GEORGIA DOT RESEARCH PROJECT 14-38

FINAL REPORT

Comprehensive Investigation of Visibility Problems on Highways: Developing Real Time Monitoring and Prediction System for Reduced Visibility and Understanding Traffic and Human Factors Implications

Georgia Department of Transportation

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16. Abstract

Instances of fog or fog enhanced with smoke (non-photochemical smog) routinely reduce driver visibility on roadways throughout Georgia. Georgia has the fifth highest reduced-visibility–associated crash frequency of any state. This report provides an overview of fog formation and types of fog, and a review of previous studies that have examined the effects of fog and reduced visibility on driver behavior and crash rates. The main purpose of this study is to create an initial fog climatology for the state of Georgia based on data previously collected from automated weather observing system/automated surface observing system (AWOS/ASOS) units to anticipate the frequency of fog and smoke occurrences across the state. The study recommends conducting a follow-on study to identify specific locations where additional safety treatments may be warranted as well as potential changes to design policy to address these issues during the design process

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Final Report

Comprehensive Investigation of Visibility Problems on Highways: Developing Real Time Monitoring and Prediction System for Reduced Visibility and Understanding Traffic and Human Factors Implications

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EXECUTIVE SUMMARY

Instances of fog or fog enhanced with smoke (non-photochemical smog) routinely reduce driver visibility on roadways throughout Georgia. There have been numerous traffic incidents that demonstrate the hazards of driving in low-visibility conditions, and Georgia has the fifth highest reduced-visibility–associated crash frequency of any state. This report provides an overview of fog formation and types of fog, and a review of previous studies that have examined the effects of fog and reduced visibility on driver behavior and crash rates. The main purpose of this study is to create an initial fog climatology for the state of Georgia based on data previously collected from Automated Weather Observing System/ Automated Surface Observing System (AWOS/ASOS) units to anticipate the frequency of fog and smoke occurrences across the state.

This report presents fog and fire frequency maps based on data from the National Oceanic and Atmospheric Administration (NOAA) and the Georgia Forestry Commission (GFC). These maps can aid in the understanding of visibility conditions and variabilities associated with geographic location and time of year. For the purposes of these maps, a visibility event is defined as any 20-minute interval that had a recorded visibility of less than 5/8 statute miles. The Kriging interpolation tool in ArcGIS® was employed to form the fog frequency maps. A detailed methodology is documented describing how these maps were made.

These results demonstrate that visibility hazards correlate to the topography of Georgia and the season. Figure ES-1 illustrates the seasonal fog frequency across Georgia (2014–2016), showing the highest frequency across the state is in the fall season and the greatest impact regionally is observed in the North Georgia mountains and along the coast. To aid in

understanding how these events could impact travel along major transportation corridors, these data were used to determine the fraction of time by season when the main Interstate Highways in Georgia were impacted by reduced visibility. These results are illustrated in Figure ES-2 and provided in tabular form in Table ES-1.

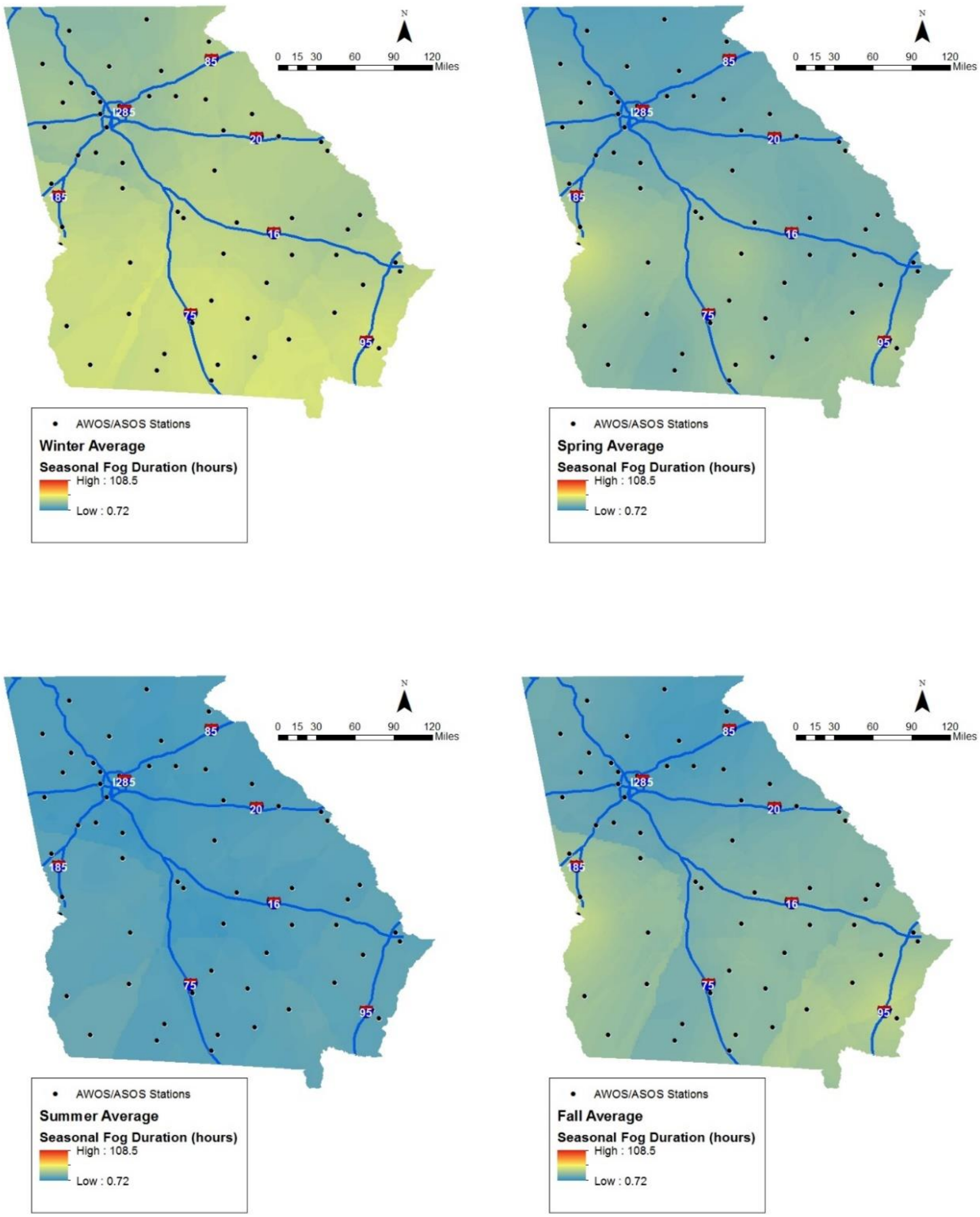

Figure ES-1: Seasonal Fog Duration Across Georgia (2014–2016)

