based broadband solar radiation measurements found very high degrees of correlation. Correlations for TCEQ sites ranged from 0.94 to 0.97, with slopes ranging from 0.47 to 0.53, indicating that PASR comprised approximately 50% of broadband solar radiation (i.e., 20 nm - 2000 nm). Figures 6 shows an example of the time series comparison between the GOES-derived PSAR values and the broadband solar measurements at the Baryland Park TCEQ solar radiation site. The nearest measurements of PASR at a ground station were in Mississippi, at the CONFRRM monitoring sites located in that state. Since those sites are outside the 4 km domain, the comparisons of GOES-derived data and ground observations are not as useful.

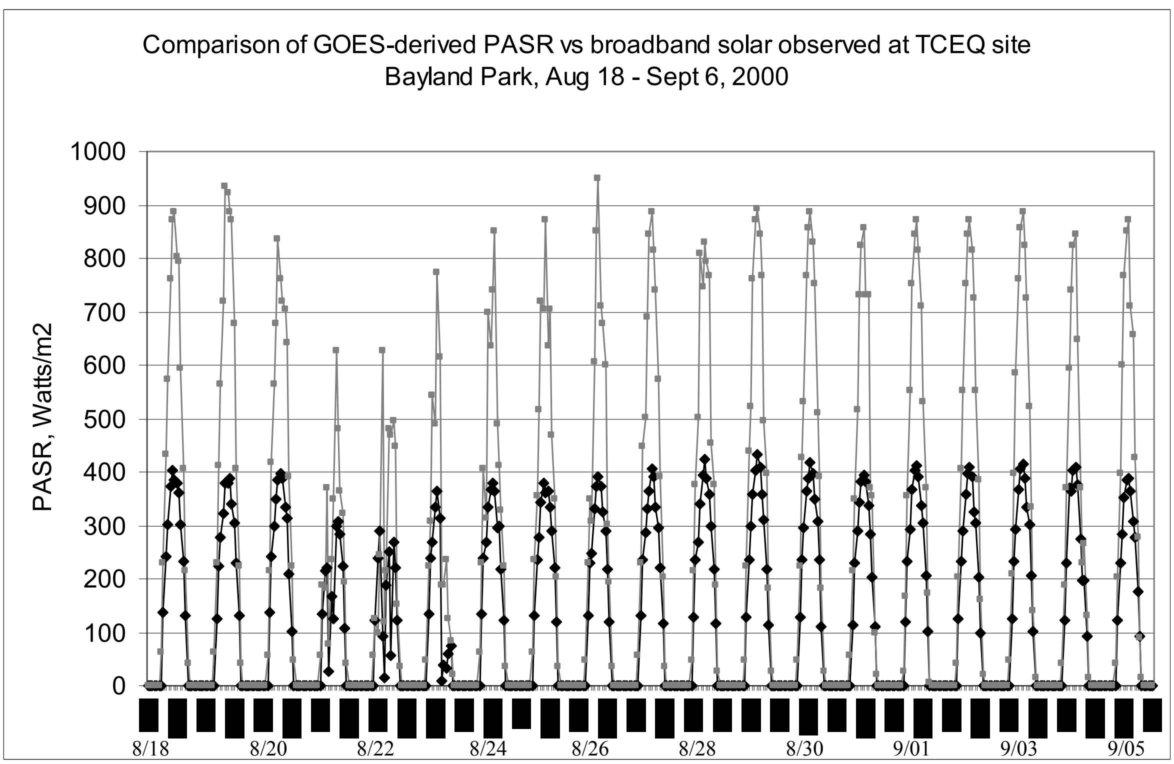

Figure 6. A sample time series comparison between the GOES-derived PSAR values and the broadband solar measurements at the Baryland Park TCEQ solar radiation site.

MM5 simulation data

In support of the TCEQ's SIP moddeling studies, Dr. John Nielsen-Gammon of Texas A&M University (TAMU) simulated the NCAR/Penn State (National Center for Atmospheric Research/the Pennsylvania State University) Mesoscale Scale Model, Version 5, Release 3.6 (MM5V3.6) (Grell, 1994) for HGA. The MM5 simulation results currently used in the HGA SIP modeling utilized the GOES-satellite skin temperature assimilation technique developed by Dr. McNider of University of Alabama Huntsville.

The vertical structure used in the MM5 simulation extended from the surface to the 5000 Pa with 43 sigma levels the frontal circulations. The first layer had a vertical thickness of approximately 17 meters. The initial and boundary conditions for the MM5 simulation were obtained from three-hourly EDAS analyses, available from NCAR. Sea surface temperature information was extracted from the surface temperatures of the EDAS analyses. The data is available through TCEQ and Texas A&M and details of the model physics options used can be found in Nielsen-Gammon (2001, 2002a; 2002b). We have used this data as the base meteorological inputs for anthropogenic emissions processing and air quality modeling to provide wind, moisture, and temperature fields, as well as parameters determining atmospheric mixing and deposition characteristics, required.

2.3 Anthropogenic emission inventory

Anthropogenic emissions are prepared with Texas Emissions Inventory (TEI) provided by TCEQ. Compared to the national emissions inventories such as U.S EPA's NET96 (National Emissions Trend for 1996) and NEI99 (National Emissions Inventory for 1999), TCEQ's Texas EI is more specifically prepared for air quality modeling studies in the Houston-Galveston ozone non-attainment area (Kim and Byun, 2003). For example, TCEQ, Environ, The University of Texas, and others have implemented emissions processing methods for building the Texas EI (ftp://www.tnrcc.state.tx.us/pub/OEPAA/TAD/Modeling/HGAQSE/Modeling/EI/) used for the HGA state implementation plan (SIP) modeling studies. In particular, the inventory data, which includes Houston-Galveston Ship Channel point-source speciated VOC emissions were developed. MOBILE6 revised by TTI (The Texas Transportation Institute) was used to estimate link-based hourly emissions for the HGA area. TCEQ's area and point source emissions are categorized into several detailed emission types by dividing total emissions geographically and with the unit functionality, as described in Table 1.

Table 1. Texas Emissions Inventory provided by TCEQ for the study of TexAQS 2000.

