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Comparison of Regional and Global Land Cover Products and the Implications for Biogenic Emissions Modeling

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Comparison of Regional and Global Land Cover Products and the Implications for Biogenic Emissions Modeling

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Introduction

Vegetation is a major source of biogenic volatile organic compound (BVOC) emissions, which have important roles in atmospheric chemistry (Fehsenfeld et al., 1992; Chameides et al., 1988; Kavouras et al., 1998; Tsigaridis and Kanakidou, 2003) and climate (Sanderson et al., 2003; Pacifico et al., 2009). Among the hundreds of BVOCs identified, isoprene and monoterpenes are among the most significant because of their relative abundance (Sindelarova et al., 2014), high chemical reactivity (Atkinson, 2000), and contributions to the formation of ozone (Chameides et al., 1988) and secondary organic aerosols (Hoffmann et al. 1997; Claeys et al., 2004; Carlton et al., 2009). Globally, isoprene and monoterpenes account for 70% and 11% of the total BVOCs emitted annually (Sindelarova et al., 2014). Average Texas statewide daily BVOC emissions were approximately 11,650 tons per day and ranked first within the continental United States in the 2011 National Emission Inventory (NEI) version 1 (EPA, 2014). Estimated emissions in Texas are not homogeneously distributed across the state. As noted by Song et al. (2008), biogenic emissions overwhelm anthropogenic emissions in the heavily forested eastern half of Texas, the latter dominates in highly developed urban areas, and yet a number of transition areas

exist where both are important to the overall VOC inventories. Accurate emission inventories from both anthropogenic and biogenic sources are required for air quality models that support the development of air quality management plans and attainment demonstrations in Texas and elsewhere in the United States where BVOCs comprise substantial fractions of the total VOC emission inventories.

For most biogenic emission models, land cover characterization, i.e. the distribution of plant functional types (PFTs), is an essential driving variable as it determines the phenological emission potential of a region (Kim et al., 2014). For instance, grasses and cropland are generally expected to have lower monoterpene emission potentials (Guenther et al., 2000) than needleleaf evergreen forest (Guenther et al., 1994). Previous studies have reported the influences of different land cover representations on modeled biogenic emissions and subsequent ozone predictions at regional and global scales (e.g. Byun et al., 2005; Guenther et al., 2006; Gulden et al., 2008; Steinbrecher et al., 2009; Kim et al., 2014; Drewniak et al., 2014). For example, Gulden et al. (2008) found that differences in vegetation profiles could lead to variations of a factor of three in mean Texas statewide biogenic emission estimates. Texas has highly diverse land use/land cover profiles over its ten climate regions. Major land cover types change from grasses and crops in the central regions to heavily forested areas towards the east. The objective of this study was to investigate the influences of different land cover representations on the estimation of isoprene and monoterpene emissions by the Model of Emissions of Gases and Aerosols from Nature (MEGAN) over eastern Texas using the Moderate Resolution Imaging Spectroradiometer (MODIS) global land cover product and a regional product with high spatial resolution and detailed land cover categories developed for the Texas Commission on

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Environmental Quality (TCEQ). In addition, emission estimates generated using MEGAN's default input data, including the default PFT distribution and gridded emission factor maps, were compared with results generated using the MODIS and TCEQ land cover data for eastern Texas. MEGAN simulations were conducted to examine the influences of different land cover datasets on the standard emission potential and emission activity factors, both separately and simultaneously. Biogenic emissions generated from different land cover scenarios were used in air quality simulations with the Comprehensive Air Quality Model with Extensions (CAMx, version 6.10; ENVIRON, 2014) to examine the effects on predicted ground-level ozone concentrations.

Methodology

MEGAN default PFT data and emission factor (EF) maps

MEGAN version 2.1 adopts the Community Land Model (CLM4) PFT scheme with a total of 16 plant functional types (Guenther et al., 2012). A default PFT dataset with a spatial resolution of 30 arc-seconds for North America is available from http://lar.wsu.edu/megan/guides.html. Only a subset of these PFTs exists in Texas, including needleleaf evergreen temperate tree (PFT1), needleleaf deciduous boreal tree (PFT2), broadleaf evergreen temperate tree (PFT5), broadleaf deciduous temperate tree (PFT7), broadleaf deciduous temperate shrub (PFT10), cool C3 grass (PFT13), warm C4 grass (PFT14), other crops (PFT15) and corn (PFT16). MEGAN2.1 also provides gridded emission factor (EF) maps based on species composition. The default MEGAN configuration uses the default PFT distribution and gridded EF maps.

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MODIS land cover product (MCD12Q1)

The MODIS land cover product is a crucial input for several MODIS products, including the MODIS Leaf Area Index and Fraction of Absorbed Photosynthetically Active Radiation (LAI/fPAR; Knyazikhin et al., 1999) and Gross/Net Primary Productivity (Running et al., 1999). The latest version of the MODIS land cover product - version 051 (MCD12Q1; Friedl et al., 2010) provides five types of land cover classification schemes at annual time steps and 500 m spatial resolution available since 2001. Type 3, shown in Figure 1a, is the LAI/fPAR Biome scheme described by Myneni et al. (1997). Type 5 data, with eight plant functional types and four non-vegetated classes (Bonan et al. 2002), was mapped to valid PFTs in Texas (see Table S1 in the Supplemental Material). For example, MODIS grass was mapped to MEGAN cool C3 grass (PFT13) and warm C4 grass (PFT14). The distribution of the two grass types was determined by the area-averaged ratio of C3 to C4 grass of MEGAN's default PFT data. A similar treatment was applied to map MODIS cereal crops and broadleaf crops into crops (PFT15) and corn (PFT16). The fractional coverage of each MEGAN PFT was calculated as the total area of the 500-m grid cells mapped as the corresponding PFT over the area of the 1-km grid cell.

TCEQ land cover product

A regional land cover product for air quality modeling in Texas was developed by Popescu et al. (2011) for the TCEQ by combining three existing databases: LANDFIRE (previously known as the Landscape Fire and Resources Management Planning Tools Project from 2004 to 2009), the

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2001 National Land Cover Dataset (NLCD), and the Texas Parks and Wildlife Department's (TPWD) Texas Ecological System Classification Project. The LANDFIRE and 2001 NLCD products were derived from Landsat imagery (Rollins et al., 2009; Homer et al., 2007); the Texas Ecological System Classification Project relied on field data collection and aerial photography to provide a land classification map at 10-m resolution for Texas (http://tpwd.texas.gov/landwater/land/maps/gis/tescp/index.phtml). As shown in Figure 1b, the TCEQ regional land cover product consisted of 36 land cover categories with 30-m spatial resolution. The TCEQ land cover classes were mapped to valid MEGAN's PFTs (see Table S2 in the Supplemental Material). For each 1-km MEGAN grid cell, the fractional coverage of each PFT was determined by summing the number of 30-m resolution cells whose centroid fell within a given grid cell.