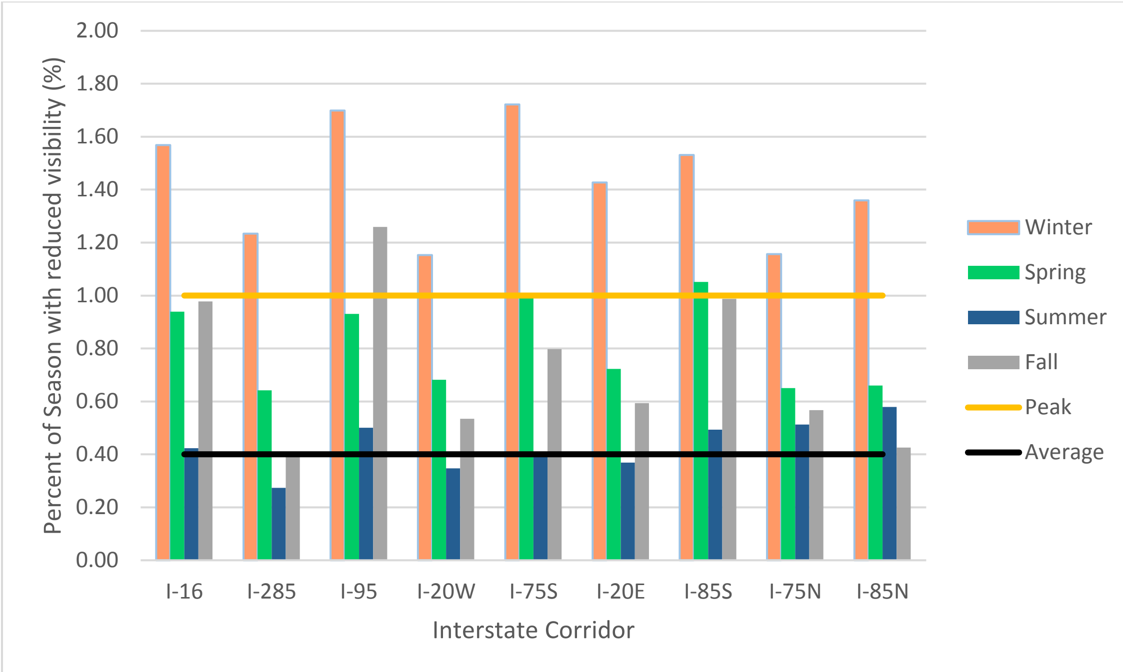

Figure ES-2: Fog Frequency Along Major Georgia Interstate Highways

Table ES-1: Fog Frequency Along Major Georgia Interstate Highways (%)

Interstate	Winter	Spring	Summer	Fall
I-16	1.57	0.94	0.42	0.98
I-285	1.23	0.64	0.27	0.40
I-95	1.70	0.93	0.50	1.26
I-20W	1.15	0.68	0.35	0.53
I-75S	1.72	0.99	0.40	0.80
I-20E	1.43	0.72	0.37	0.59
I-85S	1.53	1.05	0.49	0.99
I-75N	1.16	0.65	0.51	0.57
I-85N	1.36	0.66	0.58	0.43

Both the average and peak-season frequencies of reduced roadway visibility illustrated above are high enough to warrant consideration of countermeasures and safety treatments in vulnerable areas. While this study broadly identified areas of the state where such treatments may be desirable, additional study is required to locate the specific locations and types of treatments that will provide the most cost-effective improvements in highway safety. Specifically, GDOT should consider the following recommendations:

1. *GDOT should undertake a higher spatial-resolution evaluation of reduced visibility along selected corridors and regions to identify specific roadway segments and locations for which visibility-related safety treatments would be cost-effective. This study should include both a specific analysis of roadway crashes and fatalities associated with reduced visibility in the study areas and an analysis of the likely effectivess of potential treatments, both active and passive, in reducing visibility-related risks in these area. The corridors and areas recommended for this study include:*

    a. *I-95 in Coastal Georgia*

    b. *I-16 from Savannah to Metter (or Macon) including state routes serving the Port of Savannah*

    c. *State Routes in the North Georgia Mountains*

    d. *Interstate and selected State Routes crossing reserviors and major rivers.*

2. *Based on the results of the study recommended above, GDOT should consider revisions to its design policy to include provisions for reduced-visiblity treatments in designated locales and/or corridors during the design process.*

Implementing these recommendations will allow GDOT to significantly reduce the adverse impacts of reduced-visibilty conditions in Georgia.

ACRONYMS

AMS	American Meteorological Society
ASOS	Automated Surface Observing System
AVHRR	Advanced Very High Resolution Radiometer
AWOS	Automated Weather Observing System
CCN	Cloud Condensation Nuclei
DI	Dispersion Index
DOT	Department of Transportation
FAA	Federal Aviation Administration
FLS	Fog and Low Stratus
FTP	File Transfer Protocol
GDOT	Georgia Department of Transportation
GEO	Geostationary Satellite
GFC	Georgia Forestry Commission
GIS	Geographic Information System
GOES	Geostationary Environmental Satellite
HAR	Highway Advisory Radio
IR	Infrared
ITS	Intelligent Transportation System
LVORI	Low Visibility Occurrence Risk Index
METAR	Meteorological Terminal Aviation Routine Weather Report
MODIS	Moderate Resolution Imaging Spectroradiometer

MSG	Meteosat Second Generation Spacecraft
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Centers
NESDIS	National Environmental Satellite, Data and Information Service
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
RH	Relative Humidity
SEVIRI	Spinning Enhanced Visible and Infrared Imager
USAF	United States Air Force
USGS	United States Geological Survey
VHRR	Very High Resolution Radiometer
VMS	Variable Message Signs

INTRODUCTION

Motivation

A recent study (Abdel-Aty 2011) ranked Georgia as the state with the fifth-highest number of inclement-weather–related fatal crashes due to fog and/or smoke with 146 fatal crashes occurring over a seven-year study period. The deadliest weather-related crash in Georgia took place on March 14, 2002. The crash occurred on I-75N just south of Chattanooga and involved a 125-vehicle pileup injuring 39 and killing 4 people. The first harmful event in this incident was the collision of two tractor-trailers, one of which slid across the median into the northbound lane. The drivers of this initial event were not found to be at fault for the crash, and causation was attributed to foggy roads and low visibility (The New York Times 2002). This accident occurred 40 miles from a 1990 Tennessee pileup also along I-75, which killed 12 and injured 42 people. This portion of I-75 was already equipped with improved edge and centerline stripping, retroreflective pavement markers, flashing warning signs, as well as Tennessee Highway Patrol officers trained to intervene during heavy fog conditions (Vogt 1992). This pileup occurred in spite of the existing roadway safety measures in place and pushed the state of Tennessee to re-evaluate its fog detection and advisory systems. Reduced visibility from fog contributes to hazardous roadway conditions across the United States and is responsible for 38,000 fog-related crashes annually, leading to 620 fatalities (Ray 2013).

The frequency of fog-related crashes has driven changes in road weather management. Road weather management includes advisory, control, and treatment strategies (L. C. Goodwin 2003). In an effort to warn drivers of hazardous conditions, many jurisdictions use video monitoring systems, variable speed limit signs, illuminated warning signs, radio broadcasts, and on-site weather stations to detect the presence of fog and to alert drivers.

Forecasting fog is also a research focus, particularly in areas where fog detection equipment is widely dispersed and it is difficult to predict fog formation and dispersion. Crashes related to smoke and fog outnumbered all other weather-related causes between the months of October to February and between the hours of 5 a.m. and 8 a.m. (Ashley 2015). These times are when meteorological conditions for fog formation and the morning peak hour overlap. Developing a local climatology is often the first step employed to improve fog forecasting. Improvements in technology availability and weather station observations have made fog detection and fog advisories more common and more effective.