Source	EI sub-category	Emission Type
Area/ Nonroad Mobile	Texas area	Peak ozone day
	Texas nonroad	Peak ozone day
	Louisiana emissions	Peak ozone day
	Off-shore (shipping lanes)	Peak ozone day
	Elevated ship emissions	Peak ozone day
Point	Texas EGU	Hourly & Peak ozone day
	Texas NEGU	Peak ozone day
	Louisiana EGU	Hourly & Annual average day
	Louisiana NEGU	Annual average day
	Off-shore (platforms)	Peak ozone day
	Texas upset and additional	Hourly & Peak ozone day
On-road Mobile	MOBILE5 & 6 outputs	Hourly & link-based

3. Calculation Methods

3.1 Biogenic emissions processing with LANDSAT based land cover data

GloBEIS3 (Guenther et al., 1998; Yarwood, 1999 & 2002) is used here to process biogenic emissions for the Houston-Galveston air quality modeling. GloBEIS3 requires land use and land cover (LU/LC) and vegetation data for the estimation of biogenic emissions. One of the main purpose of this study is to compare GloBEIS3 results with the Texas biogenic LU/LC data and the LANDSAT based LU/LC data. To isolate the impact of the new LU/LC data, we utilized the observed temperature and GOES-derived radiation fields as described in the above. Combining the new LANDSAT based LU/LC data with the leaf mass density data from US Forest Service (Nowak, 2004; personal communication) we have estimated biogenic emissions with the composite LU/LC database in ArcGIS shape file format for the 8-county area and the vegetation data.

Table 2. LC classes and the mapping LC codes for GloBEIS3 processing

No.	Land Cover class [1)]	LC code [2)]	Description [3)]
1	Barren/Urban impervious	13590	Urban built
2	Forest Broadleaf	37590	Northern broadleaf
3	Forest Coniferous	37591	Northern coniferous
4	Forest Mixed	37592	Northern mixed
5	Grass	22590 22591	Northern agriculture/range - Chambers, Harris, Liberty, Montgomery and Waller Southern agriculture/range – Brazoria, Ft. Bend and Galveston
6	Impervious	13590	Urban built
7	Water	40000	Water

Note) [1)] LC classes are from Stephen Stetson's data. [2) & 3)] LC codes and descriptions area from David Nowak's table (refer to Appendix for the detailed LMD data).

The field plot information (350 plots) is combined with the satellite estimates of trees cover plots stratified by the land use type to estimate the leaf biomass by species type in each stratum. Instead of existing LC codes in GloBEIS3, new LC description table describing the detailed lead mass density (LMD) for HGA developed by David Nowak was preliminarily used to link land cover classes to new LC codes in GloBEIS3. Figure 7 provides steps used to estimate new biogenic emissions with the GloBEIS3 biogenic emissions utilizing the TFS-LULC and LMD data for HGA. Table 2 shows land cover classes available in the new data and the assigned LC codes from David Nowak. Table 3 provides biogenic NO emission factors and canopy types used in the processing. Using the 'data entry' module in GloBEIS3, the new LC codes and detailed leaf biomass data were incorporated to build a new input database for the biogenic emission processing.

Table 3. Biogenic NO emission factors and canopy type assigned

LU code	LU description	NO emission factors ($\mu g\ m^{-2}\ hr^{-1}$)	Canopy type
11590	urban residential	7.0	4
13590	urban built	4.5	4
16590	urban green	4.8	4
22590	Northern agriculture/range	100.0	4
22591	Southern agriculture/range	100.0	4
37590	Northern broadleaf	4.5	1
37591	Northern coniferous	4.5	3
37592	Northern mixed	4.5	2
37593	Southern forest	6.2	2

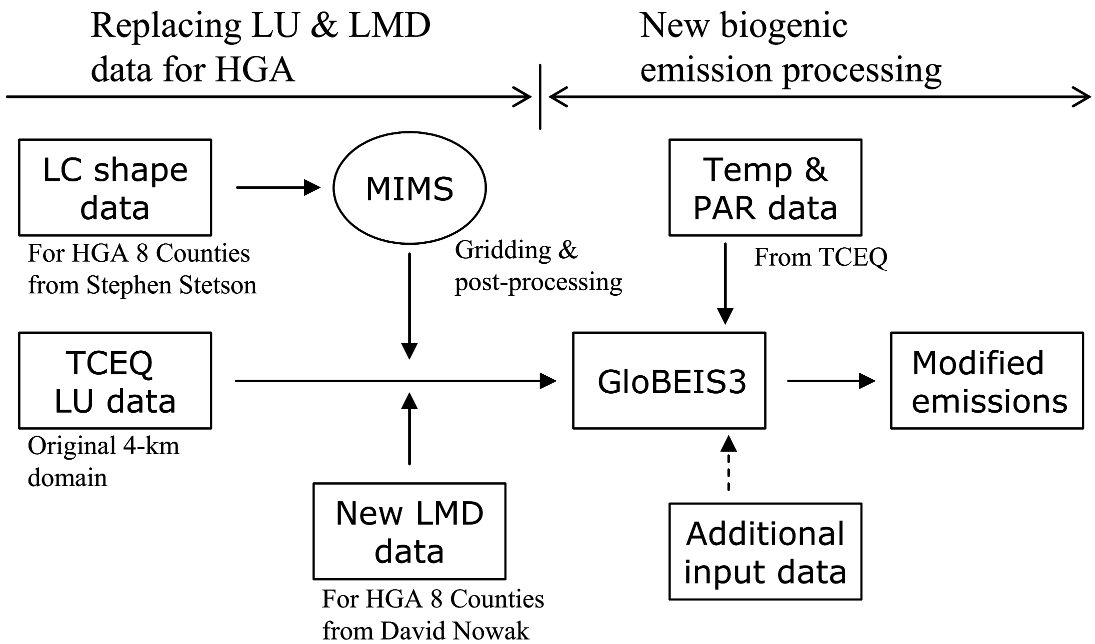

Figure 7. Modified estimation of GloBIES3 biogenic emissions utilizing new land use (LU), land cover (LC), and leaf mass density (LMD) data for the Houston-Galveston Airshed (HGA). MIMS stands for a GIS-shape file processor supported by U.S. EPA.

3.2 CAMx modeling

CAMx-ready emissions data processing

TCEQ has prepared the Texas emissions inventory (EI) used for the Houston-Galveston Area (HGA) state implementation plan (SIP) modeling studies. The inventory data are processed through the EPS2 (Emissions Preprocessing System Version 2) system (Environ 2002b), GLOBEIS3, and EPA's MOBILE6 modified by Texas Transportation Institute (TTI). The emissions data are used with the CAMx air quality model (Environ 2002a) to assess the efficacy of the emissions control strategies for the Houston-Galveston area.