Figure 1 here

MEGAN configuration

The emission rate (F) of isoprene/monoterpenes in units of flux (μg m^{-2} ground area h^{-1}) in MEGAN version 2.1 (http://lar.wsu.edu/megan/guides.html) is calculated as:

$$F = \gamma \cdot \sum \varepsilon_j \chi_j \tag{1}$$

where ε is the basal emission factor for vegetation type j with fractional coverage χ_j within a model grid; it represents the emission rate under standard environmental conditions with an air temperature of 303 K, solar angle of 60°, photosynthetic photo flux density (PPFD) transmission

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of 0.6, LAI of 5 m^2/m^2 consisting of 80% mature, 10% growing and 10% old foliage (Guenther et al., 2006, 2012). The standard emission potential (SEP) is identified as the summation term ($\sum \varepsilon_j \chi_j$). The SEP can be directly determined by the PFT distribution and PFT-specific emission factors or can be specified from prescribed gridded emission factor maps (Guenther et al., 2012). γ is the overall emission activity factor that is calculated based on the multiplication of several individual activity factors which account for variations in environmental conditions (e.g. temperature, light, leaf area index). Parameters are described in detail by Guenther et al. (2012). In MEGAN's canopy environment model, the distributions of light and temperature within the canopy are influenced by PFT-specific characteristics including canopy height/depth and leaf width/length; thus PFT distribution is also implicitly incorporated within the calculation of the overall activity factor. The soil moisture algorithm was not applied in the MEGAN configuration for this study but has been examined elsewhere (e.g. Tawfik et al., 2012; Potosnak et al., 2014; Huang et al., 2014; 2015).

The MEGAN configuration follows the approach of Huang et al. (2014), which utilized the National Centers for Environmental Predictions – North American Regional Reanalysis (NCEP-NARR) meteorological data (temporal/spatial resolution: 3 h/32 km), MODIS 4-day LAI product (MCD15A3; spatial resolution: 1 km), Photosynthetically Active Radiation (PAR) produced using the surface insolation data (with a conversion factor of 0.45) from the Geostationary Operational Environmental Satellites (GOES; temporal/spatial resolution: 1 h/4 km) that were obtained from the University of Alabama in Huntsville, and the remapped MODIS or TCEQ land cover products. The horizontal resolution of the MEGAN configuration was 1 km x 1 km.

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In order to investigate the influence of differences in land cover characterization on estimates of isoprene and monoterpene emissions, three sets of MEGAN simulations were conducted over eastern Texas. For each set of simulations, parallel MEGAN simulations were conducted using either the year-specific MODIS or the TCEQ land cover product while leaving other inputs (e.g. meteorological inputs, LAI) unchanged. The first set of MEGAN simulations (SM1) characterized the influence of different land cover data on the standard emission potential (SEP) by artificially assigning the activity factor (γ) to be unity. For the second set of simulations (SM2), year-specific meteorological fields and LAI data were used to drive MEGAN simulations for March-October within a six-year-period (2006-2011), during which Texas experienced relatively wet conditions (e.g. 2007) as well as extreme to exceptional drought (e.g. 2006 and 2011; Huang et al., 2014). Emission activity factors (γ) were first compared to investigate the differences associated with different land cover products. Then resulting emissions were contrasted to examine the influences on the SEP and emission activity factor simultaneously. For the third simulation (SM3), MEGAN's default emission factor maps were utilized in both land cover scenarios to demonstrate the use of a prescribed emission factor map. Monthly isoprene and monoterpene emissions (or emission activity factors for SM2) were assessed for four climate regions in eastern Texas – North Central Texas, South Central Texas, East Texas and Upper Coast – which included most large metropolitan areas in the state (Figure 1). Results were also generated using MEGAN's default PFT data and/or default emission factor maps.

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CAMx configuration

CAMx simulations were conducted over eastern Texas in order to examine the effects of land cover characterization on predicted ground-level ozone concentrations. An existing CAMx episode was used that spanned May 31 - July 2, 2006. The episode was developed by the TCEQ to support air quality planning efforts across areas in eastern Texas. CAMx version 6.10 was used with Carbon Bond 6 revision 2 (CB6r2) (Yarwood et al., 2012; Ruiz and Yarwood, 2013) as the gas-phase chemistry mechanism and the Zhang algorithm for dry deposition (Zhang et al., 2003). Meteorological fields were developed using the Weather Research and Forecasting (WRF) model. Boundary and initial conditions were generated by the Goddard Earth Observing System chemical transport model (GOES-Chem). Horizontal grid domains for the episode are shown in Figure S1; additional information regarding the CAMx configuration and model performance evaluation can be found at https://www.tceq.texas.gov/airquality/airmod/data/tx2006. The 4-km CAMx domain matched the MEGAN modeling domain; biogenic emission estimates from MEGAN that had a horizontal resolution of 1 km were aggregated to a 4-km spatial resolution. Biogenic emission estimates generated from the TCEQ and MODIS land cover data (identified as MEGAN SM2) were used in parallel CAMx simulations. The simulations differed only in the substitution of biogenic emissions generated from the different land cover scenarios while the configuration and all other inputs remained identical.

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Results and Discussion

Intercomparison of land cover products

Figure 2 shows the spatial distributions of PFTs from the mappings of the MODIS (averaged during 2006-2011) and TCEQ land cover products over eastern Texas. MEGAN's default PFT data are also shown for comparison. In general for the domain, the MODIS land cover data exhibited the highest coverage of C3 and C4 grasses; TCEQ data indicated the highest tree and shrub coverage while cropland was most abundant in MEGAN's default PFT data. The spatial distributions of the TCEQ and MEGAN's default PFT data were similar although their magnitudes differed. Figure 3 shows the area-averaged percent coverage of each PFT by climate region (corresponding values are shown in Table S3). North and South Central Texas (referred to as Central Texas) were dominated by C3 and C4 grasses in the MODIS land cover product with combined area percentages of 84% and 68%, respectively; tree coverage was negligible (< 2%). In contrast, the TCEQ land cover indicated significantly higher tree coverage (~28%; including all tree PFTs) in Central Texas with grass coverage of approximately 35%. MEGAN's default PFT data suggested a similar PFT profile with the TCEQ data in Central Texas, except the former classified large portions of grassland as crops (>30%) in South Central Texas. Less tree (~36%) and more grass (~40%) coverage in the MODIS data was also evident in East Texas relative to the other two products; the TCEQ data suggested more than two-thirds of the area in

East Texas was tree coverage while MEGAN's default PFT data indicated comparable coverage of needleleaf evergreen temperate/broadleaf deciduous temperate trees and crops in East Texas. Both the MODIS land cover and MEGAN's default data suggested more substantial crop coverage (~30%) than the TCEQ data within the Upper Coast climate region.

