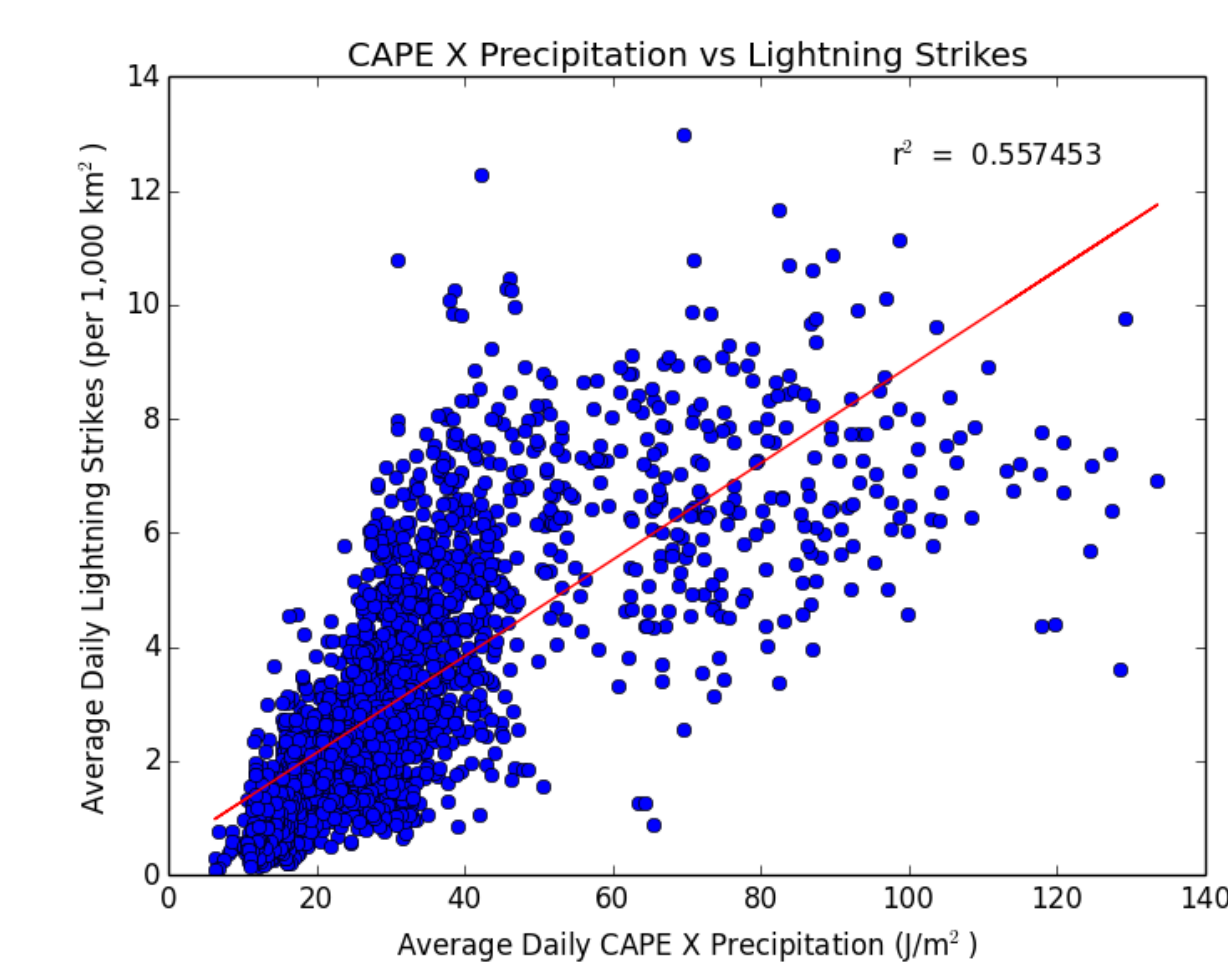
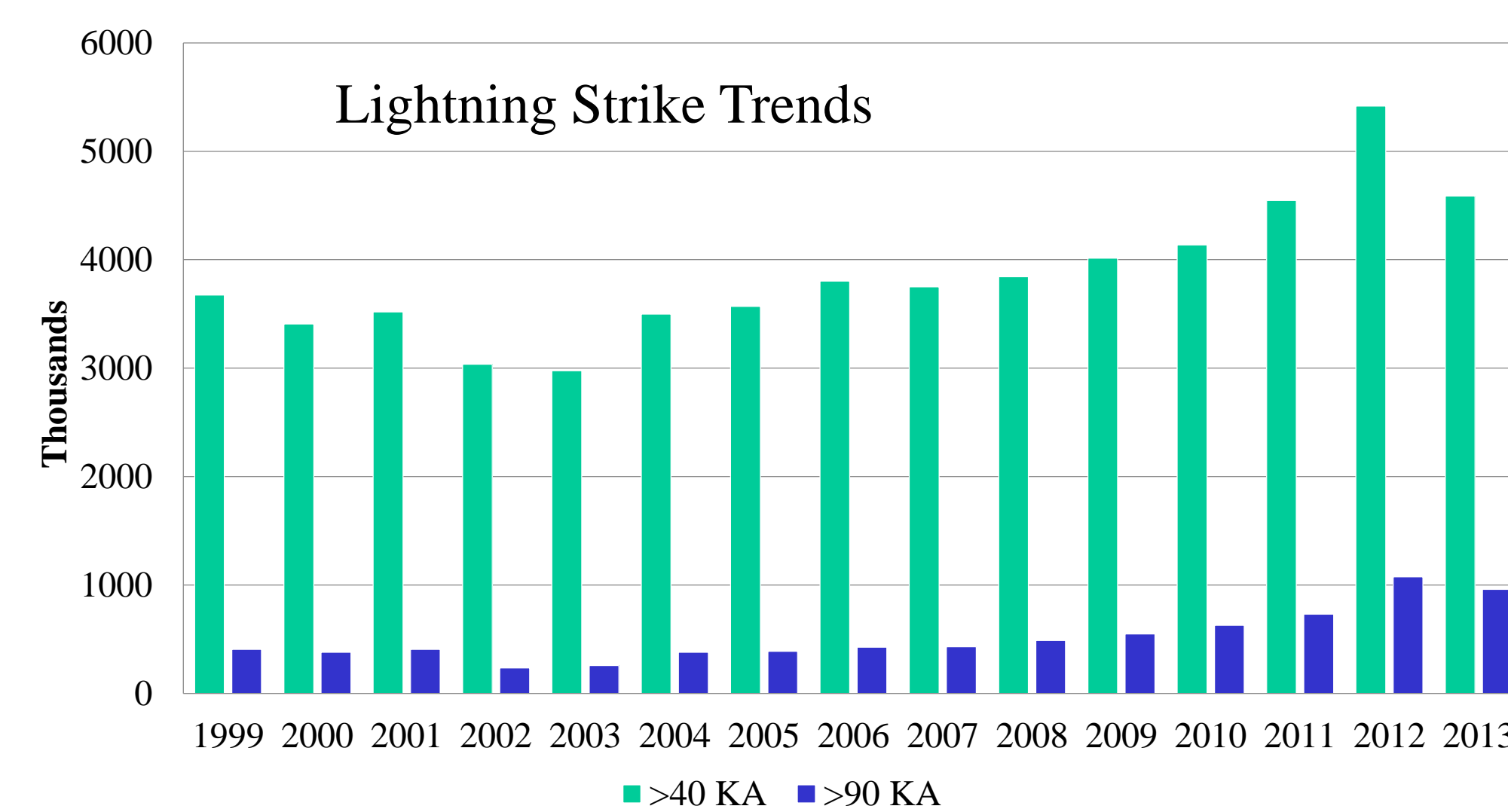