CAMx-simulations

We performed air quality simulations using CAMx with the identical science options used in TCEQ's modeling for the development of the SIP. It utilizes the Lambert conformal map projection, the piece-wise parabolic method (PPM) numerical advection and vertucal eddy diffusion algorithms for transport, and the Carbon Bond version 4 (CB-4) as the chemistry mechanism. Anthropogenic emissions input was fixed but the biogenic emissions were estimated with the two different land cover datasets as described above. The model simulation results are compared with the TCEQ's Continuous Air Monitoring Site (CAMS) monitoring data.

4. Results and Discussion

4.1 Effects of land use and land cover data on biogenic emission estimates

New biogenic emissions data prepared with the TFS-LULC and LMD data for the HGA were compared with those based on the original BIO-LULC data from TCEQ. For outside the HGA, the existing biogenic emission data were used without modification. Figure 8 compares domain-wide biogenic emissions estimated with GloBEIS3 based on the two land cover data for the HGA, which covers less than the half of the total land area for the domain. While the GloBEIS3 estimations with TFS-LULC present ~ 20 % increased biogenic NO emissions, CO and ISOP (isoprene) emissions were decreased by ~ 10 %. Since NO emissions depends on land cover types rather than the vegetation itself in GloBEIS3, the land coverage and the associated NO emissions factor by LC class for TFS-LULC presents different NO emissions for the area. For CO and ISOP emissions, not only land cover changes in TFS-LULC but also new LMD applied affected on the GloBEIS3 estimations. Especially, the differences become larger during afternoons when PASR and temperature are increased. No biogenic ISOP emissions are present before sunrise and after sunset when PASR is not available. Emissions rates for all species during the last three days (Aug. 30 ~ Sept. 1, 2000) are higher then other days because the maximum temperatures were observed during the last period of the episode.

Figure 9 depicts snapshots of NO emissions for August 25th, 2000 at 12 CST and compares the spatial changes in the emission rates for the domain. It should be noted that emission rates were the same outside the Houston-Galveston 8 county area because no modification was made on the land cover and LMD data. The GloBEIS3 estimation with TFS-LULC shows decreased NO emission rates in the Fort-Bend County. We suspect that the large difference in the NO emissions between the Fort-Bend county and its neighboring counties in the east and south is due to the artifact in the original BIO-LULC database, which partially relied on county-based GIS surrogates. With the TFS-LULC data, the NO emissions are more or less evenly distributed for the 8-county areas. Higher NO emissions in the Waller County, Southern part of the Harris County, Chambers County and Galveston County are caused by the high fraction of grass land cover. Except for the Fort-Bend County, the new biogenic NO emissions are higher than those estimated with the original land cover data. With the more detailed land cover data, the NO emissions from other seven counties are considerably increased.

In general, the biogenic CO emissions have decreased with the TFS-LULC data. In particular, areas around Montgomery and Liberty Counties show significantly lower CO emissions with new land cover data than the BIO-LULC case. Shape of the decrement area looks similar to the Mixed Forest type in the land cover class. Other VOC emissions (not shown) have decreased at the northern HGA (Montgomery County) along with the forest area. Also there is general decrease in the biogenic VOC emissions in those areas where suburban/urban development has occurred.