Figure 2 here

Figure 3 here

Potential causes for the disagreements between the land cover datasets include differences in the classification methodology, the type of satellite sensors used, uncertainty associated with the reprojection, and differences in the data spatial resolution (McCallum et al., 2006; Pouliot et al., 2014; Quaife et al., 2008). MEGAN's default PFT data were generated for North America for the 2008 time period by combining the 2001 NLCD and the Landsat based Cropland Data Layer (Guenther et al., 2012). The MODIS land cover product was developed using a top-down supervised approach based on 1860 training sites around the globe with an overall accuracy of approximately 75% (Friedl et al., 2002, 2010); yet eastern Texas was not well represented in the training sites. In contrast, the TCEQ land cover was specifically generated for air quality modeling in Texas and was developed by aggregating the much more detailed LANDFIRE classes into the Texas Land Classification System (Popescu et al., 2011). The accuracy of the LANDFIRE product in Texas and neighboring states to the northeast ranges between 60-84% and is expected to be higher when aggregated (Popescu et al., 2011). Reprojection of the MODIS dataset from the original sinusoidal projection to Lambert Conformal conic projection could result in some loss of data as suggested by Pouliot et al. (2014). The coarser spatial resolution of

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the MODIS land cover product (500 m) could also result in loss of information regarding classifications when mixed land cover types exist within a single pixel (Quaife et al., 2008). However, as shown by Figure 3, the year-specific MODIS land cover product exhibits substantial interannual variations, particularly for East Texas. For instance, broadleaf deciduous temperate trees (with high isoprene emission potential; Table S1) covered approximately 15% of the area of East Texas during 2007, a relatively wetter year, but dropped to 6% during 2011, a historical drought year. Part of this change could be associated with drought-induced tree mortality during 2011 (Texas A&M Forest Service, 2012). The TCEQ land cover data, although it has much higher spatial resolution, may not fully capture recent year-to-year changes in vegetation distributions, particularly during and after 2011, a year with exceptional drought. Nevertheless, discrepancies between the land cover datasets suggest that differences in land cover characterization have the potential to influence model predictions of isoprene and monoterpene emissions through PFT-dependent basal emission factors and emission activity factors.

Sensitivity of isoprene and monoterpene emissions to land cover characterization

Standard emission potential (SEP). With the emission activity factor (γ) assigned as unity (i.e. MEGAN simulation SM1), the resulting isoprene or monoterpene emission rate from eq 1 represents the standard emission potential. Figure S2 contrasts the spatial distribution of isoprene and monoterpene SEPs over eastern Texas generated using the MODIS (averaged over 2006-2011) and the TCEQ land cover products and PFT-specific basal emission factors, respectively.

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The spatial distributions of isoprene and monoterpene SEPs were consistent with the distribution of PFTs with strong basal emission rates (i.e. the first four PFTs in Figure 2). For example, the significant SEPs in East Texas with the MODIS land cover product were consistent with tree and shrub coverage; even with substantial coverage, grass contributed negligibly to the isoprene and monoterpene SEPs. The SEPs generated using MEGAN's default emission factor maps are also shown in Figure S2. It should be noted that MEGAN's default emission factor maps were not directly generated from MEGAN's default PFT data and PFT-specific basal emission factors; rather the PFT-specific basal emission factors listed in Table S1 represent area-weighted global averages of different ecoregions (Guenther et al., 2012).

Figure 4 shows area-averaged isoprene and monoterpene SEPs by climate region. East Texas had the highest isoprene and monoterpene SEPs among the four climate regions, attributed to the dense forest coverage. Overall, isoprene SEPs obtained from the TCEQ product were more similar than the MODIS product to MEGAN's default emission factor map; the opposite trend was evident for monoterpene SEPs. In North Central Texas, the MODIS land cover characterization resulted in significantly lower values of isoprene (by 80%) and monoterpene (by 87%) SEPs relative to the TCEQ land cover (Figure 4). Findings were similar in South Central Texas. The substantially lower SEPs with the MODIS data were associated with lower tree coverage, because the basal emission factors for isoprene and monoterpenes (sum of myrcene, sabinene, limonene, 3-carene, α-pinene, β-pinene, and *t*-β-ocimene) assigned for trees were considerably higher than those for grasses and crops (see Table S1).

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Isoprene and monoterpene SEPs from the MODIS land cover product were lower by 13% and 41%, respectively, in East Texas than from the TCEQ data. The relatively better agreement between the area-averaged SEPs between the two land cover datasets in East Texas than in North and South Central Texas was attributed to the higher tree and shrub coverage in the MODIS data (Figure 3). In the Upper Coast, isoprene and monoterpene SEPs generated with the MODIS data were approximately 40% and 30% lower than with the TCEQ data. Among the four climate regions, East Texas exhibited the greatest interannual variations in SEPs generated from the MODIS land cover data (as indicated by Figure 4); the maximum isoprene SEP over the six-year-period (i.e., year 2007) even exceeded that generated from the TCEQ data. The substantial variations in the East Texas SEPs were associated with interannual fluctuations in the coverage of trees (ranging from 28% to 40%; including all tree PFTs) and broadleaf deciduous temperate shrubs (ranging from 4% to 20%) during 2006 through 2011.

Emission activity factor (γ). In the MEGAN canopy environment model, land cover characterization is associated with the calculations of light and temperature distributions within the canopy and consequently the overall activity factor (Guenther et al., 2012). The overall emission activity factors (γ) generated from the second set of MEGAN simulations (SM2) were averaged by month and climate region for comparison. As an example, Figure S3 contrasts the spatial distributions of monthly averaged activity factors for isoprene and monoterpenes (using α-pinene) generated from the MODIS and the TCEQ land cover products for June 2011; the relative differences in emission activity factors between the two scenarios were within 10% for most grid cells. Differences in area-averaged emission activity factors associated with different land cover data were generally negligible (< 5%; Table S4). Results were similar when

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MEGAN's default PFT data were used. Most PFT-dependent canopy parameters, such as leaf length and light scattering and reflecting coefficients that are associated with the canopy environment model calculation, exhibit little or no difference among PFTs; only three parameters, canopy depth, canopy height, and leaf width differed significantly between trees and the low-growing PFTs (ref. MEGAN source codes). The canopy environment model is more sensitive to external inputs such as LAI and temperature (Tawfik et al., 2012; Huang et al., 2015), which have no differentiation among PFTs. Moreover, averaging the emission activity factors over climate regions could also mitigate the differences caused by different PFT distributions; differences could be larger at a finer spatial scale. For example, the maximum relative difference between the two land cover scenarios during June 2011 was 20%. In this particular grid cell, the MODIS data indicated 100% coverage of broadleaf deciduous temperate trees while TCEQ data indicated 96% crop coverage.

