Atmospheric Environment 92 (2014) 240–249

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Annual variability in leaf area index and isoprene and monoterpene emissions during drought years in Texas

Ling Huang, Elena C. McDonald-Buller*, Gary McGaughey, Yosuke Kimura, David T. Allen

Center for Energy and Environmental Resources, The University of Texas at Austin, Austin, TX, USA

HIGHLIGHTS

- Leaf area index (LAI) is a key input parameter for biogenic emissions models.
- Eastern Texas has diverse land cover and climatology with recent severe drought.
- Interannual variations in LAI can exceed 20%.
- LAI was lower during drought years.
- Declines in LAI and increases in temperature and surface insolation may exert competing effects.

ARTICLE INFO

Article history:
Received 18 October 2013
Received in revised form
9 April 2014
Accepted 10 April 2014
Available online 13 April 2014

Keywords:
Biogenic emissions
Drought
Leaf area index
MODIS

ABSTRACT

A pathway through which drought may affect estimates of emissions of isoprene and other biogenic volatile organic compounds is through changes in leaf area index (LAI), a key input parameter for biogenic emissions models. Spatial and temporal variations of an LAI product derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) and the relative impact of LAI versus meteorological fields and soil moisture on emissions of isoprene and monoterpenes were examined using the Model of Emissions of Gases and Aerosols from Nature (MEGAN) for four climate regions in eastern Texas. The four regions had diverse land cover and climatology during 2006–2011, years with recurring extreme to exceptional drought. Maximum monthly interannual LAI variations exceeded 20% in the North and South Central regions, but were less than 20% in East Texas and Upper Coast. Estimates of isoprene and monoterpene emissions in the two central regions were lower by as much as −24% due to significant reductions of LAI during droughts in 2006 and 2011. Maximum interannual variability in estimated monthly isoprene emissions exceeded 30%. Reductions in LAI during drought may be accompanied by increases in temperature and surface insolation that exert competing effects on biogenic emissions estimates.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Isoprene and monoterpenes are quantitatively among the most important biogenic volatile organic compounds (BVOCs) emitted globally from vegetation (Fehsenfeld et al., 1992; Guenther et al., 1995, 2006). Annual biogenic emissions in Texas ranked first within the continental United States in the 2008 National Emission Inventory (EPA, 2013), with 30% of the contribution from the dense hardwood and coniferous forests of East Texas. Recognition of the roles of BVOCs in tropospheric ozone and organic aerosol formation has been critical for air quality planning efforts in the state. In 2008, for example, biogenic emissions accounted for 29% and 40% of the total VOC inventories in the Dallas/Fort Worth and Houston/Galveston/Brazoria ozone nonattainment areas, respectively.

Droughts have been a recurring phenomenon throughout the southwestern United States. Most climate models suggest that droughts will persist in the future as climate changes in response to increased concentrations of greenhouse gases and other radiative forcing species in the atmosphere (US Global Change Research Program, 2009). In recent years, effects in Texas have been among the most severe; during 2011, more than 80% of Texas was under exceptional drought, which was associated with record agricultural losses and the worst year for wildfires in the state's history (Fannin, 2011). Understanding the effects of drought on vegetation and biogenic emissions is important as the state concurrently faces

* Corresponding author. 10100 Burnet Rd., Building 133, Mailcode R7100, Austin, TX 78758, USA.
E-mail address: ecmb@mail.utexas.edu (E.C. McDonald-Buller).

http://dx.doi.org/10.1016/j.atmosenv.2014.04.016
1352-2310/© 2014 Elsevier Ltd. All rights reserved.