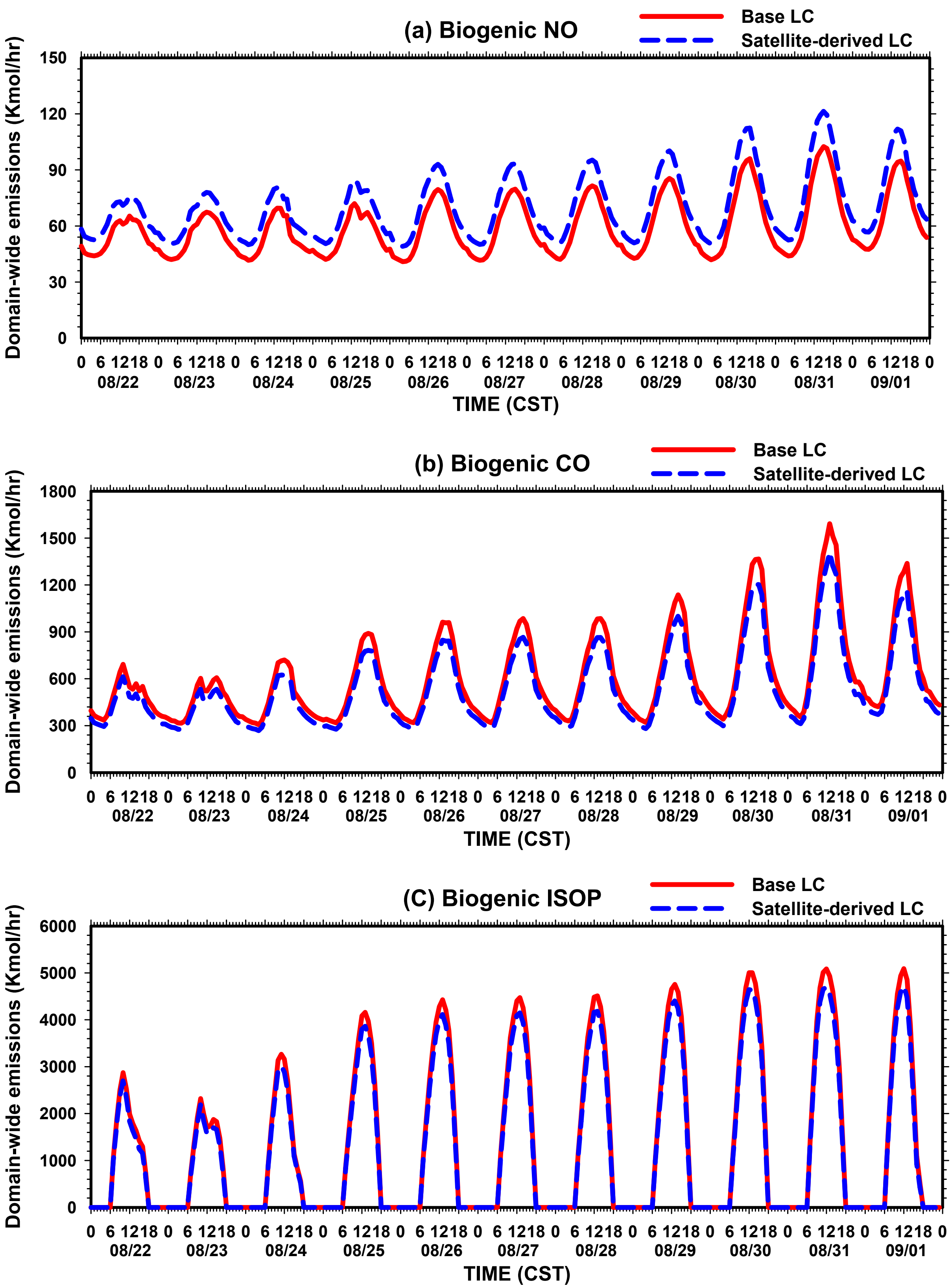

Figure 8. Diurnal cycles of biogenic emissions estimates with the TCEQ-BIO and TFS-LULC data for (a) NO, (b) CO, and (c) ISOP.

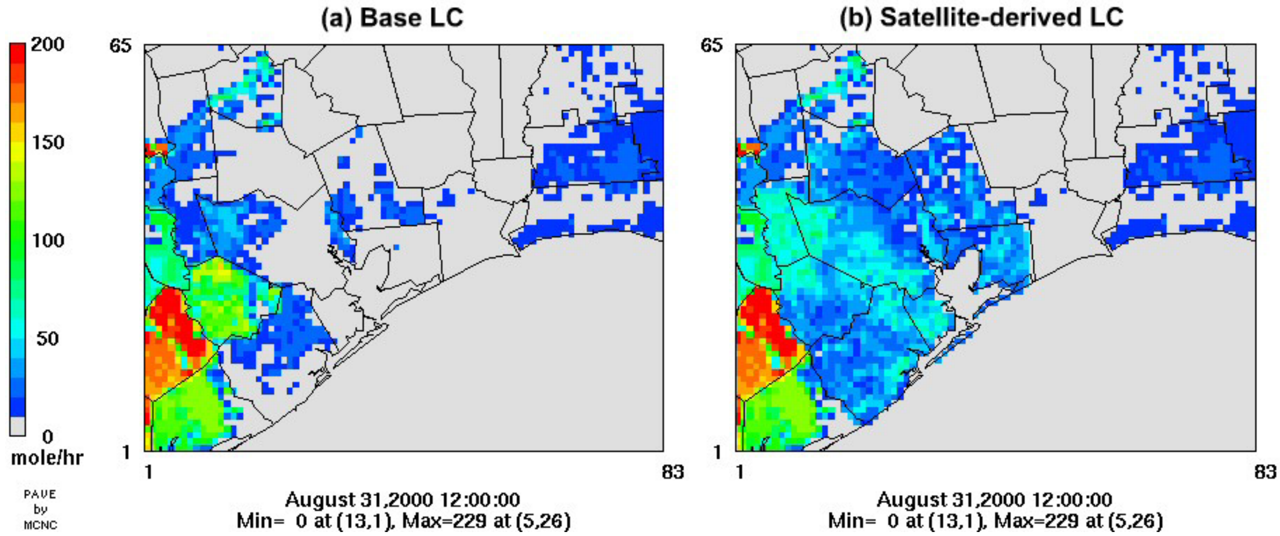

Figure 9. Spatial comparison of NO emission rates estimated using TCEQ-BIO and TFS-LULC data for Aug. 31, 2000 at 12 CST.

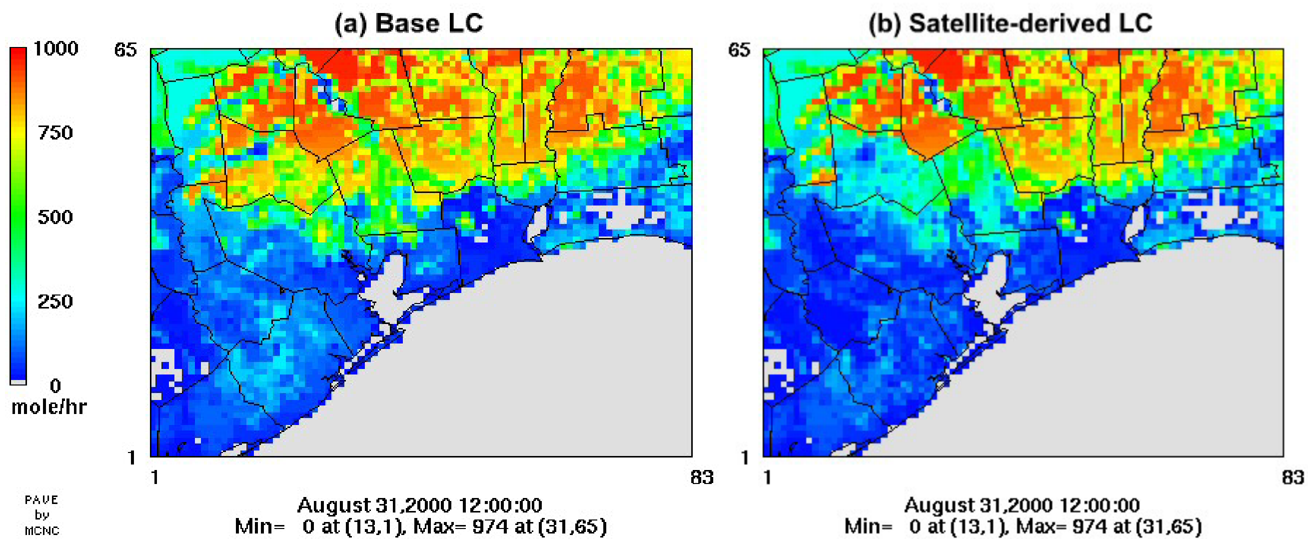

Figure 10. Spatial comparison of CO emission rates estimated using TCEQ-BIO and TFS-LULC data for Aug. 31, 2000 at 12 CST.

The areas with the most decreased ISOP emissions are located inside Liberty County, followed by Montgomery County. This is where the "Bottom Oaks" are located in the BIO-LULC database. It is suspected that the difference at this area may be due to the in-sufficient tree survey details available to match with the Satellite LU/LC classification (Mark Estes, 2004; personal communication). Most of the areas show decreased emission rates, but we can find a few spots at which ISOP emissions increased with TFS-LULC data, especially in Chambers County. No large changes in Harris County and around the Ship Channel area are observed.