Estimation of isoprene and monoterpene emissions. The isoprene and monoterpene emissions from SM2 were compared to examine the impact of land cover characterization on modeled emissions through the differences in both the SEP and emission activity factor. Table 1 shows the estimated isoprene and monoterpene emissions (sum of four climate regions for March through October) using the two land cover products as well as MEGAN's default input data (i.e. MEGAN default PFT and emission factor maps). The TCEQ and MEGAN land cover data resulted in similar isoprene emissions (differences < 5%), while emission estimates from the MODIS land cover data were, on average, ~50% lower. Interannual variability associated with the MODIS data was also weaker (~10%) compared to the other cases. For monoterpenes, the TCEQ land cover data resulted in the highest emissions. The spatial distributions of the SEPs

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determined the spatial distribution of estimated isoprene and monoterpene emissions, as illustrated in Figure 5.

Table 1 here

Figure 5 here

Figure 6 contrasts monthly area-averaged isoprene and monoterpene emissions generated using the MODIS and TCEQ land cover products for March through October of 2006-2011. Although correlation coefficients between the two scenarios were high (0.93 – 0.98), substantial differences in the magnitude of emission estimates were apparent. MODIS-based estimates for both isoprene and monoterpenes were as much as 90% lower in North Central Texas than those generated with the TCEQ land cover characterization. Similar trends were evident in South Central Texas and the Upper Coast. Relative differences between monthly isoprene emissions in East Texas ranged from -32% (underestimated by MODIS in 2011 relative to TCEQ estimates) to 19% (overestimated by MODIS in 2007 relative to TCEQ estimates); monoterpene emission estimates obtained with the MODIS land cover were consistently lower by 16% to 46% than with the TCEQ land cover. MODIS-based estimates for monoterpenes were in better agreement with estimates from the MEGAN default input data.

Figure 6 here

Similarities between the results from SM1 and SM2 suggested that the influences of different land cover characterizations on isoprene and monoterpene emissions were primarily associated with differences in the standard emission potentials; differences in emission activity factors due

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to differences in PFT distribution had a negligible contribution to the overall differences in emission estimates in this study. It should also be noted that even when the two land cover products predicted similar monthly emissions for a region, substantial differences could exist spatially. For example, total isoprene emissions from East Texas generated using the MODIS and TCEQ land cover products were within 5% (i.e., 158 Gg/month versus 164 Gg/month) during July of 2009. However, large discrepancies were observed spatially (Figure S4) with the maximum difference exceeding 100 kg/km^2/day.

When prescribed emission factor maps such as MEGAN's default emission factor maps (Figure S2) were utilized to replace the PFT-dependent emission factors (i.e. MEGAN simulation SM3), the relative differences in monthly isoprene and monoterpene emissions generated from the MODIS and TCEQ land cover data decreased substantially (Figure S5), again demonstrating that the major uncertainties in isoprene and monoterpene emissions associated with uncertainties in land cover data were associated with the SEPs. For isoprene, average relative differences (with respect to the TCEQ product) were less than 15% for all climate regions. Relative differences between monthly monoterpene emissions were approximately 25% and 17% in North and South Central Texas; differences were less than 15% in East Texas and Upper Coast. Previous studies have also reported differences in biogenic emissions caused by different PFT distributions at global or regional scales (Kim et al., 2014; Pfister et al., 2008), but are smaller than those observed in this study. For example, Kim et al. (2014) reported differences in biogenic emission estimates over a 3 km x 3 km domain covering the Seoul, Gyeonggi, and Incheon metropolitan areas of 4.2 Gg (corresponding to a 15% relative difference) for May-June in 2008, between three PFT scenarios. Pfister et al. (2008) examined the MEGAN sensitivity to three sets of

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satellite-derived LAI and PFT input data on global and regional scales and reported a factor of two or more difference in monthly isoprene emissions. The much higher spatial resolution (1 km x 1 km) and temporal LAI resolution (4 day) employed in this study could have resulted in more significant differences in isoprene and monoterpene emissions between the two land cover products in the central regions of Texas.

Impact of land cover characterization on predicted ozone concentrations

Parallel CAMx simulations were implemented to estimate the impact of land cover characterization on ozone concentrations through differences in biogenic emissions. Figure 7 shows the spatial distributions of mean and maximum differences in maximum daily average 8-hour (MDA8) ozone concentrations, respectively, between the two land cover scenarios (shown as C_{MODIS} minus C_{TCEQ}) during June 2006. MDA8 ozone concentrations from the MODIS land cover data were lower than with the TCEQ data with mean differences of 2 to 6 ppb, while maximum differences exceeded 20 ppb. The most substantial differences were near highly developed urban areas with relatively abundant NO_x emissions, including Austin and San Antonio in South Central Texas, Dallas/Fort Worth in North Central Texas, and Houston in the Upper Coast. Figure 8 shows differences in MDA8 ozone concentrations at ambient monitoring sites surrounding the three metropolitan areas. MDA8 ozone concentrations with the MODIS land cover data were generally lower than with the TCEQ data by approximately 2 ppb; however, maximum differences in the Houston area reached 30 ppb. These results indicated that

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differences in biogenic emission estimates due to different land cover representations have the potential to lead to substantial differences in predicted ozone concentrations.

Figure 7 here

Figure 8 here

Conclusions

Uncertainties in land cover characterization could lead to uncertainties in modeled biogenic emissions and consequently predictions of air quality. This work investigated the influence of two land cover products for eastern Texas on isoprene and monoterpene emission estimates from MEGAN. In addition, estimates generated using MEGAN's default PFT distribution and gridded emission factor maps were included for comparison. In general, forest coverage was significantly lower in the global MODIS land cover product compared to the regional TCEQ product in Central Texas, which resulted in lower estimated monthly isoprene and monoterpene emissions by as much as 90%. Predicted isoprene emissions generated from MEGAN's default input data agreed more closely with those obtained using the TCEQ data; in contrast, predicted monoterpene emissions were in closer agreement with those based on the MODIS product. The influences of land cover characterization on isoprene and monoterpene emissions were dominated by contributions to differences in the standard emission potential that are dependent

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on PFT-distribution; differences in the MEGAN overall emission activity factor associated with different land cover data were generally negligible in this analysis.