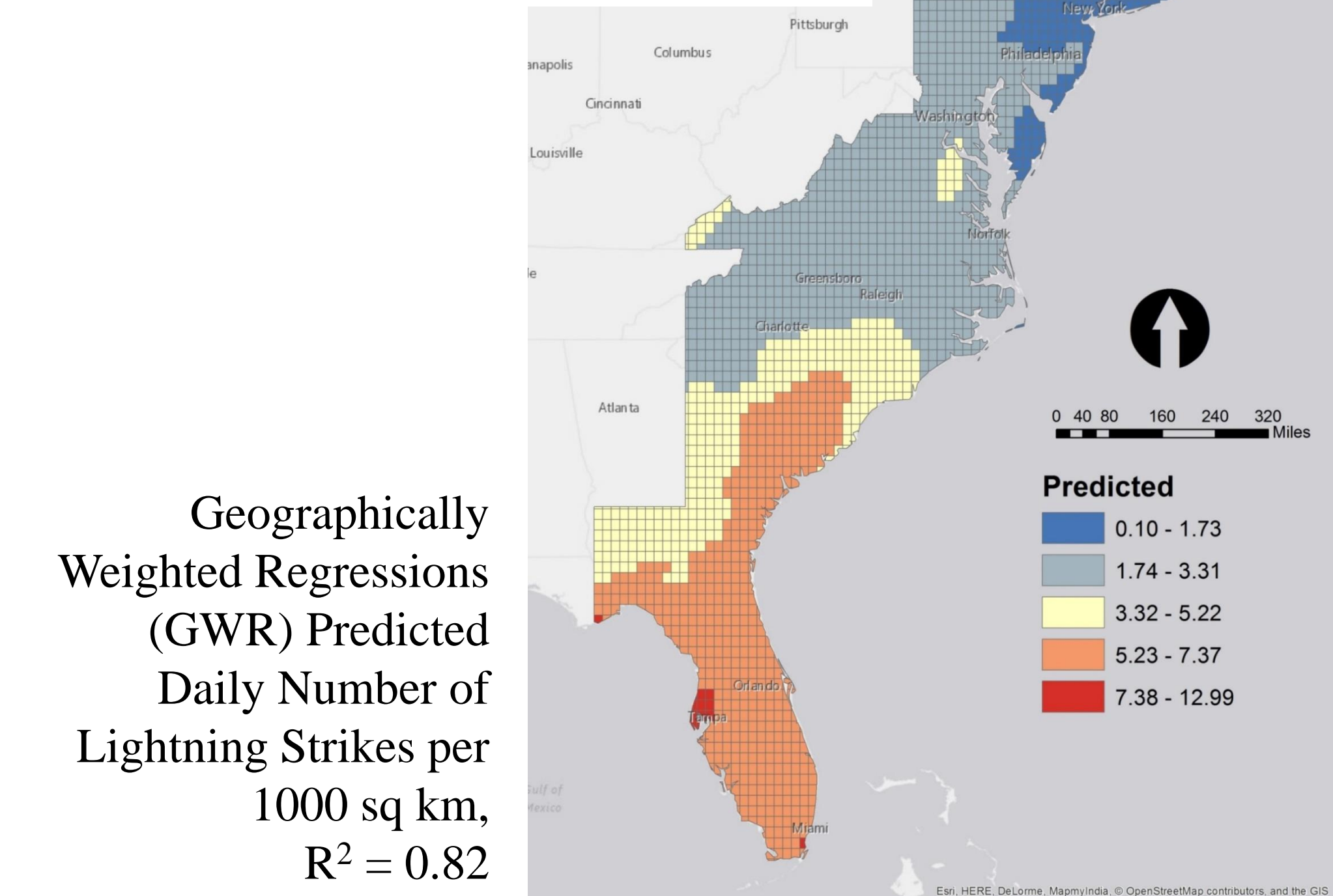
Emma Ding, Jasenka Rakas, Cheng Ding

Introduction

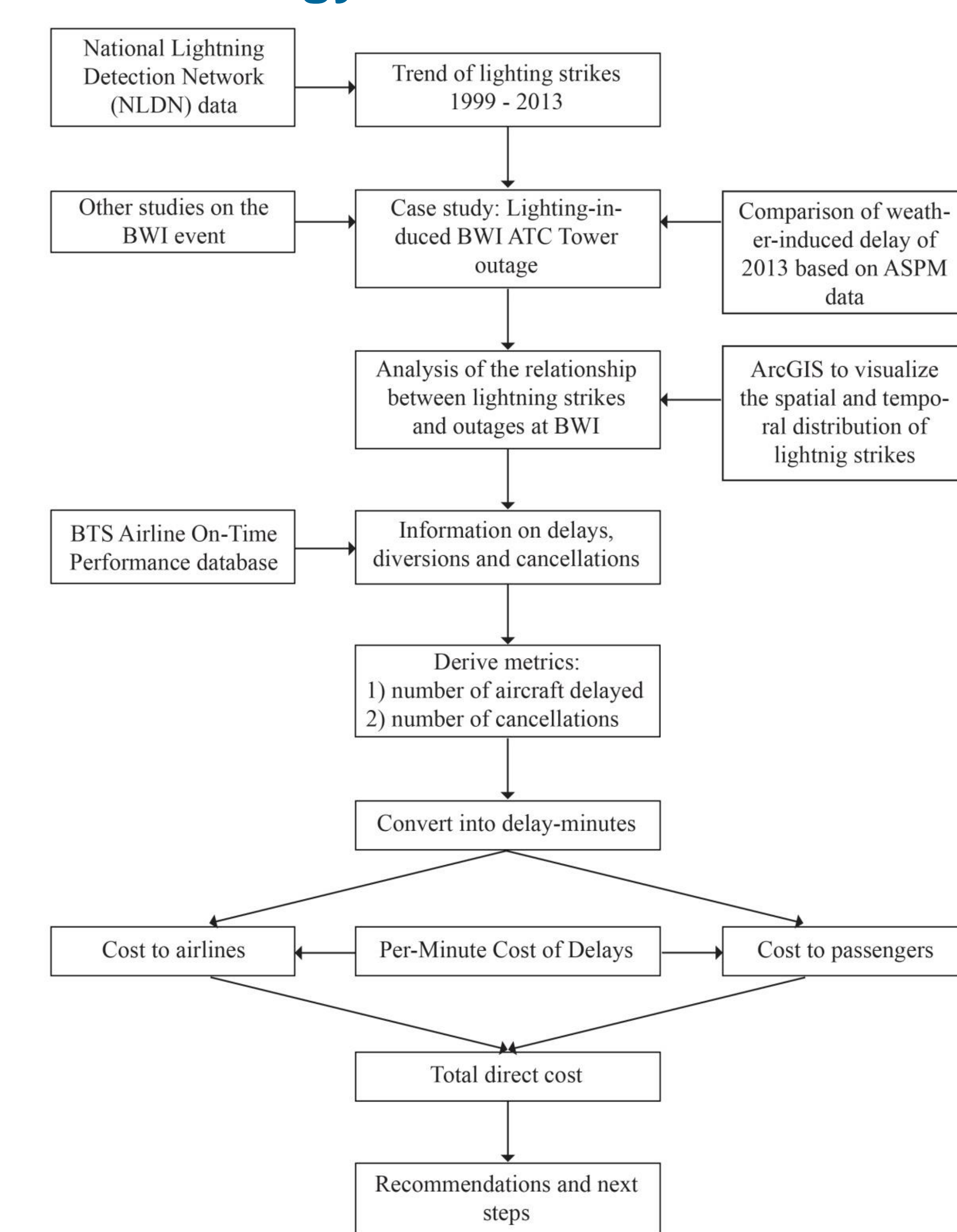
This research analyzes lightning strikes and weather conditions, and investigates how lighting-induced outages of airport infrastructure and facilities impact airport performance from an economic perspective. We focus on lightning-induced air traffic control (ATC) tower outages because the ATC tower is the most critical piece of infrastructure at an airport. We examine the impact of flight delays and cancellations resulting in ATC tower outages at three airports: Baltimore-Washington International (BWI), Atlanta International (ATL) and O'Hare International (ORD). The study reveals that flight delays and cancellations caused by such outages resulted in economic losses of about two million dollars for each airport, per outage.



Predicted Daily Number of Lightning Strikes by Ordinary Least Square (OLS)