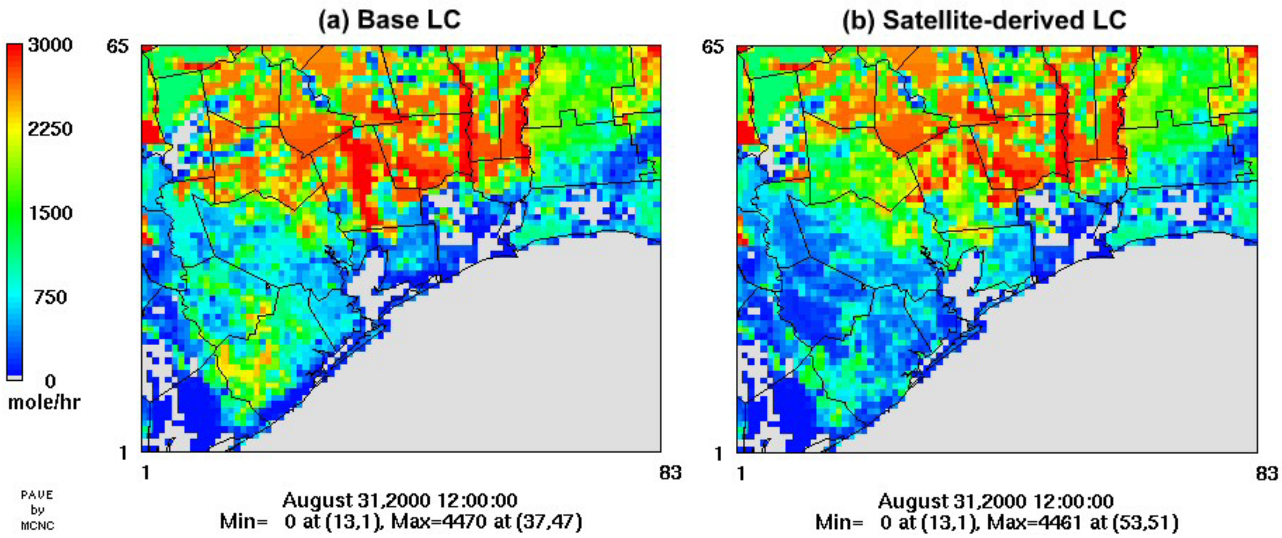

Figure 11. Spatial comparison of isoprene (ISOP) emission rates estimated using TCEQ-BIO and TFS-LULC data for Aug. 31, 2000 at 12 CST.

Isoprene emissions are mostly biogenic origin, therefore, differences shown here would affect ozone concentrations over the downwind areas of the high isoprene emissions areas. On the other hand, the contributions from the biogenic emissions for NO and CO are relative small (~5% and 8% of the domain totals) compared to their anthropogenic counterparts, such as mobile, area, and point sources. Therefore, it is expected that the changes in the biogenic NO and CO emissions would have negligible impact on air quality simulation results. Figure 12 compares the biogenic emissions of NO, CO and ISOP relative to the total emissions over the model simulation domain.

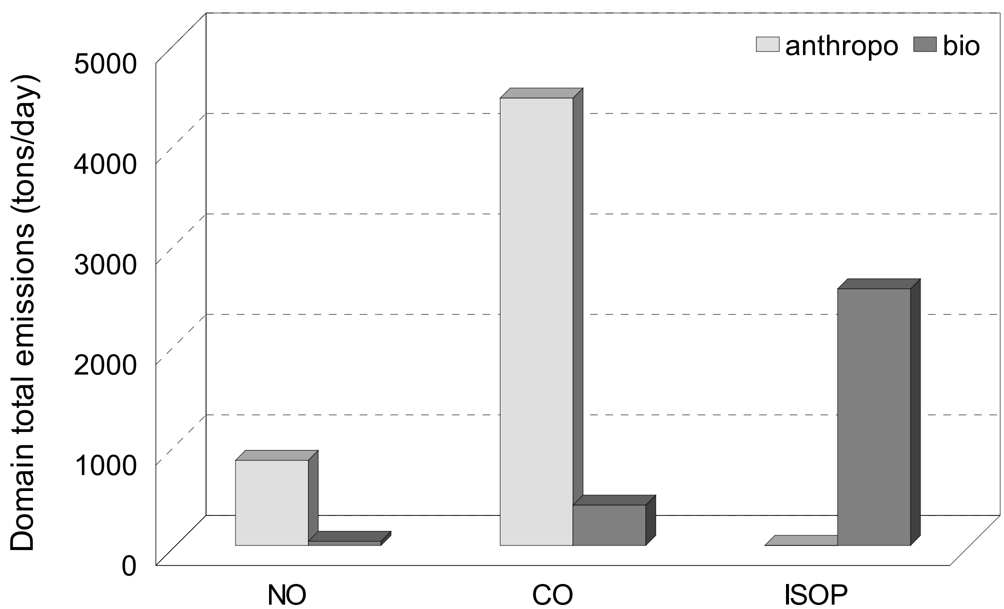

Figure 12. Comparison of domain total NO, CO and ISOP emissions from anthropogenic and biogenic sources during the period.

4.2 Sensitivity of Ozone predictions to the different biogenic emissions

To estimate impacts of biogenic emission changes corresponding to the land cover changes on ambient ozone concentrations in air quality model predictions, we have prepared two emission inputs to CAMx with GloBEIS3 using TCEQ-BIO and TFS-LULC data coupled with TCEQ's anthropogenic emissions inventory processed through EPS2. CAMx simulation results are compared with TCEQ Chemistry Air Monitoring Site (CAMS) observations (Figure 13).