Photochemical modeling was conducted to investigate the effects of differences in estimated biogenic emissions associated with land cover characterization on predicted ozone concentrations. Mean differences in MDA8 ozone concentrations were 2 to 6 ppb with maximum differences exceeding 20 ppb. Overall, these findings suggested that the uncertainties associated with land cover data could lead to significant uncertainties in modeled biogenic emissions that could be even greater than using different biogenic emission models (e.g., Hogrefe et al., 2011). Land cover in Texas is highly diverse, varying from dense forest in East Texas to grasses and croplands towards the central regions. Misclassification between trees and grasses/crops has the potential to lead to large differences in biogenic emission estimates. This could also be of particular importance in other regions of the world where rapid land cover change is occurring, such as deforestation due to an expansion in agricultural operations (e.g. South America, Geist and Lambin, 2002). Continued focus should be on reducing uncertainties in the representation of land cover through field validation and in the basal emission factors assigned for each PFT.

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Tables

Table 1: Isoprene and monoterpene emissions (Tg) for different land cover scenarios during March through October of 2006-2011.

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Isoprene	**2006**	**2007**	**2008***	**2009**	**2010**	**2011**	**Mean**	**IAV****
MODIS	0.86	0.80	0.82	0.85	1.04	1.05	0.90	10.6%
TCEQ	1.76	1.28	1.60	1.53	1.97	2.34	1.75	15.9%
MEGAN default	1.72	1.23	1.55	1.49	1.91	2.34	1.71	16.6%
Monoterpenes	**2006**	**2007**	**2008***	**2009**	**2010**	**2011**	**Mean**	**IAV****
MODIS	0.18	0.19	0.21	0.23	0.24	0.26	0.22	11.4%
TCEQ	0.45	0.41	0.40	0.40	0.50	0.52	0.45	9.2%
MEGAN default	0.25	0.23	0.22	0.23	0.28	0.29	0.25	9.7%

*October 2008 is unavailable due to missing PAR data.

**Interannual variability (IAV) was determined as the average absolute percent departure from the 2006 through 2011 mean according to the approach of Tawfik et al. (2012).

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Figure Captions

Figure 1. (a) MODIS Land Cover Type 3 Product (MCD12Q1) over eastern Texas for 2011. (b) Thirty-six land cover/land use types in eastern Texas developed for the TCEQ by Popescu et al. (2011). Developed metropolitan areas are shown in red.

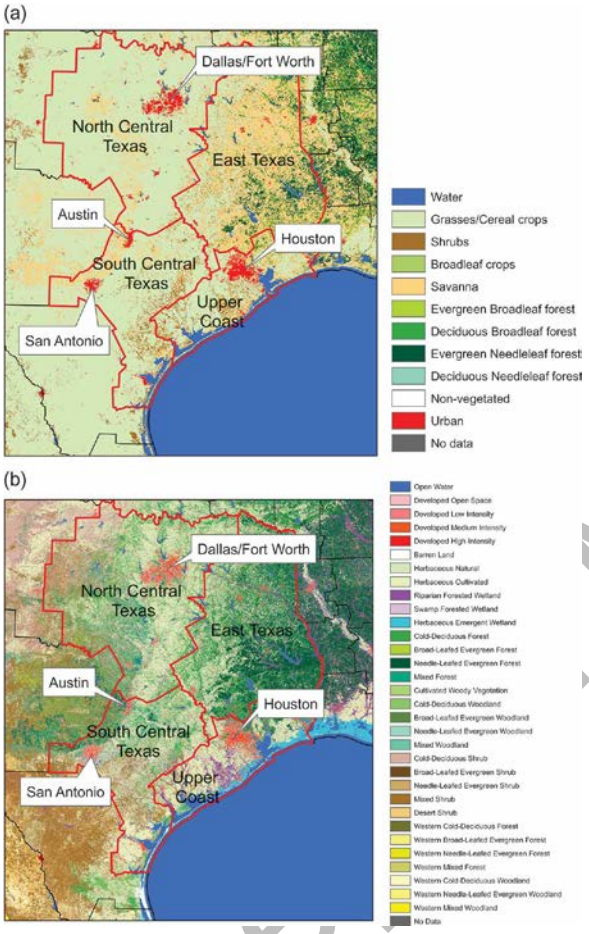

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Figure 2. Percent coverage of PFTs for the MODIS (averaged during 2006-2011) and TCEQ land cover products and MEGAN's default PFT distribution. Note that needleleaf deciduous boreal tree (PFT2) was not shown due to negligible coverage.

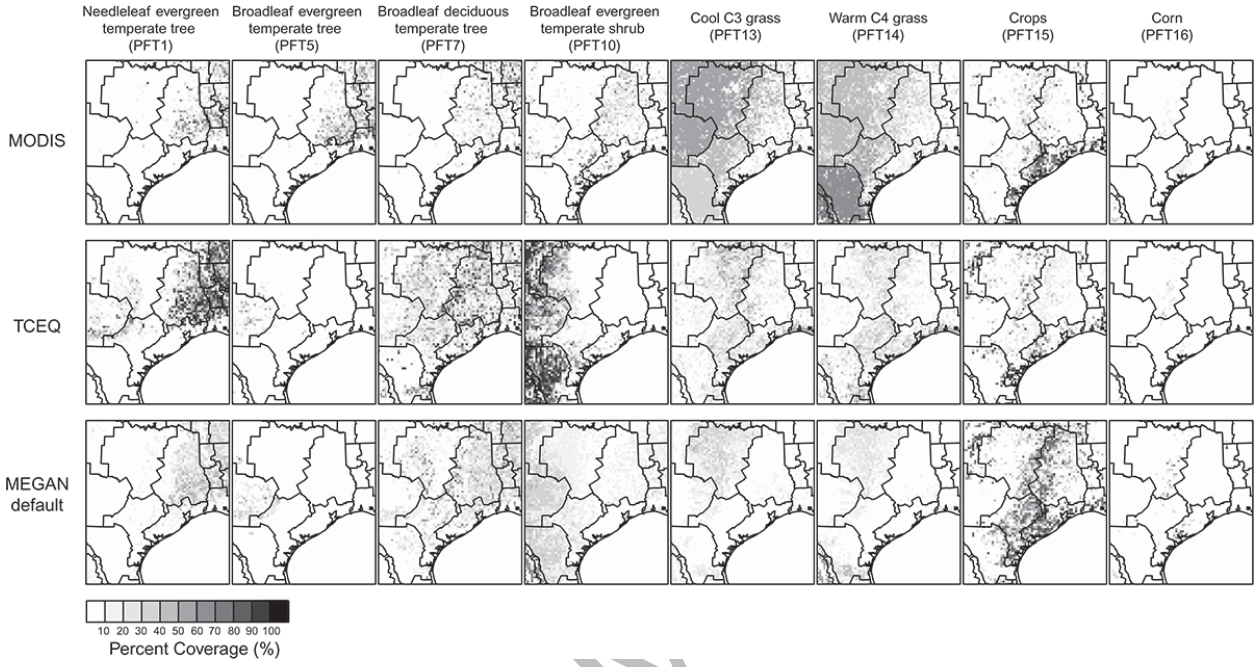

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Figure 3. Area-averaged percent PFT coverage in (a) North Central Texas, (b) South Central Texas, (c) East Texas and (d) the Upper Coast for the MODIS and TCEQ land cover products and MEGAN's default PFT distribution (see Figure 2 for PFT descriptions). Note that needleleaf deciduous boreal tree (PFT2) was not shown due to low coverage. Black lines confine the maximum and minimum range during 2006-2011.