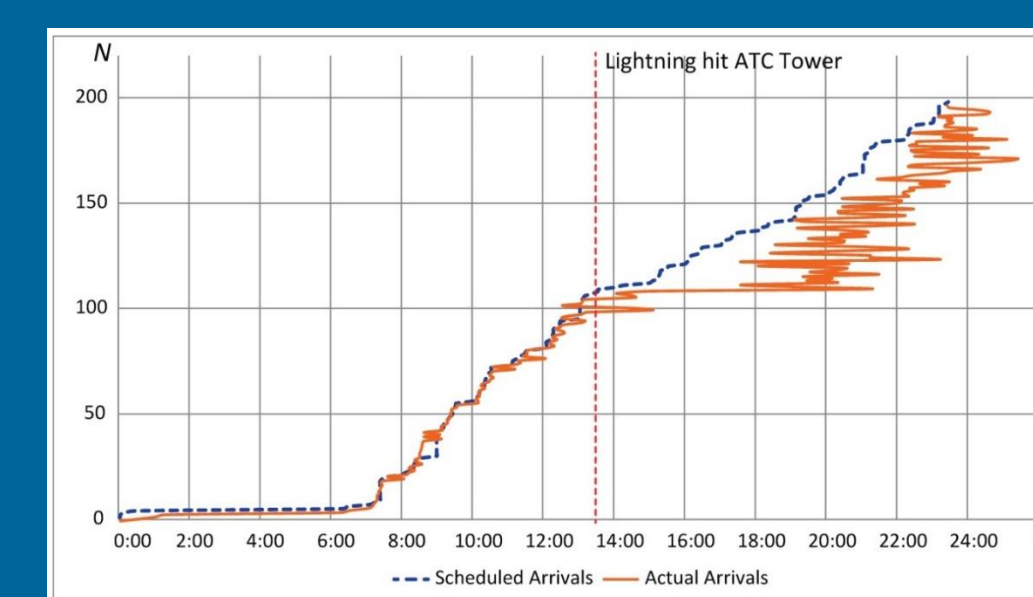


Methodology

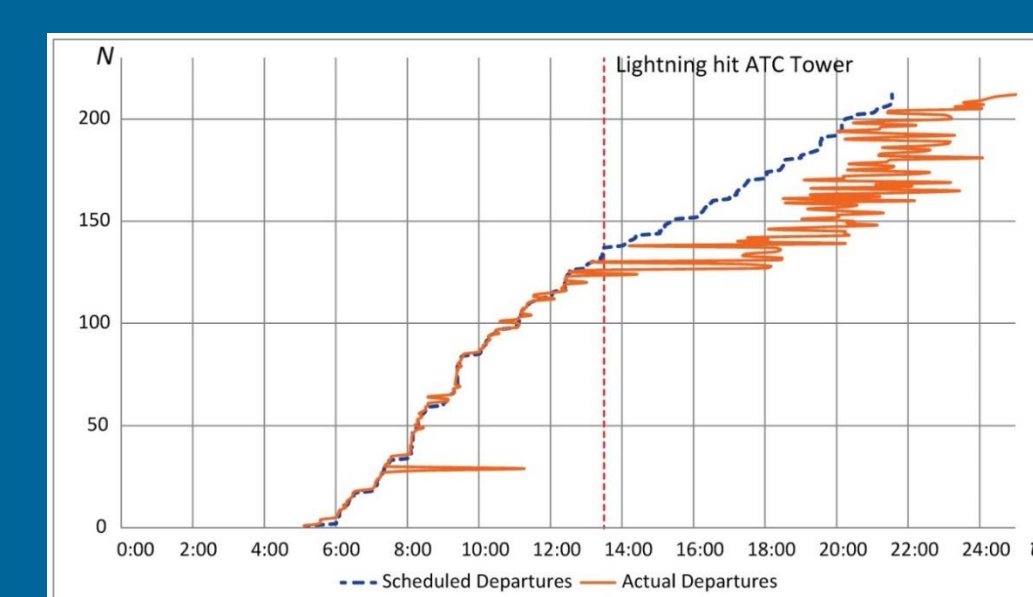


BWI Case Study

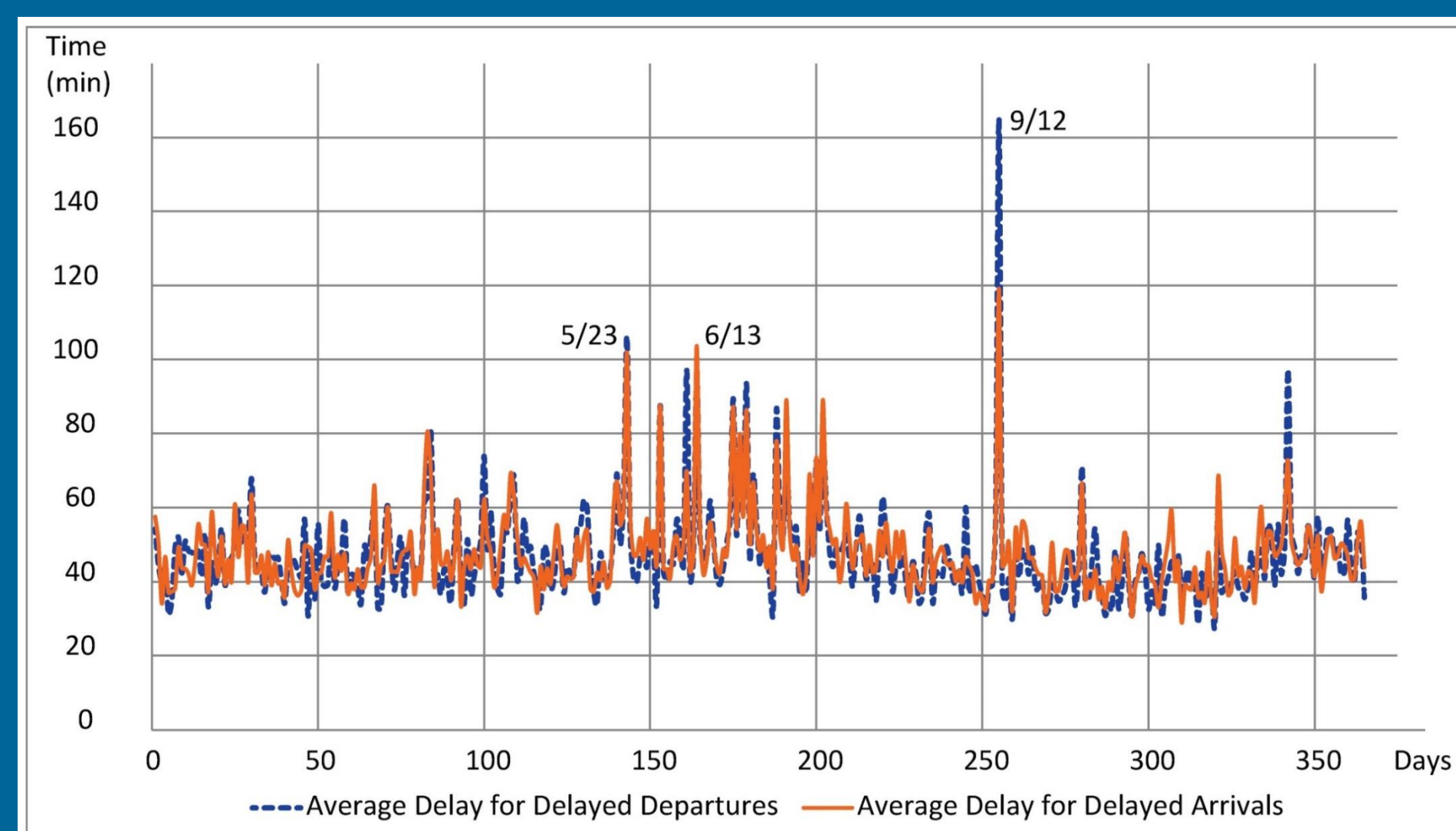
On September 12, 2013, lightning struck within 300 meters of the ATC tower at BWI, causing injury to an air traffic controller, and closing down the ATC tower and airport.