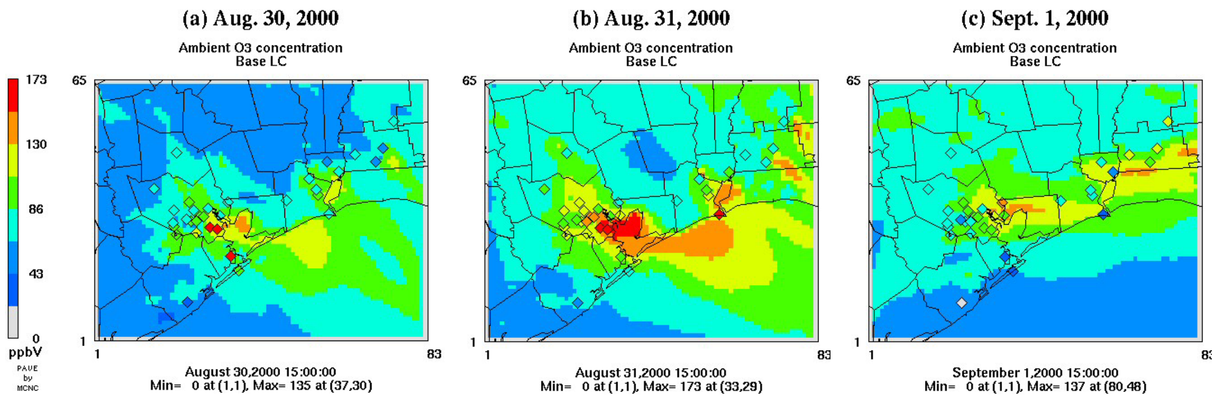

Figure 13. Ozone concentration distributions predicted by CAMx with the base case (original biogenic emissions) for (a) Aug. 30, (b) Aug. 31, and (c) Sept. 1, 2000 at 15 CST. Diamond symbols represent observed surface ozone concentrations at the CAMS sites.

Since there were appreciable changes in biogenic emissions with favorable weather conditions (i.e. high temperature and PAR) for the last three days, we present snapshots of differences in O_3 and ISOP concentrations at 15 CST of each day and time series analysis at two sites on which both O_3 and ISOP measurements were made during the span.

Differences in ozone concentrations

The impacts of biogenic emissions on the air quality depends on the dominant wind directions. For example, on August 25th and 29th, the areas of large differences occur away from the Ship Channel industry and therefore the regional peak ozone values are not changed significantly. However, on August 30th, 31st, and September 1, areas of perceivable ozone reduction are shown near the Ship Channel as well (Figure 14).

CAMx simulations present more than 10 ppb (up to 25 ppb) differences with the two biogenic emissions. As ISOP emissions decreased with TFS-LULC, O_3 concentrations also decreased for these days. The areas of large difference are located southern part of Harris County, Fort-Bend and Galveston Counties during afternoons. It is believed that the reduced biogenic emissions with TFS-LULC caused lower ambient concentrations of VOC species, mainly ISOP, in the background area and provided less opportunity for NO_x emitted from the Parrish power plant in Fort-Bend County to form as high ozone levels downwind as with TCEQ-BIO.

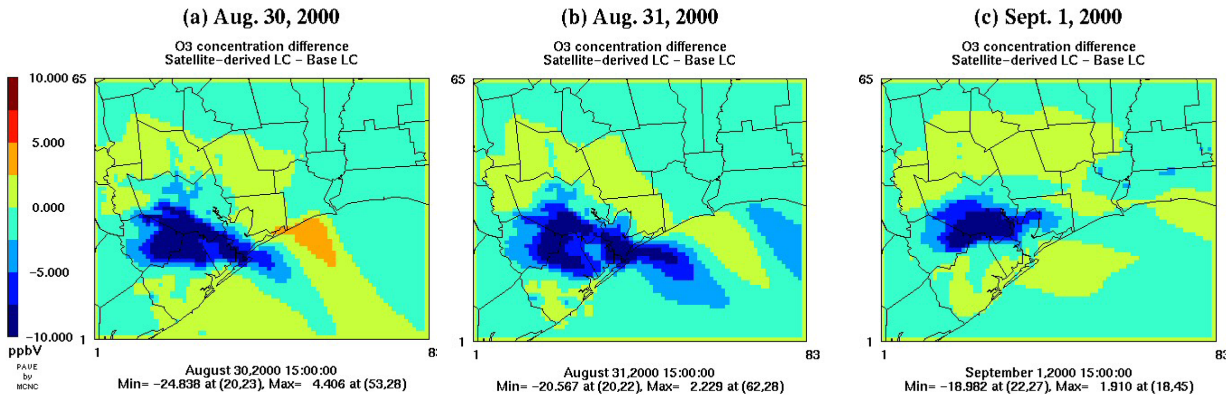

Figure 14. Ozone concentration differences in CAMx simulations with different biogenic emissions using the two LC data for (a) Aug. 30, (b) Aug. 31, and (c) Sept. 1, 2000 at 15 CST.

Time plots for predicted O_3 concentrations compared to measurements at the La Porte and Clinton show O_3 concentrations have decreased by ~ 10 ppb for the last three days and maximum differences around 15 CST (3 pm) as both simulation and observation reach the daily peaks (see Figure 15). Also, there are large area of lower ozone concentrations predicted with the new biogenic emissions in the Port Bend County and Brazoria County. The southwest area is NO_x rich, because there is a large amount of NO_x from mobile sources, and from the Parish power plant in that area. Therefore, the ozone originating in that area is probably formed in VOC-limited conditions, so changes in the VOCs (isoprenes) from biogenics will have a substantial effect. Occasionally, August 29 and 31 in particular, it seems to show that the footprint of the Parish power plant plume is more pronounced in the run with the new biogenic emissions.

As for the ozone changes in the Baytown area, we think that those are due to the problem with the new dataset's characterization of the Trinity River bottomland forests in Liberty and Chambers Counties. In Chambers County, the new data seems to account for the unique vegetation distribution in the bottomland forest, but in Liberty County, it does not. The TCEQ data set categorized the entire bottomland forest as a unique LU/LC with a unique vegetation distribution, whereas the new dataset does not. The result is that the new data shows much lower isoprene emissions in Liberty County than the TCEQ data, but similar or greater emissions in Chambers County. Note that the NOAA and DOE aircraft measurements of VOCs taken during TexAQS seem to indicate that the isoprene emissions really are higher along the bottomlands than in the adjacent areas, so this effect seems to be verified by the VOC data.