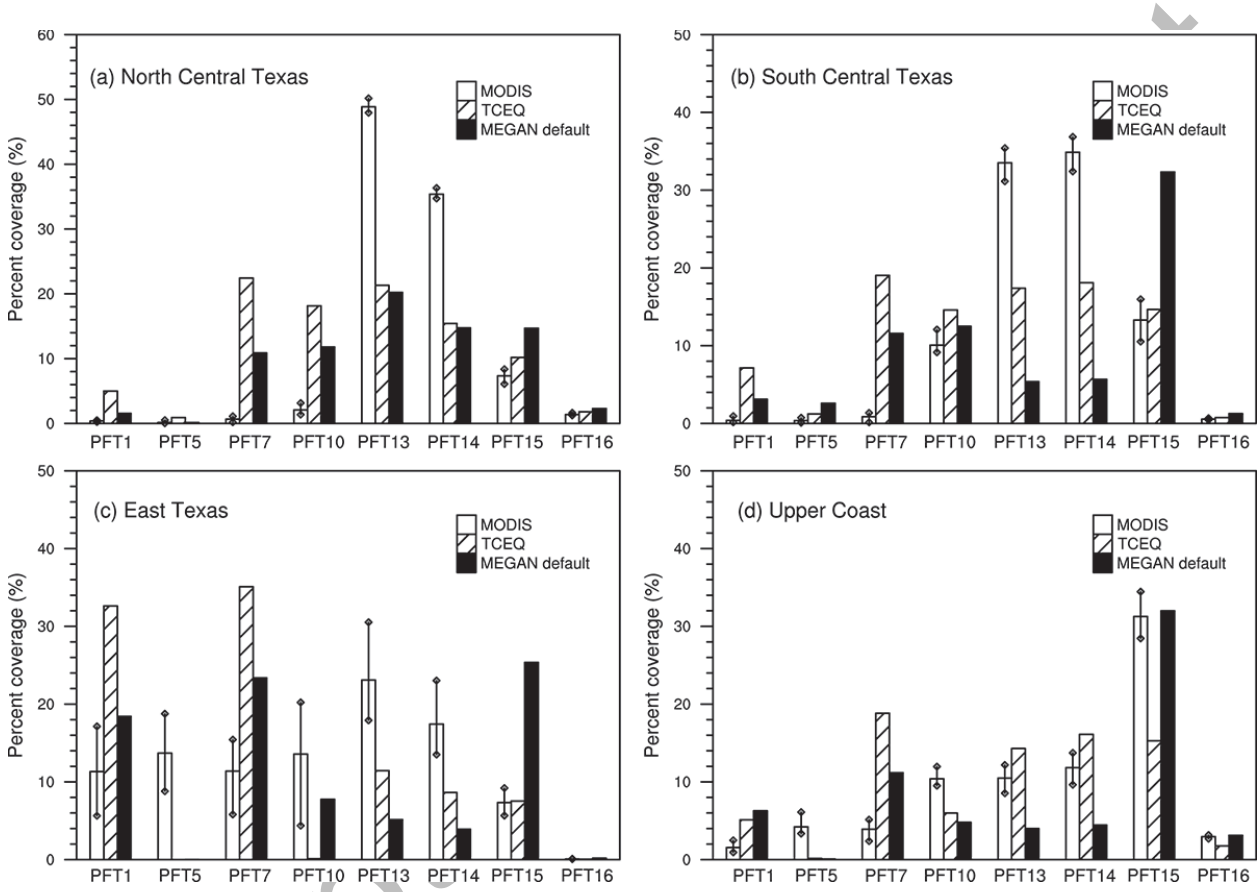

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Figure 4. Area-averaged isoprene (left) and monoterpene (right) SEP (kg/km^2/h) generated by the MODIS (averaged over 2006-2011) and TCEQ land cover products and MEGAN's default emission factor maps (results from SM1). Black lines confine the maximum and minimum range during 2006-2011.

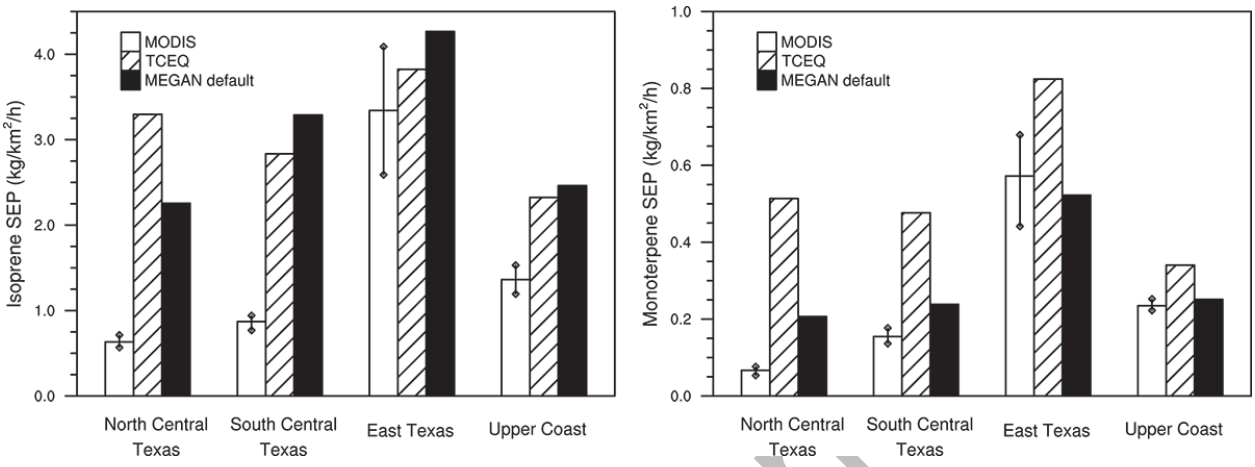

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Figure 5. Spatial distributions of summer-averaged (June-July-August) isoprene (top) and monoterpene (bottom) emissions (kg/km^2/day) generated using the MODIS and TCEQ land cover products for 2011 (results from SM2). Results generated from MEGAN's default input data are also shown.