N-t Departure Delay Diagram

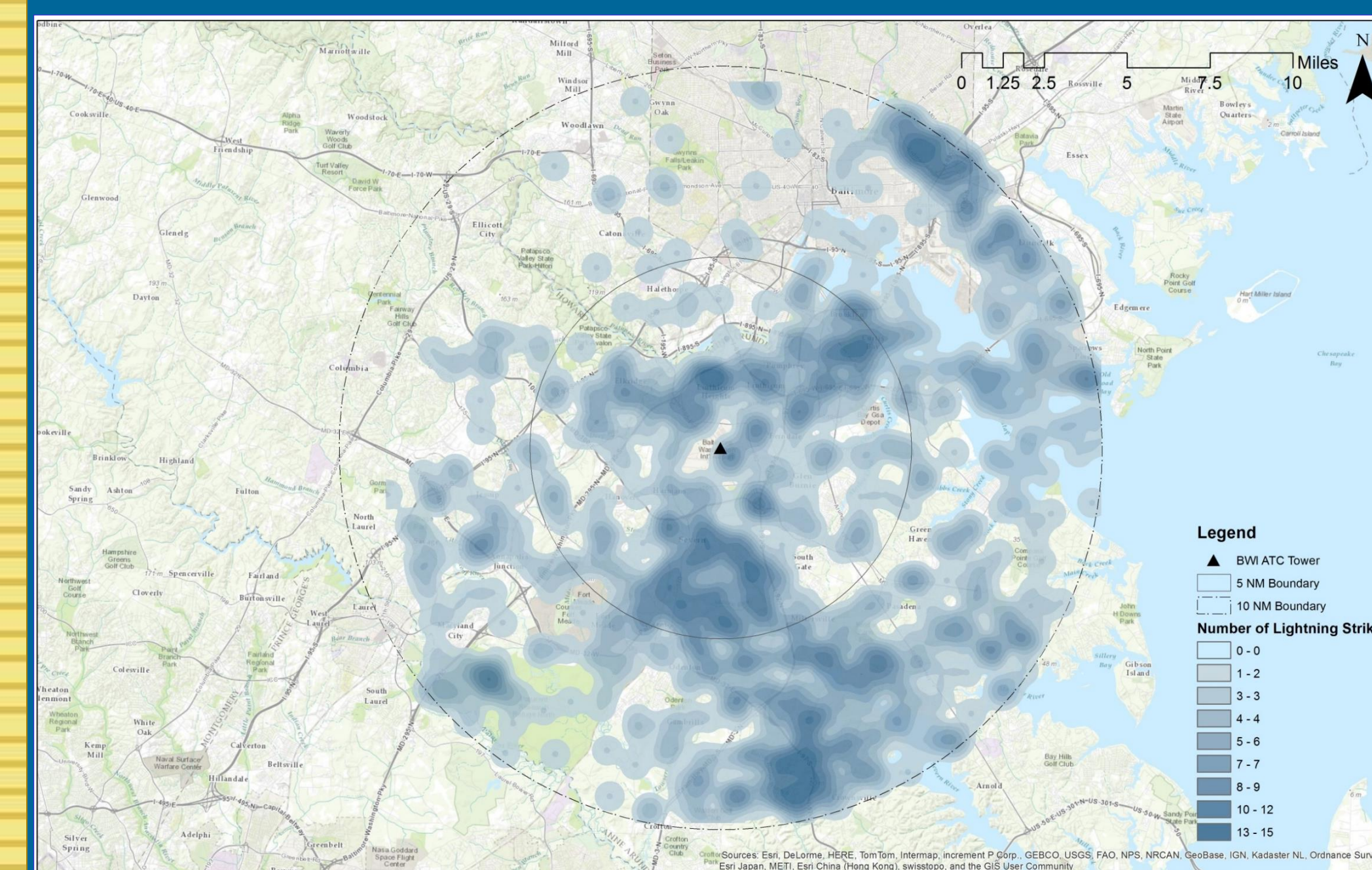


N-t Arrival Delay Diagram

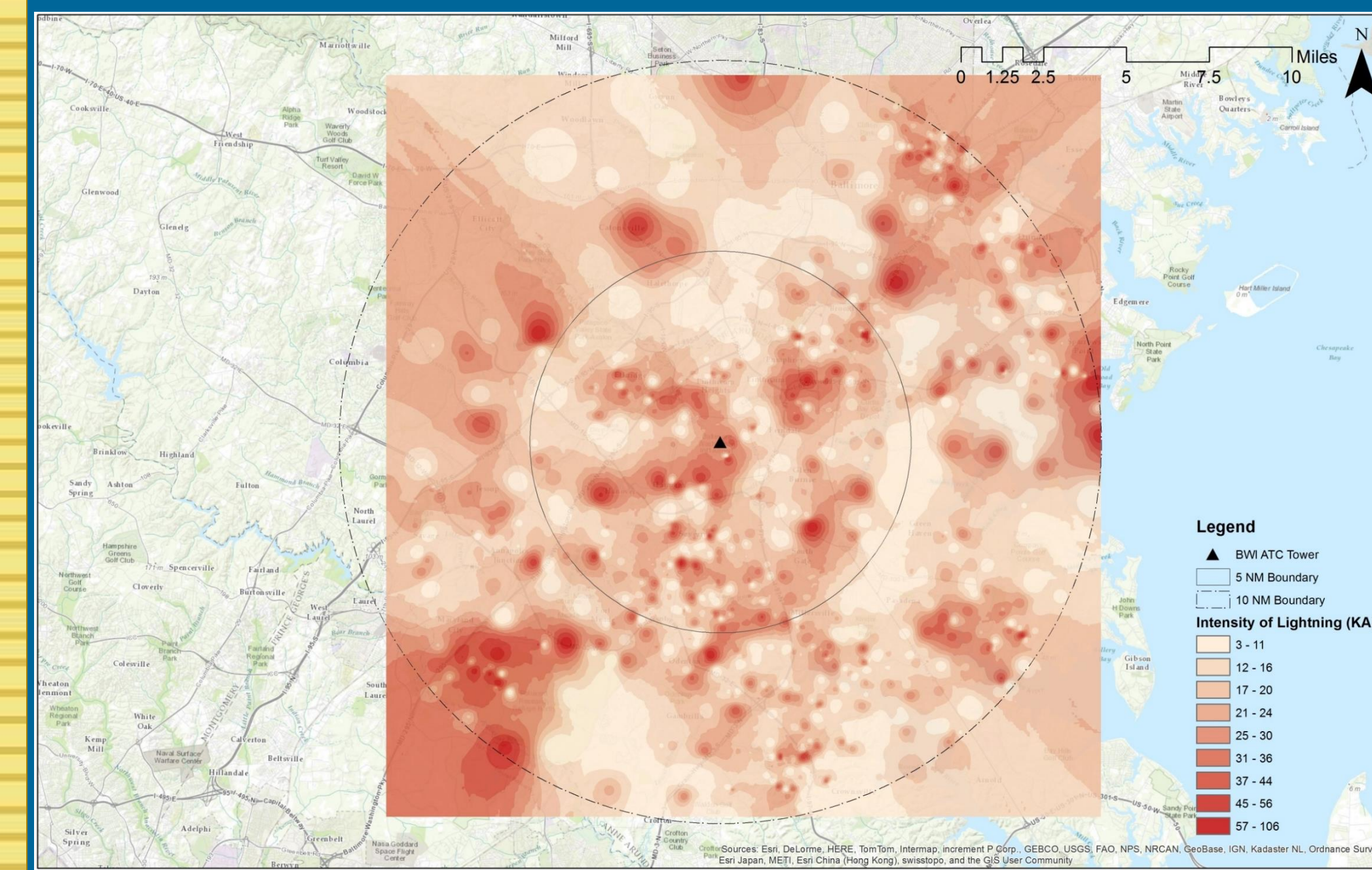


Daily Average Delays for Delayed Departures and Arrivals in 2013

Density of lightning from 1 hour before to 10 hours after the outage at BWI