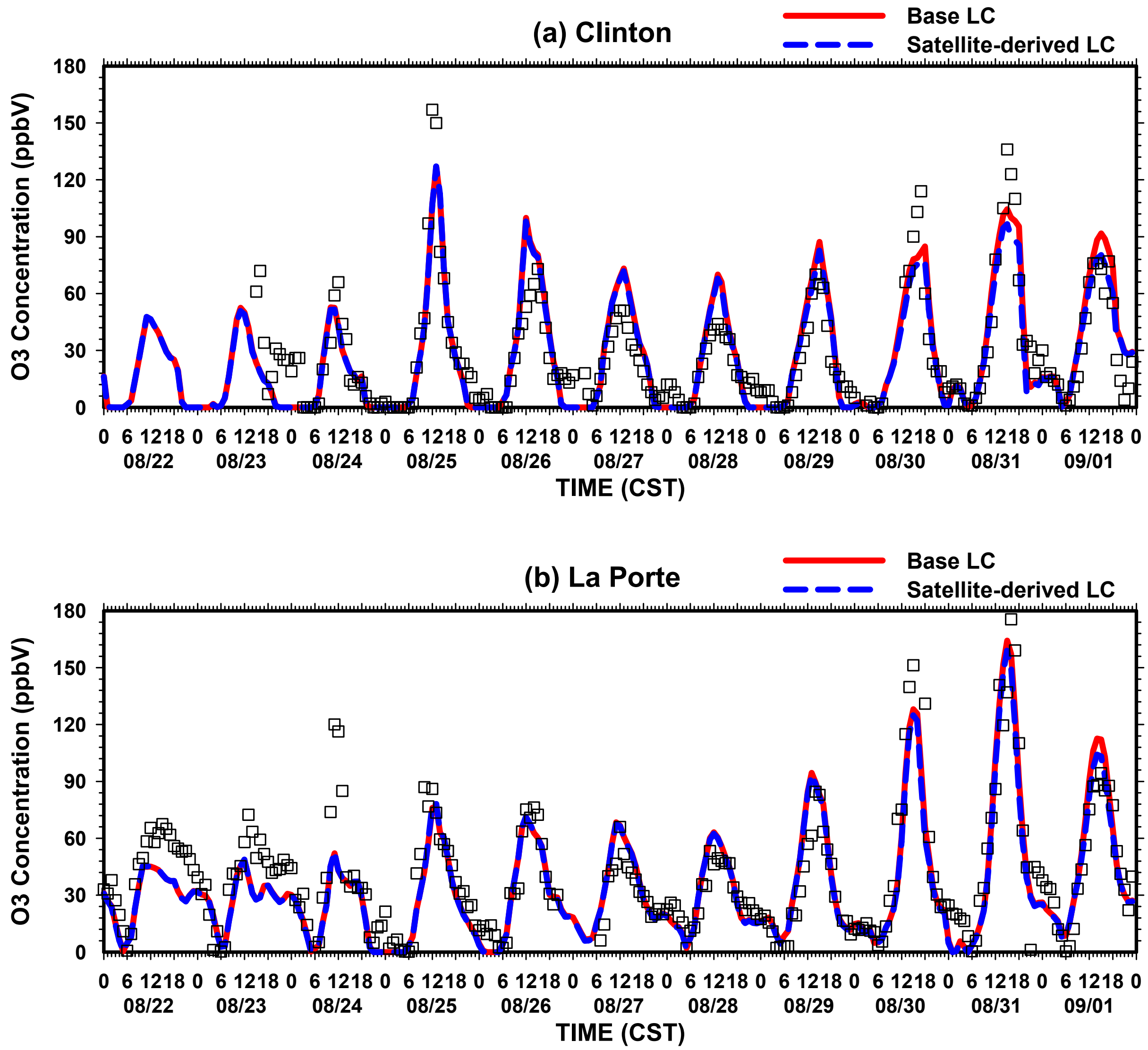

Figure 15. Predicted O_3 concentrations using two LC data compared to those observed at (a) Clinton and (b) La Porte sites during the period of Aug. 22 ~ Sept. 1, 2000.

<u>Differences in ambient isoprene concentration</u>

By comparing ISOP concentration simulated, we can evaluate the effects of land cover changes on each county. In Figure 16, ISOP concentrations in Harris and Galveston counties remain relatively the same, while those in other encompassing counties decreased except in Chambers County. The diurnal cycle plots of ambient isoprene concentrations at the two measurement sites usually shows two peaks a day by morning and by afternoon (see Figure 17). GloBEIS3 begins to estimate diurnal ISOP emissions from 7 AM (CST) as the photosynthetically-active solar radiation becomes available. At this time photochemistry is not yet active; therefore we see as much difference in the ambient isoprene concentrations as reflecting the difference in biogenic emissions estimated with the two land cover data. However, the difference begins to decrease as photochemistry becomes active and isoprene molecules are used for the ozone formation.

Another difference in peak appears around 3 PM when ISOP emissions reach the daily maximum, It is suspected that most of the fresh NO_x molecules in the atmosphere have been consumed to form terminal products or sequestered as PAN. Therefore the propagation of the OH radical diminishes considerably and further ozone formation is essentially stopped at that moment. We also suspect that the vertical eddy diffusivity in the CAMx model may be too low to represent the rigorous convective boundary layer mixing. This can be seen from time series plots for La Porte and Clinton sites. We will investigate the causes of these peculiar temporal characteristics the future sensitivity studies.

5. Conclusions

We have analyzed impacts of using the satellite-derive land use and land cover data on the biogenic emissions estimates. Combined with the field plot information, satellite estimates of tree cover (stratified by the land use type specified in the new dataset), and detailed leaf mass density data for the Houston-Galveston area developed by the US Forest Service, we estimated changes in the biogenic emissions. Air quality modeling simulations were performed using the original and new biogenic emissions input.

The results showed that the TFS LANDSAT data resulted in higher amount of biogenic NO emissions, lower isoprene and CO emissions than those from the TCEQ's original LU/LC data. Because of the contributions of NO and CO emissions to the anthropogenic counterparts were relatively small, most of the differences in the air quality were resulted from the differences in the isoprene emissions amount. There were considerable differences in biogenic isoprene emissions and subsequently the ozone predictions were affected up to 10 ppb, but the magnitudes varied each day depending on the upwind or downwind positions of the biogenic emission sources relative to the anthropogenic NO_x and VOC sources. Although the assessment had limitations due to the heterogeneity in the spatial resolution, the study highlighted the importance of biogenic emissions uncertainty on air quality predictions. However, the study did not allow extrapolation of the directional changes in air quality due to the changes in the LU/LC data from this study because of the vastly different LU/LC category definitions and uncertainties in the vegetation distributions in the two datasets.