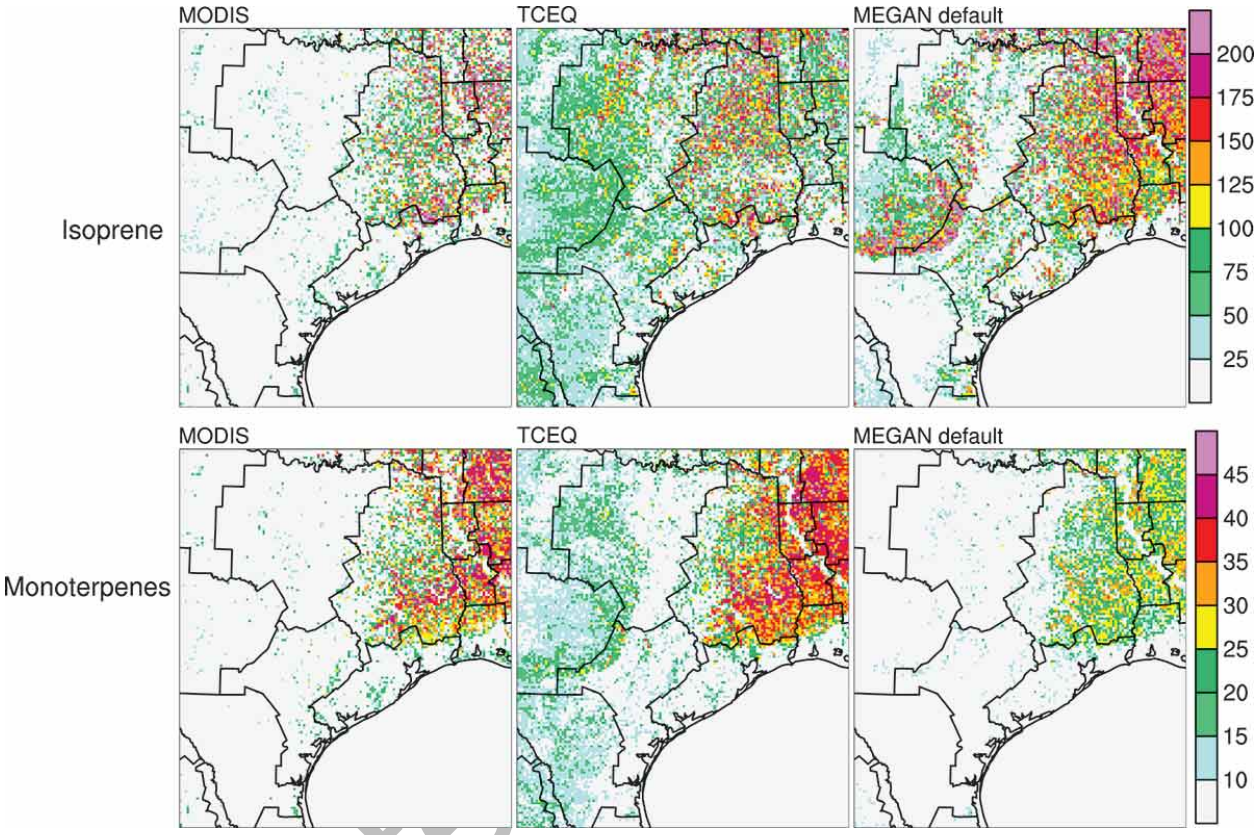

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Figure 6. Comparison of monthly averaged isoprene (top) and monoterpene (bottom) emissions (kg/km^2/day) generated from the TCEQ and MODIS land cover data and MEGAN default input data for March through October of 2006-2011 (results from SM2). October 2008 was not shown due to missing data.

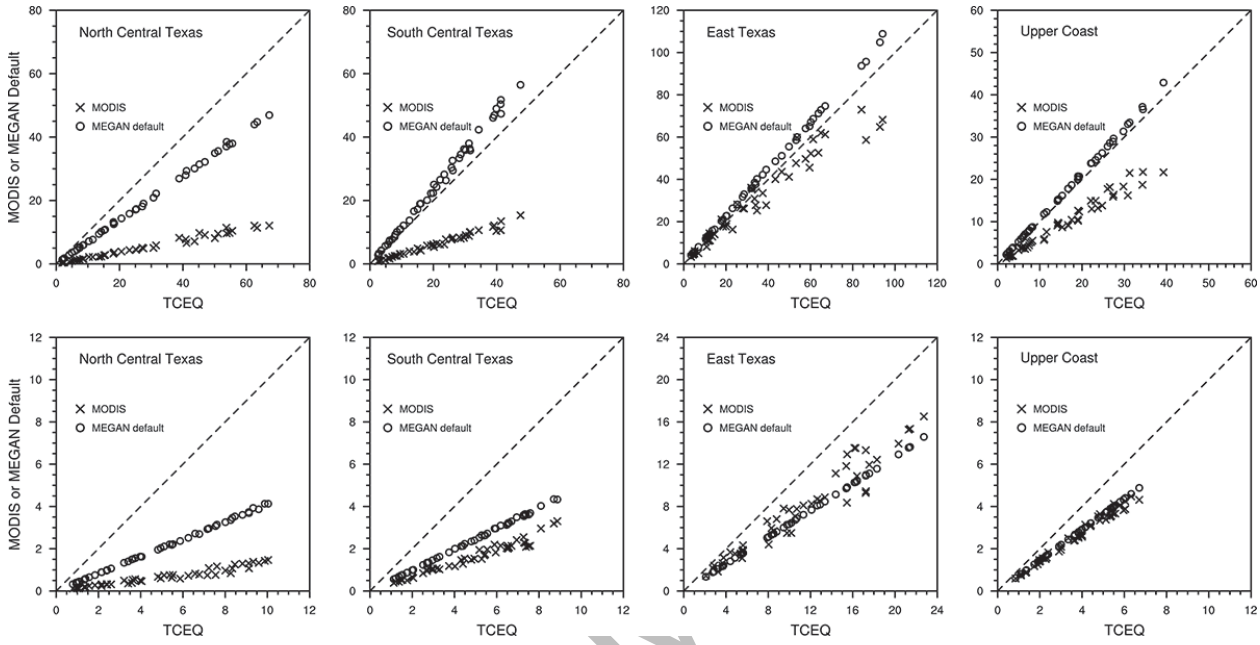

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Figure 7. Spatial distributions of (a) mean and (b) maximum differences in MDA8 ozone concentrations (ppb) between the MODIS and TCEQ land cover scenarios (as C_{MODIS} minus C_{TCEQ}) during June 2006. Major cities and counties in close proximity are highlighted.