Fog Formation and Dispersion

Fog formation is both seasonally and temporally dependent, and spatially variable. Different types of fog occur depending on the environmental conditions present. However, all types of fog require cloud condensation nuclei (CCN) and sufficient humidity for water to condense on the CCN (Ray 2013). Cloud condensation nuclei are very small particles (<0.5 µm) and can be in either a solid or liquid state (Saraf 2011). Fog formation is typically identified by its effects on visibility due to the suspension of ice crystals or water drops and is defined by visibility conditions less than 0.6 mile, or 1 kilometer (Duynkerke 1990). Heavy fog is distinguished by visibility conditions of ¼ mile or less due to fog formation (Peace 1969). CCN concentration contributes to how transparent fog is, with higher CCN concentrations making fog more opaque (Court 1966).

Fog forecasting and dispersion modeling is important for improving roadway safety, especially in areas regularly plagued by heavy fogs. Fog forecasting can also be important in regions that are dependent on the presence of fog, as in southern Africa, where fog and low stratus clouds are a crucial resource as a source of water (Cermak 2012). Forecasting and modeling fog dispersion has proved difficult historically and often has extensive and cumbersome data requirements. Knowledge of wind patterns, boundary layer conditions, radiation, and local conditions, including topography, surface moisture, and surface configuration, are all important for fog forecasting (Duynkerke 1990). Of these requirements, the thermodynamic and kinematic processes of fog are relatively well understood and quantified by models while fog microphysics and boundary layer conditions are less fully understood (Croft 1997).

Fog dispersion is predominately influenced by: longwave radiative cooling at the fog top, gravitational settling of water droplets, fog microphysics, and shortwave radiation (Duynkerke 1990). In addition, terrain has a large effect on fog dispersion. In a Polk County, Florida, smog (smoke + fog) incident that resulted in a 70-car pileup, the smog was observed moving through the adjacent low-lying areas and was bounded by a small hill during light surface wind conditions, illustrating the impact of local terrain effects (Collins 2009).

Types of Fog

As discussed in the previous section, fog formation is a combination of cooling, air moisture (humidity), and vertical mixing of air parcels. These factors have different effects on fog formation, and the dominating factor determines which type of fog will form. This report examines four types of fog: radiation fog, advection fog, frontal fog, and upslope fog, with an emphasis on radiation fog as this is the most prevalent type of fog found in Georgia.

One of the first extensive fog classification systems was created by H.C. Willett in 1928 (Willett 1928). His system first divides fog into air mass fogs and frontal fogs. Air mass fogs occur within a single homogenous air mass due to meteorological processes within the air mass and can be divided into radiation fog, advection fog, and maritime fog. Frontal fogs occur at the transition zone of two air masses with characteristics different from the other (Willett 1928).

Radiation Fog

Radiation fog is essentially a low-level stratus cloud close to the surface of the earth. Radiational fog formation requires cool surface temperatures, moisture availability, relative humidity that can quickly reach >90 percent, and cool dry air aloft (Underwood 2004). Nocturnal cooling of the earth's surface leads to the formation of a moist air layer due to the radiation of heat from the earth's surface that allows the surface to cool (Abdel-Aty, 2015). Radiation fog formation requires an equilibrium between nocturnal radiational cooling and dynamic turbulence to aid in the diffusion of heat and moisture into the surface layer (Meyer 1990). This type of fog typically dissipates quickly once the earth's surface starts to warm from the sun, but can be very dense until the sun rises (Abdel-Aty, 2015).

Advection Fog

Advection fog has two types: fog due to the movement of a warm moist air mass over a cold surface and fog due to the movement of a cold air mass over a warm-water surface

(Willett 1928). This type of fog is more common to the Pacific coast as these areas are close to the ocean, which provides a source moisture and heat (Ray 2013). In Georgia, this type of fog is normally found only along the coast and, to a lesser extent, near the major reservoirs.

Frontal Fog

Frontal fogs occur at the transition zone of two air masses with different properties. This can occur via precipitation, which introduces moisture to the previously unsaturated cooler air below a cloud through rain droplets (Stull 2011). The fog is formed by the evaporation of these warmer droplets into the cool air it is falling through (Abdel-Aty, Comprehensive investigation of visibility problems on highways: developing real time monitoring and prediction system for reduced visibility and understanding traffic and human factors implications 2015). Frontal fogs can be very transitory in nature and depend on wind patterns to move air masses causing these transition zones (Willett 1928).

Upslope Fog

Upslope fog is formed by the movement of moist air up a sloping terrain such as a mountain or hill (Abdel-Aty, Comprehensive investigation of visibility problems on highways: developing real time monitoring and prediction system for reduced visibility and understanding traffic and human factors implications 2015). The air mass cools adiabatically as it rises to its lifting condensation level and forms upslope fog in the process (Stull 2011). This type of fog is relatively rare in Georgia, although it has been observed in the North Georgia mountains.

Previous Climatologies

At this time, there is not a fog climatology available specifically for Georgia. However, several fog climatologies have been prepared for the United States, the Southeast, and for neighboring states. Florida, in particular, has its own climatology specific to different regions in the state (Ray 2013). The climatology for North Florida may prove to have valuable applications for South Georgia as these regions have a similar climate.

One of the earliest climatologies published for the United States is Court's 1966 "Fog Frequency in the United States" report (Court, 1966). This report provided updates to existing fog distribution maps for the conterminous United States. This map used data collected by 251 first-order Weather Bureau stations through the year 1960. The updated maps showed that fog frequency ranged from an average of 10 to 30 days per year of dense or heavy fog. The report classified an event as fog when visibility was ¼ mile or less. Notably, the data collection occurred over a period when standard observation frequencies were changing and moving to continuous-watch weather stations. This study specified radiation fog as the most common type of fog found in the Appalachian valleys, including North Georgia.

A later climatology from 1969 by Peace, looked at the spatial distribution of heavy-fog–prone areas using fog statistics from 256 first-order weather stations across the United States (Peace 1969). Isopleths (lines of equal concentration/probability) were used to show areas of heavy fog, and the fog isopleths showed areas in North Georgia having an average of 30 to 40 days annually with heavy fog. The central part of Georgia gets an average of 10 heavy fog days per year. Contributing factors to the high number of annual fog days in

North Georgia are irregular terrain, substantial moisture, and orographic lift. The study also found that among the stations studied, there was considerable local variability in fog distribution within a region.

A third climatology in 1973 looked at monthly fog frequency across the United States (Hardwick 1973). This climatology used fog statistics from 244 first-order National Oceanic and Atmospheric Administration (NOAA) weather stations to look at temporal, diurnal, and regional distributions of heavy fog in the United States. This report looked at the "mean annual number of days with heavy fog and the mean monthly number of days with heavy fog" (Hardwick 1973). Based on the maps presented in this report, different regions in Georgia experienced anywhere from 10 to 70 mean days with heavy fog. The areas with the highest number of mean days with heavy fog were the Valdosta area, experiencing 30 to 40 days, and the coastline and mountainous regions, experiencing 20 to 30 days. December through April saw the highest mean monthly numbers of days with heavy fog in Georgia. This seasonal variation is in line with trends observed by other reports.