Intensity of lightning from 1 hour before to 10 hours after the outage at BWI



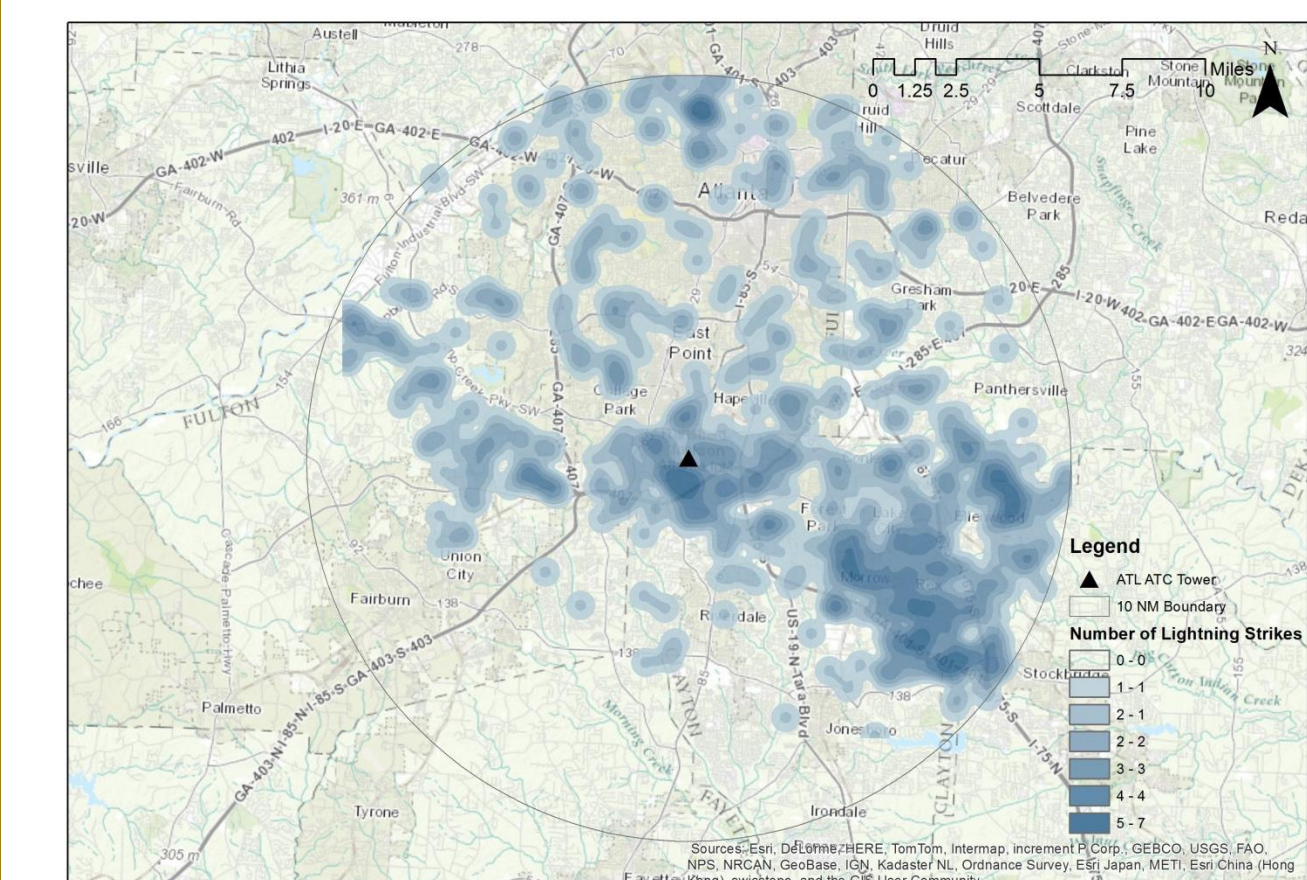
Calculation of Costs

$$\text{Total direct cost} = \sum \text{Delay cost} + \sum \text{Cancellation cost}$$