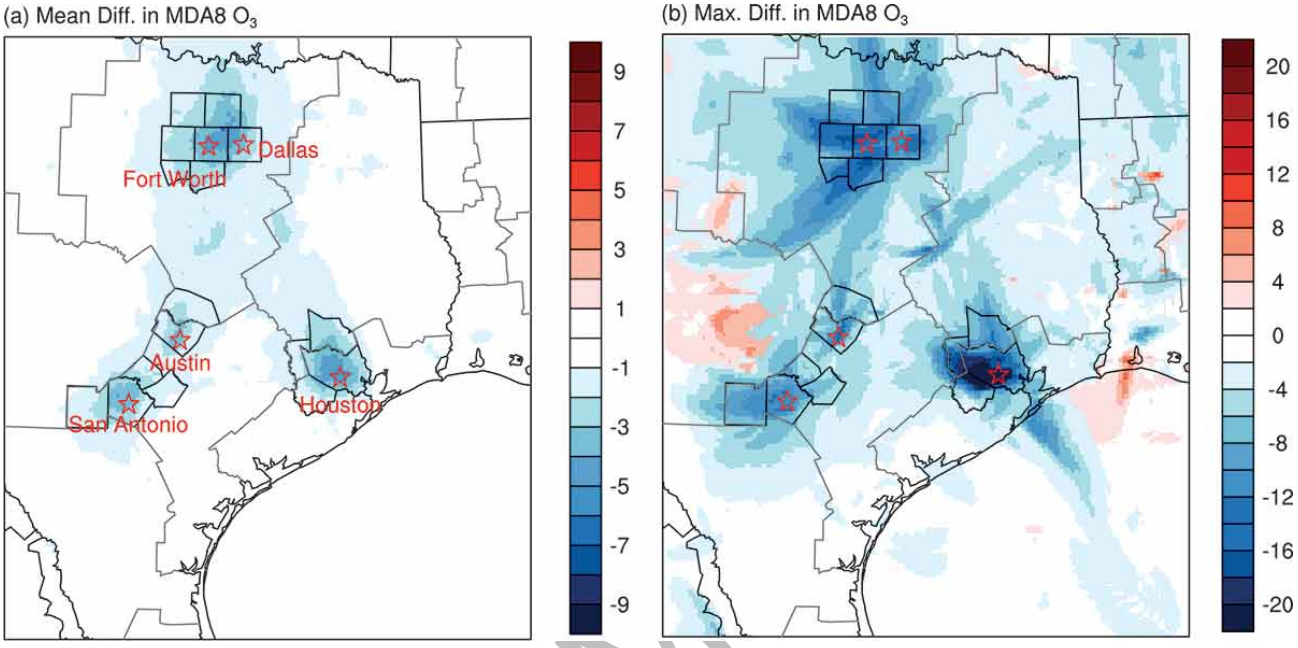

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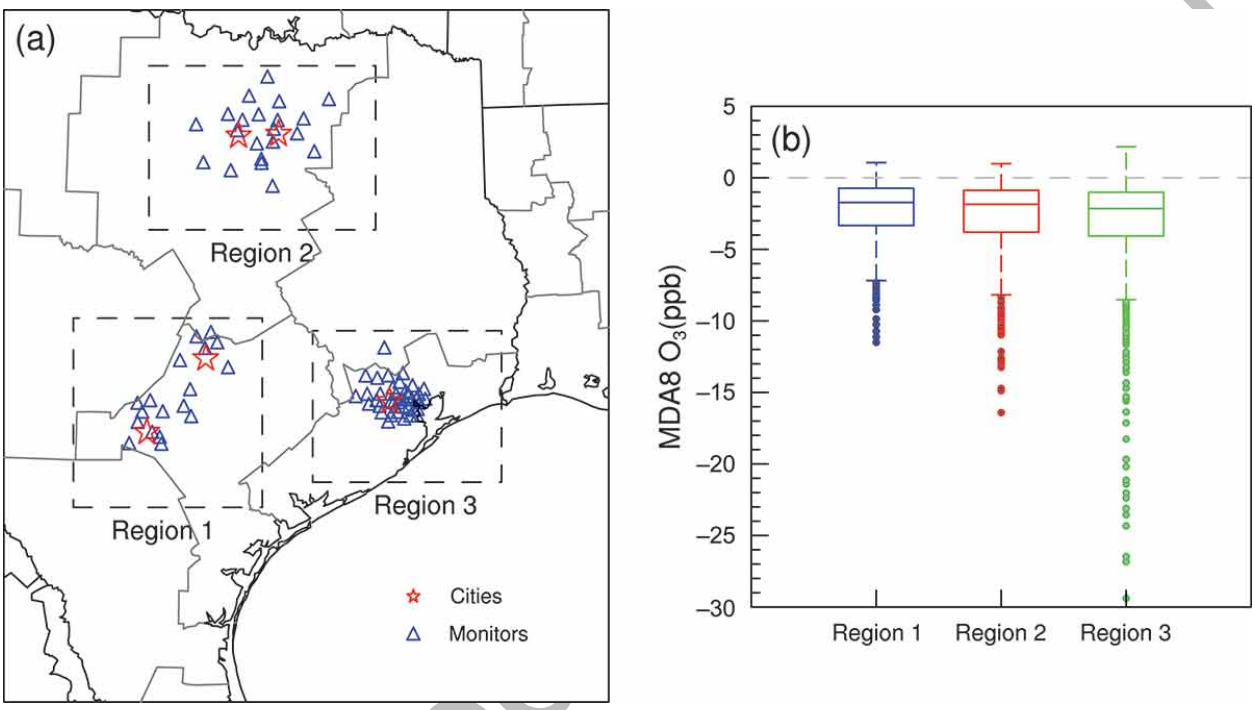
Figure 8. (a) Locations of selected ambient monitors near major metropolitan areas in eastern Texas and (b) box and whisker plot of differences in MDA8 ozone concentrations (ppb) between the MODIS and TCEQ land cover scenarios (as C_{MODIS} minus C_{TCEQ}) during June 2006. In the box and whisker plot, the box represents the 25th and 75th quartiles with the central horizontal line as the median value. The top and bottom whiskers extend to 1.5 times the interquartile range from the box. Values that lie outside the whiskers are plotted as individual points.



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IMPLICATIONS

Uncertainties in the estimation of biogenic emissions associated with the characterization of land cover in global and regional data products were examined in eastern Texas. Misclassification between trees and low-growing vegetation in central Texas resulted in substantial differences in isoprene and monoterpene emissions estimates and predicted ground-level ozone concentrations. Results from this study indicate the importance of land cover validation at regional scales.

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