Fog Detection Technologies

The two main classes of fog detection data are satellite data observations and ground-based observations from meteorological stations. This section of the report will focus primarily on satellite fog detection methods, as ground detection methods rely on data that are not available for every area and can be discontinuous. Historically, the biggest problem with using satellite imagery to detect fog formation has been distinguishing fog and low stratus (FLS) from other surfaces detected by satellites. Additionally, the spatial and temporal resolution of satellite data has not been useful for forecasting fog formation, particularly on a local scale. With advances in technology and new modeling software available, many researchers have found ways to overcome these limitations and have been able to successfully use satellite data to detect fog formation.

Many different studies have been conducted developing models to detect fog formation using different satellite data, ground conditions, and modeling approaches. One such study was conducted by Bendix in 2005 and looked at ground fog detection from space (Bendix 2005). Since ground fog can be difficult to differentiate from low stratus clouds using satellite data, methods that existed prior to that study were only able to predict poor visibility from the ground based on the detection of low stratus clouds. Bendix discussed the four conditions necessary for the detection of ground fog from space: (1) Ability to discriminate between low stratus clouds and the ground, (2) ability to calculate the optical depth of the cloud and other microphysical properties, (3) determination of the geometrical thickness/height of the layer of clouds, and (4) final distinction between low stratus clouds and fog with ground contact. The study focused on step two of this process using moderate resolution imaging spectroradiometer (MODIS) data from Germany in conjunction with radiative transfer calculations. The method proposed for evaluating low stratus cloud geometrical properties demonstrated a 28 percent error in distinguishing between low stratus clouds and fog. Some of the error may be associated with issues with sub-pixel resolution in satellite imagery. Despite this high percentage error, the method developed by that study can be helpful for indicating areas with a high probability of ground fog, particularly in areas where no other visibility-forecasting abilities exist.

A study conducted by Cermak in 2007 and then continued into 2008, used Meteosat® Spinning Enhanced Visible and Infrared Imager (SEVIRI) data to detect nighttime FLS (Cermak 2007). Information on the spatio-temporal distribution of FLS historically has only been obtained from satellite data as weather stations are not equipped with a spatial component. One difficulty in this is separating FLS from other surfaces detected by the satellite. Generally, this was done using the blackbody temperature difference, but unfortunately this method has interferences from radiatively important trace gases, especially carbon dioxide (CO_2). This study proposed a new method of detecting FLS that was not affected by CO_2 using SEVIRI data. From feasibility studies of the methodology, it was shown that it is possible to detect FLS at night at a high resolution without a regional bias.

Another study conducted by Cermak in 2009 used geostationary satellite (GEO) data to create maps of the FLS distribution in Europe (Cermak 2009). That study demonstrated how satellite data can provide a more continuous and spatially/temporally extensive picture of fog distribution than ground-based methods. The temporal and spatial resolution of these maps has not been achievable until now with the use of GEO data. The study included data collected over a two-year period over the four seasons and did not include data for the open ocean. Maps of FLS distribution presented in the paper are based on data from Meteosat Second Generation (MSG) systems, shown beside a map of FLS distribution based on data from surface weather stations. The map shows the weather station data are much more discrete and discontinuous, whereas the MSG data are continuous and present a picture of FLS distribution for the European continent.

Satellite imagery can also be incorporated with meteorological data to predict and analyze patterns of dissipation and movement of fog as shown in a study conducted by Saraf for the Indo-Gangetic Plains region (Saraf 2011). The fog of the Indo-Gangetic Plain south of the Himalayas is characterized as radiational fog capable of becoming smog if smoke is present. The winter fog of this region has been effectively mapped using NOAA advanced very-high-resolution radiometer (AVHRR) satellite data. The patterns of dissipation and movement of fog in this region were analyzed by incorporating both meteorological and satellite data. The study incorporated air temperature, relative humidity, elevation, and wind speed into a geographic information system (GIS) raster-calculator to predict fog formation for this region. The model was tested by forecasting fog for past days and comparing the results to satellite imagery from those days. The study found that fog forecasting results were a close match for actual fog occurrence.

Ward also used GIS to examine winter fog occurrence; however, the study was done for the New York metropolitan area (Ward 2008). This study looked at dense winter fog occurrence in the New York metropolitan area for the winter season spanning 2006–2007. These fog occurrences were related to their initiating synoptic weather conditions and with topographic and local surface characteristics. These relationships were analyzed using GIS techniques and fog product imagery to improve forecasting of local fog formation, dissipation, and scale. This study showed that when elevation and surface characterization data are available, the influence of different types of synoptic classes can be analyzed to show how synoptic conditions influence spatial patterns of dense fog during winter months.

Similarly, Ellrod used data from five different multi-vehicle accidents across the United States and Canada caused by low visibility to analyze the capabilities of Geostationary

Environmental Satellite (GOES) techniques to detect low visibility conditions due to the occurrence of fog (Ellrod 2006). The study also looked at the warning time GOES data gave and if that time was sufficient to help prevent those accidents from occurring. The results show that the GOES imagery indicated fog conditions and gave 1 to 3 hours advance warning. All five accidents occurred shortly after sunrise, which is when GOES infrared (IR) imagery is more prone to interference from solar reflectance, and visible imagery is unavailable at a good resolution due to poor lighting. During these conditions the GOES data must be supplemented with surface visibility stations, and not simply Meteorological Terminal Aviation Routine Weather Report (METAR) data from local airports. The Ellrod report recommended more environmental sensors along roadways and direct access to those data by the National Weather Service (NWS).

The studies discussed in this section show how satellite data can be used to forecast fog formation and dissipation. Some studies looked at smaller scale fog formation and using satellite data to predict fog formation on a micro-scale. Other studies looked at larger scale fog formation and incorporated ground-based observations and meteorological data to improve the accuracy of their forecast. Many of the studies also were able to evaluate the accuracy of their models using historical data and comparing their models to observations. As technology and data availability improves, the value of these models would also be expected to improve, making them more useful for fog advisory purposes.

Fog Advisory Technologies

A variety of fog advisory technologies have been developed and implemented across the country to alert drivers of limited visibility conditions. Studies have been conducted to determine the validity of such technologies. An article written by Freeze in 2016 for the Federal Highway Administration's website details the Tennessee Department of Transportation's low visibility warning system (Freeze 2016). In Tennessee, a section of I-75 just east of Cleveland is particularly prone to fog-related visibility problems. Following a serious chain reaction incident in this area in 1990, the first fog detection and warning system was put in place for this section of interstate. The fog detection system can detect fog three miles north and south of the Hiwassee River and gives drivers an 8-mile notice that they are approaching the foggy area. The fog detection system consists of 9 forward-scatter visibility sensors, 14 microwave radar vehicle detectors, and 21 closed-circuit television (CCTV) cameras. The warning component of the fog-detection system consists of: 6 static warning signs with flashing beacons, 10 changeable speed limit signs, 10 overhead dynamic message signs (DMS), and two highway advisory radio (HAR) transmitters. The system also has an on-site control center that can pass information along to the local Highway Patrol office and six interchange on-ramps that have remotely controlled access gates to limit access to the interstate.

