Spatial Modeling of Cloud-to-Ground Lightning (2005-2008) along an Urbanization Gradient in Gwinnett County, GA: the Influence of Pollution

Ona Strikas (oms10@fsu.edu)**,** James B. Elsner (jelsner@fsu.edu)
Department of Geography, Florida State University, Tallahassee, FL

Questions and Rationale

Does lightning cluster in certain areas when observed over repeated storm events? If so, does clustering vary with increasing levels of urbanization and pollution? How does this vary with different grain sizes?

More specifically, is there an amplification in recorded flashes with greater road density- perhaps associated with wind tunneling or pollution? Is there a urban effect associated with Atlanta that can be spatially modeled?

By comparing lightning flash density with metrics of urbanization- such as road density, distance from Atlanta, direction from Atlanta, pollution levels we can determine the possible effects urbanization might have flash density clustering.

Methodology

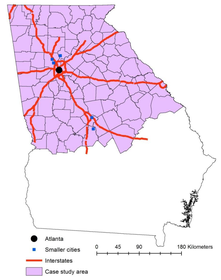
Cloud-to-Ground (CG) flashes are selected from 93 northern counties in Georgia, avoiding all tropical meteorological influence. Only warm season single cell storm CG flashes for May through August are included. Special attention is paid to Gwinnett County, identified as a lightning hotspot by Stallins and Bentley (2006)

Pointwise correlation (Getis Ord G-function) is executed to verify that repeated CG flashes is not a random or Poisson process, but demonstrates clustering. Upon clustering validation, grid cell sizes for analysis were chosen at 1km^2, 4km^2, 16km^2, and 64km^2 grids. Covariate data layers include the following: 2010 Census block population; road, highway and interstate density data; distance to Atlanta; and FAA aviation obstacles.

After processing the flashes and covariates at various grain sizes, a linear regression is executed to determine the flash density variation with covariate variation. Multicollinearity is checked, and collinear layers are removed when necessary. A backward step algorithm is used to eliminate unproductive explanatory variables.

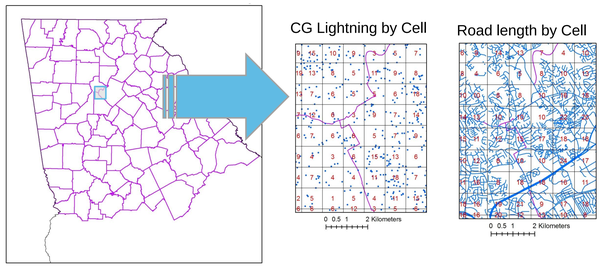
Most preprocessing was completed in ArcGIS10.0, and the other preprocessing, G-functions as well as regressions were completed in R Statistical Software.

Study Area & Data

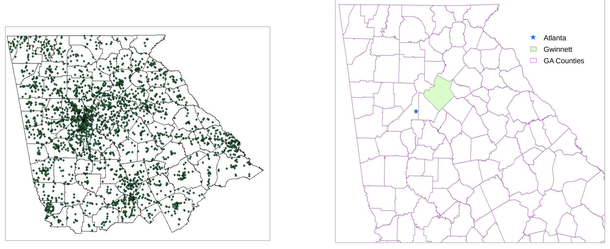


Data type	Source
CG Lightning	National Lightning Detection Network
Road network	ESRI Data Packages
City locations	U.S. Census
PM10	E.P.A.

Methodology Figures

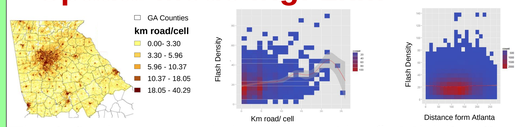


Explanation of CG lightning aggregation and road length summation at 1km^2: <500m locational accuracy & >95% detection accuracy. Road length accuracy: <5m



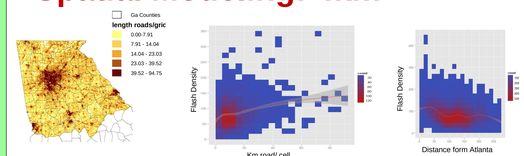
Left: Map of listed FAA obstacles sites in study area for flash density analysis. The height of these objects vary from 18-2000 feet above ground level. Right: Map indicating Gwinnett County in relation to Atlanta

All of North Georgia Grids Spatial Modeling: 1km^2



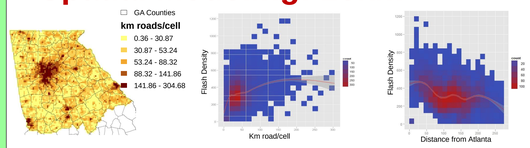
The left shows road density at 1km^2, Middle: flash density positively correlates with road density, the right shows no trend between flash density and distance to Atlanta.