This research only focused on the direct effects of using high resolution land cover data on the biogenic emission estimates and subsequent ozone predicted by CAMx. Land use and land cover significantly affect land-surface energy budget and meteorological conditions. Therefore, in order to account for the full effects of LU/LC changes on the local air quality, one must first address changes in the meteorological conditions. We have started evaluating methods utilizing the LANDSAT derived LU/LC data in the MM5 meteorological simulations. In addition, 1990 land cover data set is under development based on the past LANDSAT data to evaluate the changes during the last decade. In the near future, we will assess the overall effects of the different land use input on the meteorological conditions, biogenic and anthropogenic emissions, and air quality.

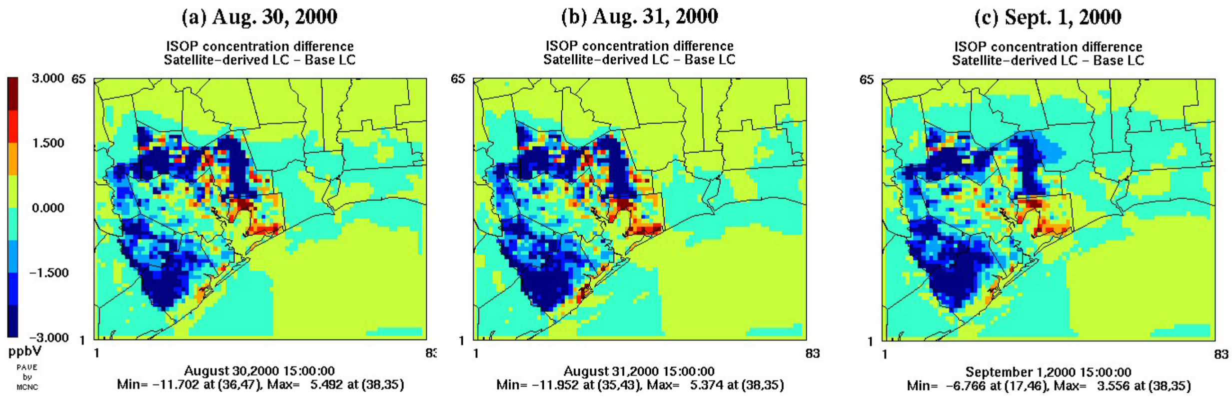

Figure 16. ISOP concentration differences in CAMx simulations with different biogenic emissions using the two LC data for (a) Aug. 30, (b) Aug. 31, and (c) Sept. 1, 2000 at 15 CST.

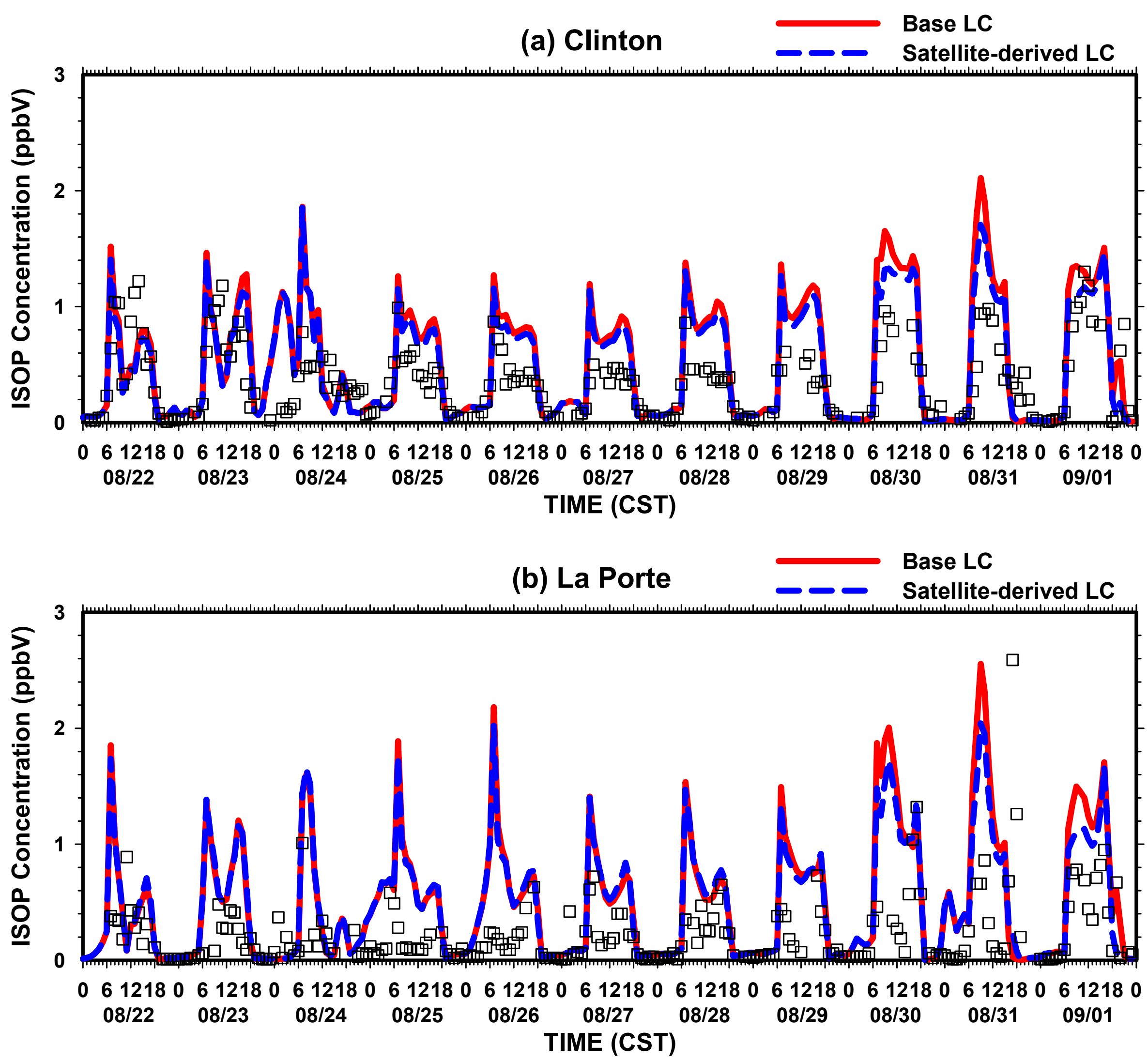

Figure 17. Predicted ISOP concentrations using two LC data compared to those observed at (a) Clinton and (b) La Porte sites during the period of August 22 - September 1, 2000.

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