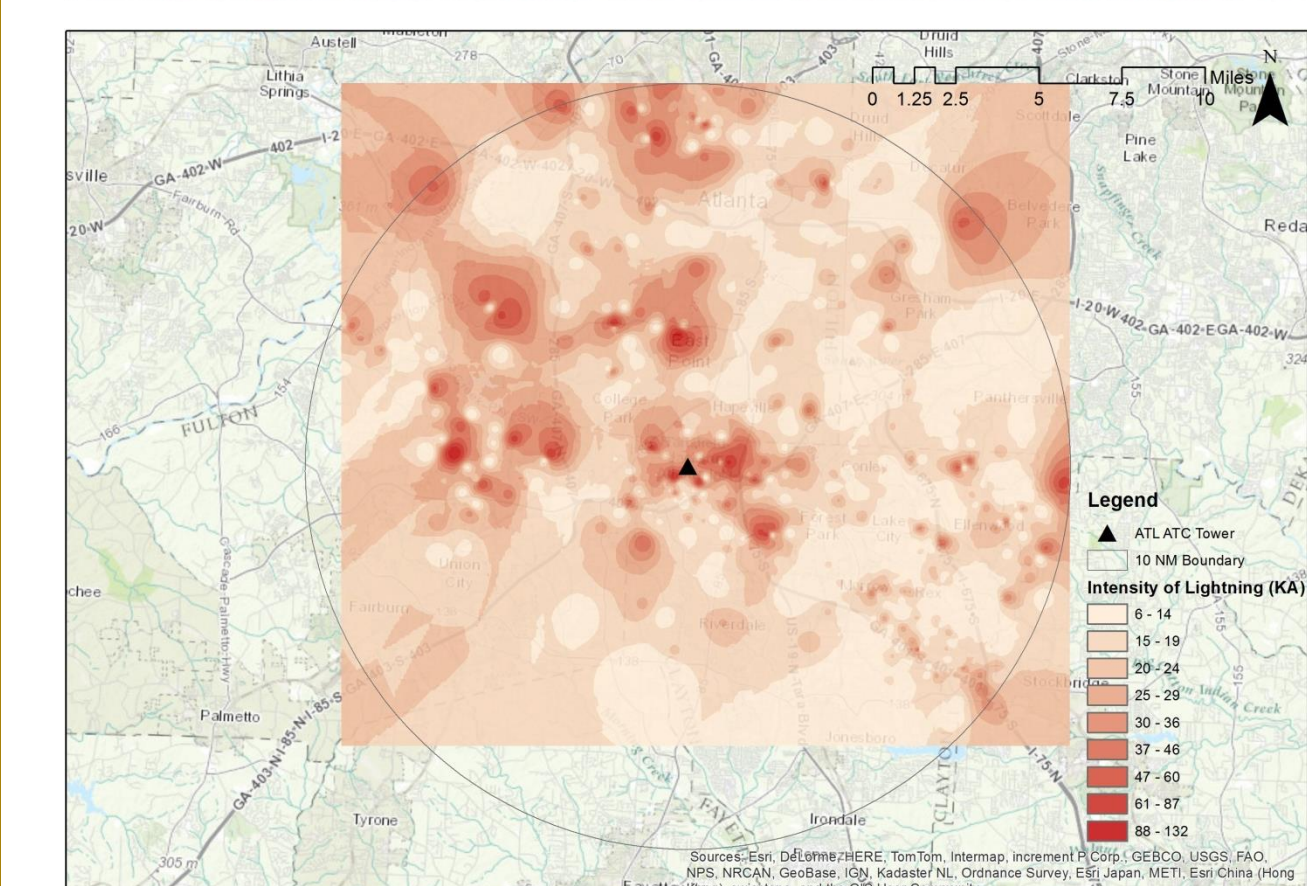
Cost Calculation for BWI Outage

Total Delay Cost (\$)	Weather-induced Delay (min)	5,215
	Total Passenger Cost	335,044.63
	Total Airline Cost	407,656.55
	Total Delay Cost	827,723.73
Cancellation Cost (\$)	Number of Cancellation	42
	Equivalent total delay time (min)	7,419.3
	Total Cancellation Cost	1,056,629.50
Total Direct Cost (\$)		1,887,850.72