Spatial Modeling: 4km^2



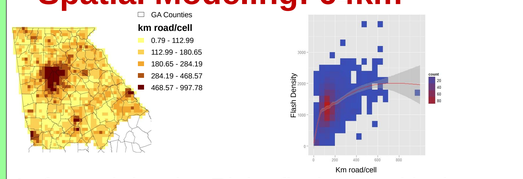
Left: Road density; Middle: n=2000 grids flashes positively correlate with roads, Right: flashes negatively correlate with distance from Atlanta

Spatial Modeling: 16km^2



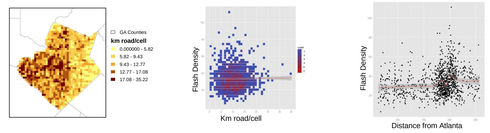
Left: road density, Middle: flashes positively correlate with road density, Right: flashes negatively correlated with distance to Atlanta

Spatial Modeling: 64km^2



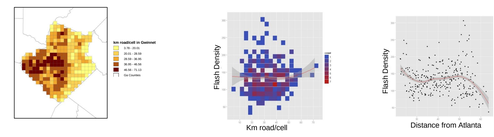
Left: road density, Right: flashes positively correlate with road density.

Spatial Modeling: Gwinnett County : 1km2



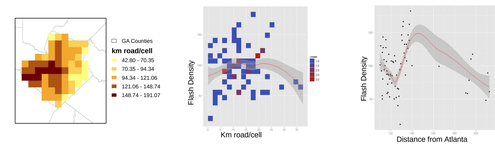
Gwinnett County, GA has previously been identified as a hotspot for lightning (Stallins & Bentley 2006). The left shows road density at 1km^2, Middle: no trend between flash density and road density, the right shows no trend between flash density and distance to Atlanta.

Gwinnett Modeling: 4km^2



Left: Road density in Gwinnett; Middle: no trend between flash density and road density. Right: flashes negatively correlated with distance from Atlanta at large values

Gwinnett Modeling: 16km^2



Left: Road density in Gwinnett; Middle: no trend between flash density and road density. Right: sigmoidal trend between distance from Atlanta and flash density

Modeling of FAA Aviation Obstacles

Year	ean Flash Density/km^2	Flash Density/km^2 within 100m of FAA obstacle	p-value of t-test
2005	7.75	10.59	1.995e-9**
2006	2.91	5.54	9.68e-12**
2007	6.37	7.44	.000658
2008	3.92	5.02	4.96e-05

Discussion and conclusions

The point-wise correlation demonstrated clustering in all subsets for CG flash densities. Population was removed as an independent variable due to collinearity with road density (r^2=.98; r^2=.90). All scales demonstrate a positive correlation between road length (km road/km^2 area- a metric for density). Only the larger scales demonstrate a negative correlation between distance to Atlanta and flash density. There is no correlation between distance to Atlanta and flash density at 1km^2.

The Gwinnett analysis supports Gwinnett County being a hotspot for lightning, and within Gwinnett County, the incidence of lightning not being dependent on road density. At larger values, distance from Atlanta becomes negatively correlated with flash density in Gwinnett.

The FAA aviation obstacles, expectedly, exhibit higher incidence of lightning than North Georgia as a whole. This trend is consitent across years. Inferential modeling yields new insights into the field of urban lightning.

Selected Sources and References

Bentley, M. and Stallins, J. (2005), "Climatology of Cloud-to-Ground Lightning in Georgia, USA, 1992–2003". International Journal of Climatology. 25:1979-1996.
National Lightning Detection Network-Vaisala SSC
World Wide Lightning Location Network
Stallins, J. Bentley, M. (2006), "Urban lightning climatology and GIS: An analytical framework from the case study of Atlanta, Ga". Applied Geography 26:3-4.
R Development Core Team (2011). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.
Rose, L, et al (2008), "Concurrent cloud-to-ground lightning and precipitation enhancement in the Atlanta, GA (United States), Urban Region". Earth Interactions. 12:11-28.