Available online at www.sciencedirect.com
ScienceDirect
Applied Geography 26 (2006) 242–259
APPLIED GEOGRAPHY
www.elsevier.com/locate/apgeog

Urban lightning climatology and GIS: An analytical framework from the case study of Atlanta, Georgia

J. Anthony Stallins[a,*], Mace L. Bentley[b]

[a]Department of Geography, Florida State University, Tallahassee, FL 32303-2190, USA
[b]Department of Geography, Northern Illinois University, Dekalb, IL 60115-2895, USA

Abstract

There are three underdeveloped components of urban cloud-to-ground lightning studies: (1) the integration of multiple flash descriptors into more informative summary metrics of flash production, (2) the comparison of flash patterns by thunderstorm type, and (3) the correspondence of urban flashes with underlying land use. We used a GIS to integrate these components as part of an analysis of warm season (May–September) flashes for Atlanta, Georgia, a sprawling region in the thunderstorm-prone southeastern US. Our integrated metric of flash counts and flash days demarcated two large contiguous areas of high flash production in northeast Atlanta. Flashes which developed under conditions related to local surface heating and air mass instability more closely corresponded to urban land uses. Frontally-produced lightning was infrequent over the central city. Instead, peaks in production shifted to the periphery of the urban core, an observation suggestive of building barrier effects.

Keywords: Urban heat island; Land use; Lightning; Atlanta; Climate

Introduction

Urban areas alter the patterns of cloud-to-ground (CG) lightning. The first studies to suggest that cities have altered flash production tallied the number of days in which thunder or thunderstorm-related phenomena were observed. This methodology was used to document increased thunderstorm activity for Chicago (Changnon, 1968) and St. Louis

*Corresponding author. Tel.: +1 850 644 8385; fax: +1 850 644 5913.
E-mail address: jstallin@mailer.fsu.edu (J.A. Stallins).

0143-6228/$ - see front matter
doi:10.1016/j.apgeog.2006.09.008

(Changnon, 1978). More recent studies have mapped CG flash data obtained from ground-based lightning detection networks such as the National Lightning Detection Network (NLDN) in the US. Steiger, Orville, and Huffines (2002) used these data to describe patterns of flash production in the vicinity of Houston, Texas. Westcott (1995) used NLDN data to document enhanced flash production downwind of several North American cities in the midwest (Dallas-Ft. Worth, St. Louis, Columbus, Louisville, Oklahoma City, and Omaha). Urban flash studies have expanded to international locations as more detection lightning networks are installed (Areitio, Ezcurra, & Herrero, 2001; Naccarato, Pinto, & Pinto, 2003).

In this paper, we use GIS to document the warm season (May–September) patterns of urban flashes for Atlanta, Georgia over the interval 1992–2003. GIS applications in meteorology are increasingly frequent and offer new ways to combine and analyze weather data (Chapman & Thornes, 2003; Shipley, 2005). We employed GIS to map Atlanta's flashes so as to utilize three analytical methods that have not been extensively applied in urban lightning research. Each of these methods has the potential to improve how we visualize CG flash patterns and how we understand the mechanisms of urban lightning.

To analyze point data, some subdisciplines of physical geography have developed integrated metrics that combine density, frequency, and dominance. Forest biogeographers, for example, average relativized percent estimates for tree density (number of trees per unit area), dominance (basal area of a tree), and frequency (number of trees) to develop a measure of the importance of a particular tree species (Curtis & McIntosh, 1951). Lightning is an analogous point pattern phenomena that might benefit from an integration of multiple descriptors. Typically, flash maps present only one flash descriptor at a time. In this study, we combined the two most widely used flash metrics, density (or intensity of flashes) and flash day counts (or frequency of flashes).

Secondly, urban flash patterns can be assessed according to the synoptic setting under which thunderstorms develop. Thunderstorms generated along the less energetic, localized instability associated with air masses and thunderstorms generated along broader, synoptic-scale frontal boundaries produce different motions and thunderstorms dynamics. These thunderstorm types have the potential to influence urban flash patterns.

Thirdly, the patterns of urban flash patterns have been cast in rather generic terms (upwind, downwind, over the city center) and land-use, as a driving influence, has been descriptively generalized. Although it is recognized that urban areas have the propensity to alter patterns of CG lightning, few studies have coupled flashes and land use categories. This is critical since the extent flashes translate into hazards is in part dependent upon the underlying land-use type. For Atlanta, we examined how flash production coincided with two land-use classes: the high-density urban cover which is a source of urban heating, and the lower density urban land-uses where the suburban population resides. By making a more nuanced, GIS-based characterization of how flash production coincides with land-use, how it changes according to synoptic setting, and how integrated flash metrics can be applied, our investigation stresses a context dependency that has been only moderately developed in other urban flash hazard studies.

Background

Anthropogenic modification of thunderstorm activity in the vicinity of cities has a long and well-documented history (see review in Changnon, 2001). With the availability of data