This interstate segment is also equipped with several passive systems to improve lane visibility, including improved retroreflectivity pavement markings for edge of pavement, and halving the separation of the skip lines. Combined with the active systems, these treatments have greatly reduced fog-related crashes in this area (Freeze 2016).

A study of similar detection technology used for traffic management in Alabama was conducted by McFadden in 2000 and 2001 (McFadden, 2000). Alabama is using an intelligent transportation system (ITS) to help detect fog and then adjust speed limits and lane configurations based on weather conditions (McFadden, 2001). Between 1996 and

1999 the state of Alabama earmarked $7 million for fog detection ITS programs in Mobile. These funds were earmarked in part due to an incident that took place March 20, 1995, on the I-10 Bayway Bridge. This incident involved 193 vehicles and resulted in 91 injuries and 1 fatality. The components of the resulting system include: a weather monitoring station, visiometer, variable message signing, changeable speed limit signs, vehicle detection systems, tunnel control room operation center, and closed circuit television. When first initiated, this Alabama program focused on their four largest cities (more than 40 percent of all statewide crashes) and counties that showed an increase of 10 percent or more in fog-related crashes from 1996 to 1998 to identify which jurisdictions were good candidates for ITS treatments for fog.

McFadden also documents several specific locations in Alabama that could benefit from various treatments. One example is, of course, Mobile where the city initiated a fog warning system project after the previously mentioned incident. In addition, Baldwin County was identified as a candidate to implement video technology to help reduce fog-related crashes due to its location along the shore and because the county has the most shoreline of any county in Alabama. Similarly, Lee County had a high rate of fog-related crashes due to its predominantly rural roadways and potentially because of its higher population of young drivers.

The use of fog indices to communicate hazardous weather conditions to the public was examined by Lavdas and Achtemeier (1995). This report examined Florida Highway Patrol accident records from 1979 to 1981. These records included weather and visibility information at the time of the crash and were compared to contemporaneous NWS surface and upper air observations for the area. The study found that relative humidity and the dispersion index demonstrated the most significance in relation to the crash severity and occurrence. Relative humidity (RH) and the dispersion index (DI) were combined to create the Low Visibility Occurrence Risk Index (LVORI), which quantifies visibility-related risk. The LVORI was created to be used on a broad geographical scale as a public safety index, especially for smoke- and fog-prone areas. The report also used NWS data to classify fog as either advection or radiation fog. This distinction is important as localized radiation fogs are typically more dangerous for drivers than widespread advection fogs.

The addition of lighting devices or pavement modifications are additional forms of advisory technologies. A report by Lynn et al. in 2002 provided recommendations to help reduce the frequency of fog-related multi-vehicle crashes that occur on the Fancy Gap and Afton Mountain interstates in Virginia (Lynn et al., 2002). The Afton Mountain in-pavement fog guide light system was installed as a countermeasure for fog-related crashes. While these fog guide lights did positively impact roadway visibility, the number of vehicles involved in fog-related crashes increased after installation. This increase in crash rate was attributed to potentially increased speed and/or driver complacency because of the fog lights. The actions recommended in the report included installation of video cameras, variable message signs (VMS) in fog-prone areas, and the use of HAR to warn of fog conditions.

VMS as a fog advisory treatment have also been studied by Rama and Luoma (Rama and Louma, 1997), who evaluated two methods of transmitting updated information to drivers and driver acceptance of this information. The study looked at transmitting information by several types of VMS. The study took place on a 14 km–long stretch of road in southern Finland where conditions are known to change quickly and frequently. The study involved interviewing drivers about the new signage in incremental periods after its installation, as well as collecting data from local road weather stations. During fog conditions, the system was reported to lower drivers' speeds by 8–10 km/h. The system was also found to be effective at communicating adverse conditions to drivers when road and weather conditions were not easily detectable. Drivers also reported the signs helped refocus their attention and encourage them to use more caution while driving.

Early detection of hazardous visibility conditions can also be based on historical weather data. A study by Ray (Ray, 2013) for the Florida Department of Transportation looked at fog location and frequency in Florida from 2002 to 2009. From these data, a fog climatology was formed, and fog prediction techniques were evaluated based on that climatology. Historically, fog predictions have been difficult because many times observation equipment is located far from the site of fog occurrence. Ray's report made several recommendations about how to improve Florida's fog-warning system based on fog frequency, distribution, and historical locations of poor visibility from fog. One recommendation was to improve the coordination and quality assurance of weather data collected by different groups in Florida, as well as locate the weather-collecting stations close to accident-prone areas to improve accuracy and early detection. The report also recommended using satellite data to fill in gaps where weather station data are unavailable. In addition to satellite data, the study found a need for better resolution elevation data, as fog is more prone to form in low-lying areas. The report identified Payne's Prairie near Gainesville and the City of Tallahassee as areas especially prone to fog that need extra visibility sensors and that could be good locations to evaluate the effectiveness of different visibility technologies. In addition to visibility sensors, the report recommended placing

Automated Surface Observing System (ASOS) sensors in places especially prone to fog formation.

Previous Studies on Fog and Its Relation to Driver Behavior

Studies have been conducted to determine the relationship between fog and driver behavior. Edwards studied driver behavior under different weather conditions (Edwards, 1999a). That study was conducted by a research team in Wales taking weekly speed surveys of 200 vehicles on a motorway in Wales during three different weather conditions: fine, rainy, and misty. Data were recorded at the same time of day (8–9 a.m. on Tuesdays) over a 6-month period from October to March. In comparing speeds during inclement conditions to those under good conditions, the study found that while there were small reductions in speed during inclement-weather driving conditions, these reductions were not sufficient to account for the poor driving conditions.

Another report by Edwards (Edwards, 1999b) investigated the relationship between weather and crash severity based on weather conditions reported in police accident reports in Scotland and Wales. In evaluating crash severities, this report used a system of severity ratios that took the number of fatal and serious accidents as a ratio of the total number of accidents and then compared this ratio to weather conditions. For this report, crash data from 1980 to 1990 were collected. The severity ratio for fog was reported to be 25:256 overall. This report found that five municipalities in the region showed a significant increase in accident severity during fog conditions compared to when the weather was good. The report also found the fog-related accident injuries were more severe than for other weather conditions with 25 out 1000 fog-related accidents being fatal, compared to 15 out of 1000 snow-related accidents being fatal.

Markku and Heikki looked at driver behavior and compared driver perception of weather and road conditions to driver behavior changes as a result of this information (Markku and Heikki, 2007). The study surveyed drivers in Finland for their perceptions of weather, driving behaviors, if they checked the weather before their trip, and changes to their trip itinerary. The research team also collected data from traffic weather forecasts, traffic counters, and weather measurement stations. The study found that most drivers considered the actual weather conditions to be better than conditions predicted by the weather forecast. The study also reported that drivers reduced their speed by an average of 6–7 km/h. The study concluded that drivers alter their behaviors more based on their on-road experience rather than from traffic weather forecasts. However, the study also found that drivers were not adequately able to assess roadway conditions accurately enough to properly adjust their driving behaviors. The researchers projected that local and temporally accurate warnings updated frequently would have an increased effect on the driving behaviors of those who check conditions and might make others more likely to check conditions before their trip. The study also discussed the increased role that this kind of information could have as vehicles are equipped with better mobile-information technology.