ATL Case Study



ATC Tower outage at ATL Airport on 4/23/2009

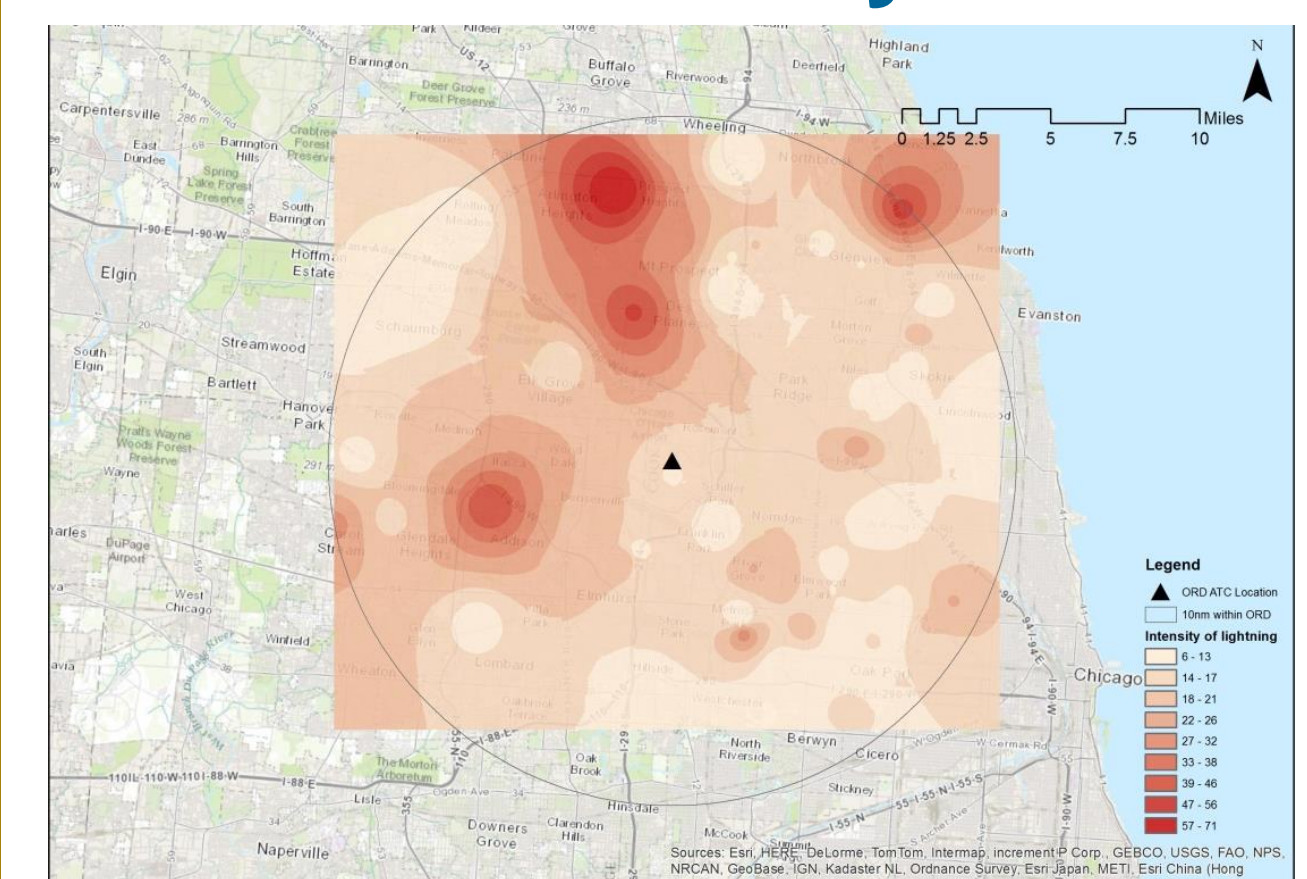


Density of Lightning within 10 nm of ATL in the 12 hours before the outage

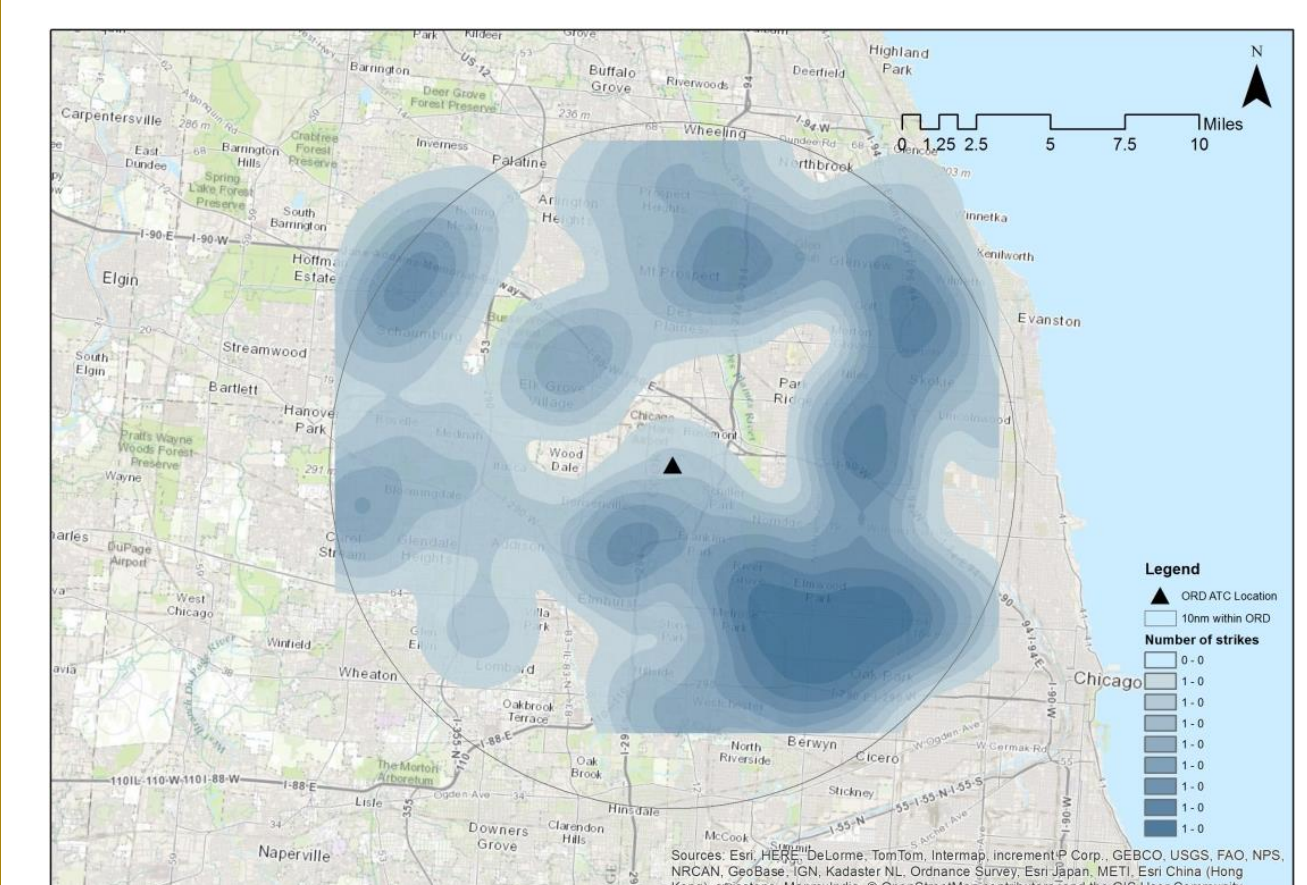
Intensity of Lightning within 10 nm of ATL in the 12 hours before the outage

Total Direct Cost of lightning-induced delays and cancellations: **\$2,476,620**

ORD Case Study



A Lightning-induced ATC Tower outage at ORD Airport on 06/24/2013



Density of Lightning within 10 nm of ORD in the 12 hours before the outage

Intensity of Lightning within 10 nm of ORD in the 12 hours before the outage

Total Direct Cost of lightning-induced delays and cancellations: **\$2,586,990.25**

Conclusion

This research is a first attempt to quantify the consequences of lighting-induced ATC Tower outages on airport performance from an economic perspective. BWI, ATL and ORD were used as case studies to quantify the total direct cost, which were significant at each airport, per outage.

Acknowledgements

This research was conducted by the National Center of Excellence for Aviation Operations Research (NEXTOR II). The authors would like to thank Chuck Graves from the FAA Operations Engineering Branch, Yi Liu and Yang Ju from the University of California, Berkeley, and Jing Xiong from the World Bank for their guidance and useful comments throughout the study.