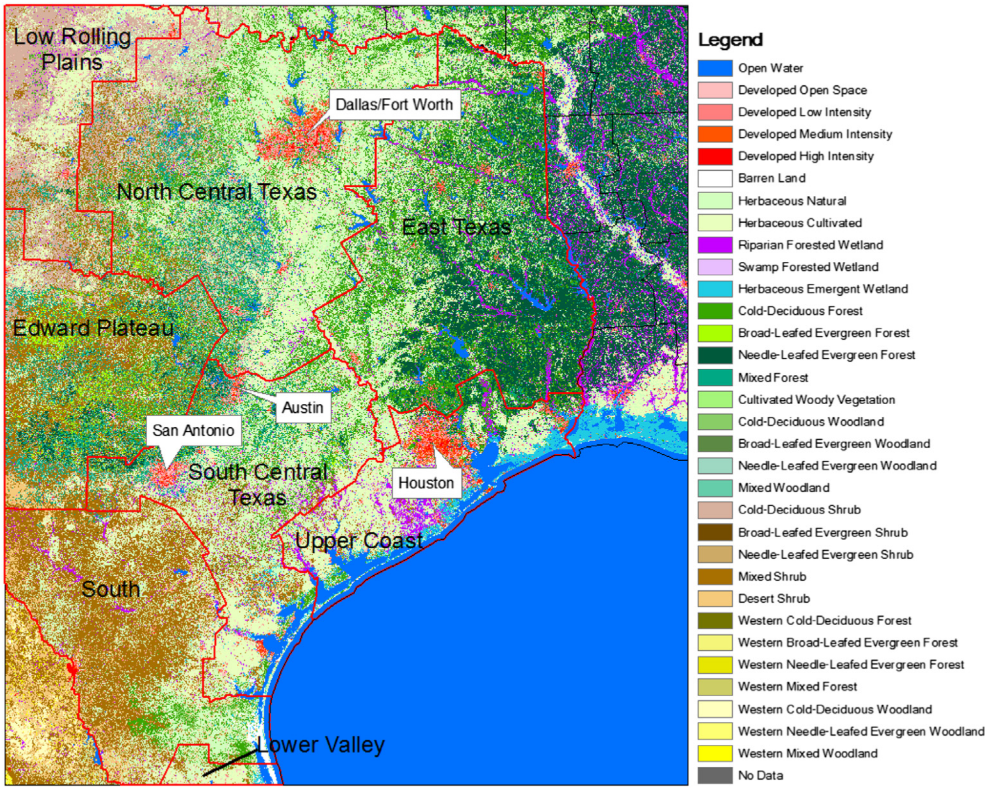

Fig. 1. Thirty-six land cover/land use types in eastern Texas (Source: Popescu et al., 2011) with boundaries of climate divisions in eastern Texas and developed metropolitan areas shown in red. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Source: National Oceanic and Atmospheric Administration

requirements to achieve and maintain attainment with the National Ambient Air Quality Standard (NAAQS) for ozone in several large metropolitan areas.

Previous studies have suggested that the impacts of drought on isoprene and monoterpene emissions depend on its severity, with relatively small effects during mild drought but more significant reductions during prolonged and extreme conditions (Brilli et al., 2007; Fang et al., 1996; Fortunati et al., 2008; Funk et al., 2005; Lavoir et al., 2009; Niinemets, 2010; Pegoraro et al., 2004). For example, Lavoir et al. (2009) found a factor of two decrease in monoterpene emissions from *Quercus ilex* in Southern France during pronounced summer drought. Leaf isoprene emissions rates have been shown to be less sensitive to water stress and recover more rapidly than photosynthetic rates and stomatal conductance (Brilli et al., 2007; Funk et al., 2005; Pegoraro et al., 2004). Based upon a conceptual model of leaf-level isoprene response to drought stress (Niinemets, 2010), Potosnak et al. (2014) proposed that emissions are initially stimulated by increased leaf temperatures due to reduction in stomatal conductance; continued drought stress suppresses emissions by reductions in substrate availability and/or isoprene synthase activity. Ryan et al. (2014) noted a lack of consensus regarding the effects of drought on reported isoprene emissions and the potential protection afforded to plants under drought stress by isoprene, indicating a need for further study.

Gulden et al. (2007) estimated interannual variability in fluxes of isoprene and monoterpenes to be 25% and 19%, respectively, in Texas. These estimates were within the range of 5%–35% reported for interannual variations in isoprene fluxes elsewhere (Abbot et al., 2003; Pressley et al., 2005; Lathiere et al., 2006; Palmer et al., 2006; Duncan et al., 2009; Arneth et al., 2011; Tawfik et al., 2012). One pathway through which drought may affect BVOC emissions is through reductions in leaf area (Vilagrosa et al., 2003; Limousin et al., 2009; Hummel et al., 2010). Leaf area index (LAI), representing the ratio of total upper leaf surface of vegetation to land surface area, is a key input parameter, along with local meteorological fields, land use/land cover classification, and soil moisture, in biogenic emissions models. Interannual variability in LAI was found to result in weak (~4%) variations in annual isoprene emissions estimates globally, but variations exceeded 30% for specific regions and months (Guenther et al., 2006). Gulden et al. (2007) identified LAI as a significant contributor to interannual variations of biogenic emissions estimates in Texas.

This work quantifies and contrasts annual and seasonal variability in the 4-day LAI product derived from the MODIS instrument and the relative influence of LAI on predictions of biogenic emissions using MEGAN across four climate regions in eastern Texas. The analysis focuses on 2006–2011, which included years with extreme to exceptional droughts as well as years with average and above average precipitation patterns.

2. Methodology

2.1. Climatology and land cover of eastern Texas

The National Oceanic and Atmospheric Administration, National Climatic Data Center (NOAA–NCDC) divides Texas into 10 climate regions, shown in Fig. 1. Most large metropolitan areas in the state are located within one of four climate regions: North Central Texas (sub-tropical steppe or semi-arid savanna), South Central Texas (sub-tropical sub-humid mixed prairie, savanna and woodlands), East Texas (sub-tropical humid mixed evergreen–deciduous forestland) and Upper Coast (sub-tropical humid marine prairies

Download English Version:

https://daneshyari.com/en/article/6339363

Download Persian Version:

https://daneshyari.com/article/6339363

Daneshyari.com