A report by Qiu and Nixon (2008) for the *Journal of the Transportation Research Board* looked at studies on the interactions of traffic safety and weather conducted from 1970 to 2005. The researchers conducted a meta-analysis of 34 papers and 78 reports related to the topic. Their study looked to use enough primary studies to make their meta-analysis reliable. The main focus was on the effect of snow and precipitation events on traffic safety, but they did identify a need for more papers estimating crash risks during inclement weather conditions with high winds, fog, low temperatures, and a combination of inclement weather events. Their study found that snow has a greater impact on crash rates than rain but that slippery pavement was the biggest component of the crash reports studied. This is significant because many times rain and snow events are associated with reduced visibility and, when combined with a fog event, can be especially dangerous. These precipitation events can also be an inciting factor for fog events as they often increase moisture levels in the air.

A report written by Achtemeier (1998) and published by the U.S. Forest Service discussed smoke and its sources, as well as why it is a problem particularly in the southeast United States. Traditional (as opposed to photochemical) smog is created when the relative humidity is already at 100 percent and water vapor is added to the air from mass burning, which can cause the air to become supersaturated. In the case of supersaturation, if there are a sufficient number of particles for the water to condense on, which is common in the south, the supersaturated air will become fog. This study cited added numbers of tourists and people visiting areas with seasonal burning, who are not aware of the burning and how to handle it, as one of the reasons for increased crash rates. In South Carolina, there were eight smoke-related highway incidents over the period of nine months. The report predicted that similar numbers can be assumed for surrounding states. Court cases related to property damage and accidents incurred by controlled burning were also presented in the report. To reduce liability, many southern states, including Georgia, now require certification for large prescribed burns. In addition to traffic interruptions, air quality legislation and wildlife conservation efforts all play into the occurrence and frequency of controlled burns.

These competing factors all influence policy and land management decisions in southern states. For example, the Atlanta metropolitan area and some rural areas (e.g., Washington County) in Georgia have a near total ban on summertime agricultural and sylvicultural burning due to air quality concerns.

Regional patterns in weather-related crashes in the United States from 1995 to 2005 were discussed in a report for the 24th Conference on *International Interactive Information and Processing Systems for Meteorology, Oceanography and Hydrology* (Pisano, et al., 2008). The United States was split into four regions—Northeast, Midwest, South, and West—with most crashes caused by weather occurring in the South and the Midwest. Most weather-related crashes in the South were found to be a result of rainfall or slick pavement. The national average for crashes with wet pavement present was 75 percent of all weather-related crashes, but in the South this percentage jumped to 90 percent. This trend was attributed to the regional weather as the South sees the most rain of any region. Other contributing factors to this spike in wet pavement–related crashes were the increased number of vehicle miles traveled and higher populations.

In addition to responsive behaviors, mitigation measures that can be taken in response to inclement weather have also been studied. Goodwin documented the best practices for road weather management (Goodwin 2002a). The report broke the methods into three groups: advisory, control, and treatment strategies. The report also contains 30 case studies for improvements made to roadways during inclement weather. Georgia was not included in this case study, however Alabama, South Carolina, and Tennessee were considered. These areas can be assumed to have similar road and terrain conditions to Georgia due to their proximity. For Alabama, their worst crash was the one that occurred in 1995 and involved

193 vehicles. This crash precipitated the use of a fog-warning system for Mobile, Alabama, which has reduced the crash risk in the area where installed and also reduced average speed of vehicles around the curve. In South Carolina, the federal court began requiring fog mitigation techniques be incorporated in the construction phase of I-26. In Tennessee, a 99-vehicle pileup was a key factor for the low-visibility warning system used on the interstate today. Since the system was installed, the freeway has been closed twice due to fog and smoke.

METHODOLOGY

Data Sources

In this study, researchers obtained surface observation data from ground-based weather stations and then used those data to generate a fog climatology for the state of Georgia. Weather stations that report these data are widely used for aviation operations and weather forecasting in addition to climatology. Data were obtained from Automated Weather Observing System (AWOS) units, and from Automated Surface Observing System (ASOS) stations across Georgia as shown in Figure 1. AWOS units are operated by the Federal Aviation Administration (FAA) and are some of the longest operating weather stations. AWOS units report conditions at 30-minute or hourly intervals and provide data in a Meteorological Terminal Aviation Routine Weather Report (METAR) format. Different types of AWOS units are capable of measuring different surface conditions. AWOS data used for creating a climatology for Georgia are: temperature, dew point, visibility, variable visibility, cloud ceiling height, and precipitation type. ASOS units are operated as a joint effort between the NWS, FAA, and the Department of Defense. These units collect temperature, precipitation, wind, sky cover, visibility, and pressure data. These data are collected in 20-minute intervals and the units are typically installed at airports.

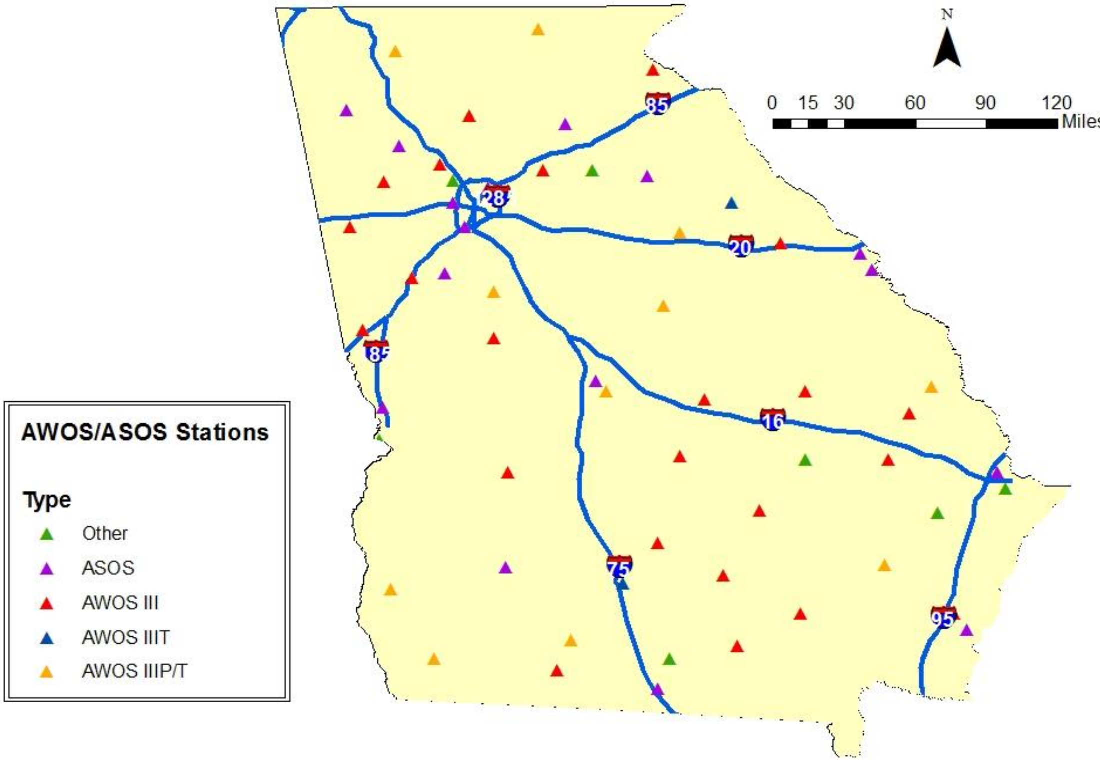

Figure 1: AWOS/ASOS Station Locations across Georgia

Surface Observations

For this report, data from 63 AWOS/ASOS units across Georgia were used to determine the frequency of fog events. Data were obtained from the NOAA website, which maintains a publicly accessible file transfer protocol (FTP) site providing data from 1901 to 2017 from AWOS/ASOS units across the country. A fog event was classified as any 20-minute period during which a condition of visibility less than ⅝ of a mile prevailed. From this, the total seasonal fog duration was calculated. The seasons were separated with winter occurring from December to February, spring occurring from March to May, summer occurring from June to August, and fall occurring from September to November. Fog frequency data were collected for the years 2014 to 2016, and each year's fog data are presented separately and as a seasonal average over the 3 years. After calculating the total seasonal fog frequency at each station, the researchers used Kriging interpolation to generate a fog frequency map for the state of Georgia using ArcGIS. The Kriging method interpolates values using a semi-variogram model to fit a surface across different known points (Croft 1997). This method of interpolation provides the best linear unbiased prediction (BLUP) for values that fall between known points or curves (Ray 2013).

In addition to surface weather conditions, information about fire occurrences across Georgia was used. In regions prone to fires due to drought, debris clearing, or other natural and man-made causes, visibility can become an issue. Two different data sets were used: one data set provided monthly total acres of each county in Georgia that experienced a fire and the other data set distinguished the total acres plagued by fire in each county by cause. These data from 2014 to 2016 were provided by the Georgia Forestry Commission. Fire occurrence can be more common during drought seasons, however most fires are caused by humans and so these data did not show the same temporal trends as the fog frequency data.

RESULTS

AWOS/ASOS Climatology and Fog Frequency

Fog frequency maps were created for the years 2014, 2015, and 2016 using the AWOS/ASOS-reported fog conditions for United States Air Force (USAF) station locations in Georgia. A fog occurrence was classified as any 20-minute interval that had a recorded visibility of less than ⅝ statute miles. The Kriging interpolation method in ArcGIS was used to estimate the number of fog occurrences between the irregularly spaced station locations. Figure 2 to 5 illustrate the seasonal average fog duration from 2014 to 2016 and the Kriging interpolation over the state of Georgia. These averages are illustrated together in Figure 6.. Fog occurrences were most prominent during winter. Fog is also more prevalent in the northern mountainous region and the southeastern coastal portion of the state.

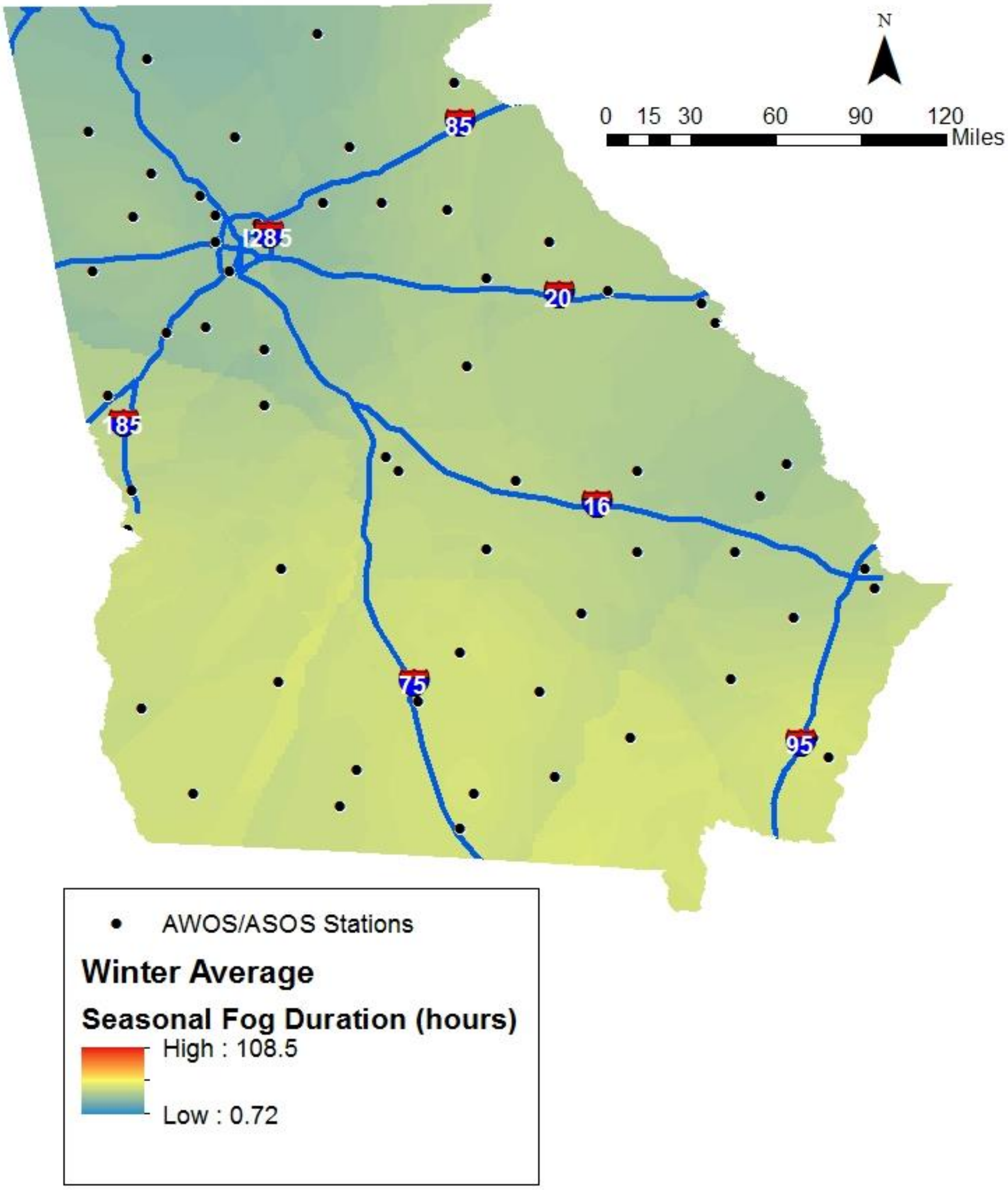

Figure 2: Seasonal Average Fog Duration Winter (2014–2016)

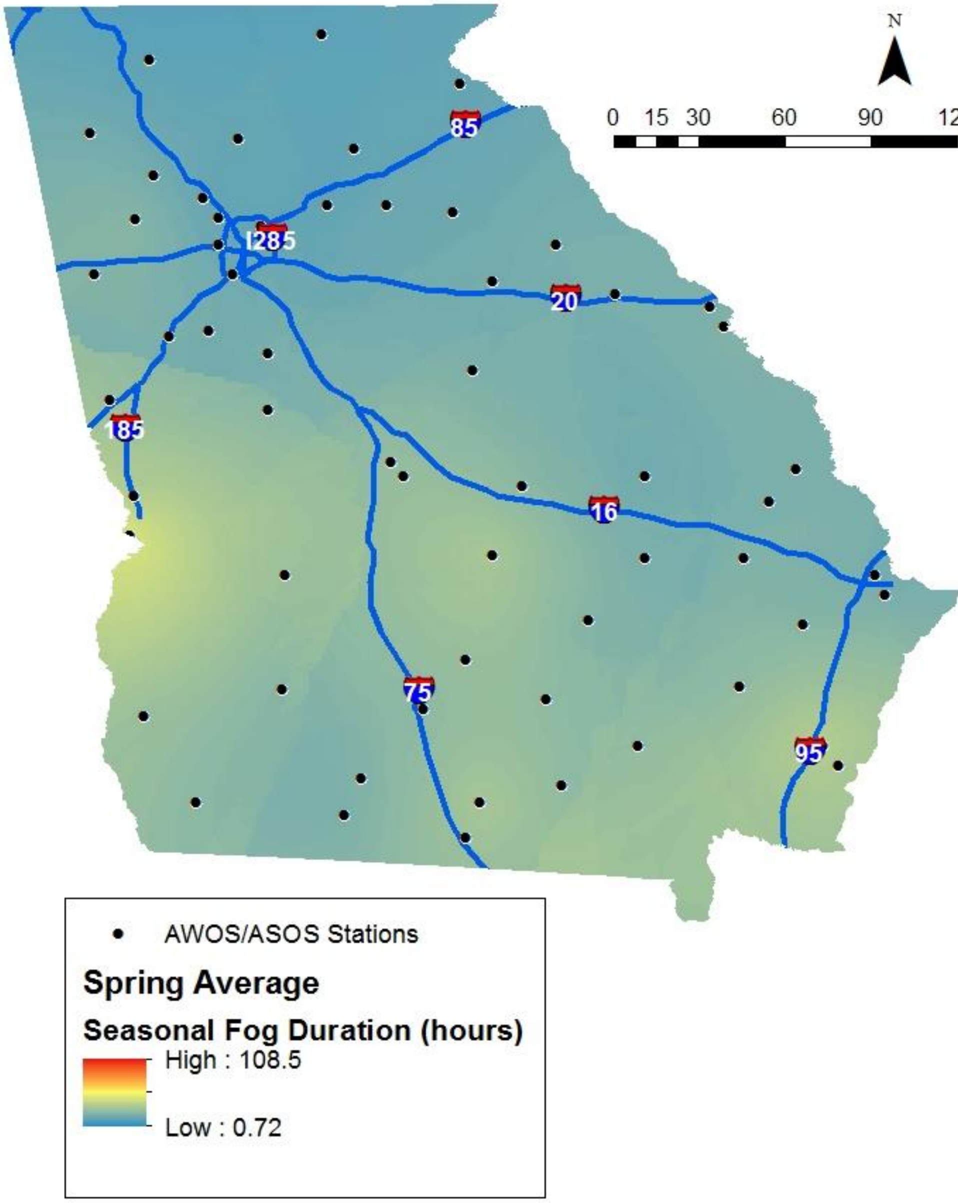

Figure 3: Seasonal Average Fog Duration Spring (2014–2016)

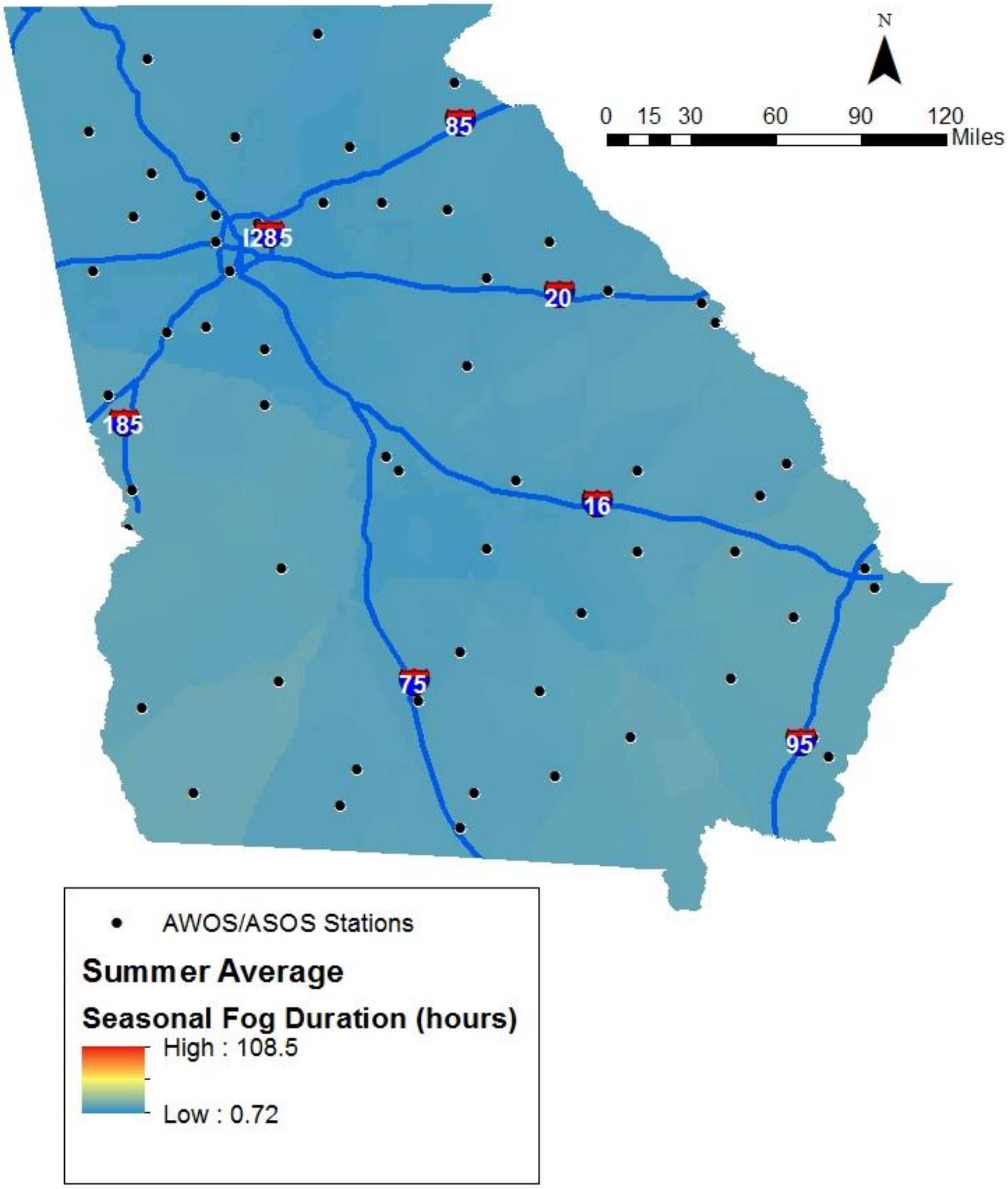

Figure 4: Seasonal Average Fog Duration Summer (2014–2016)

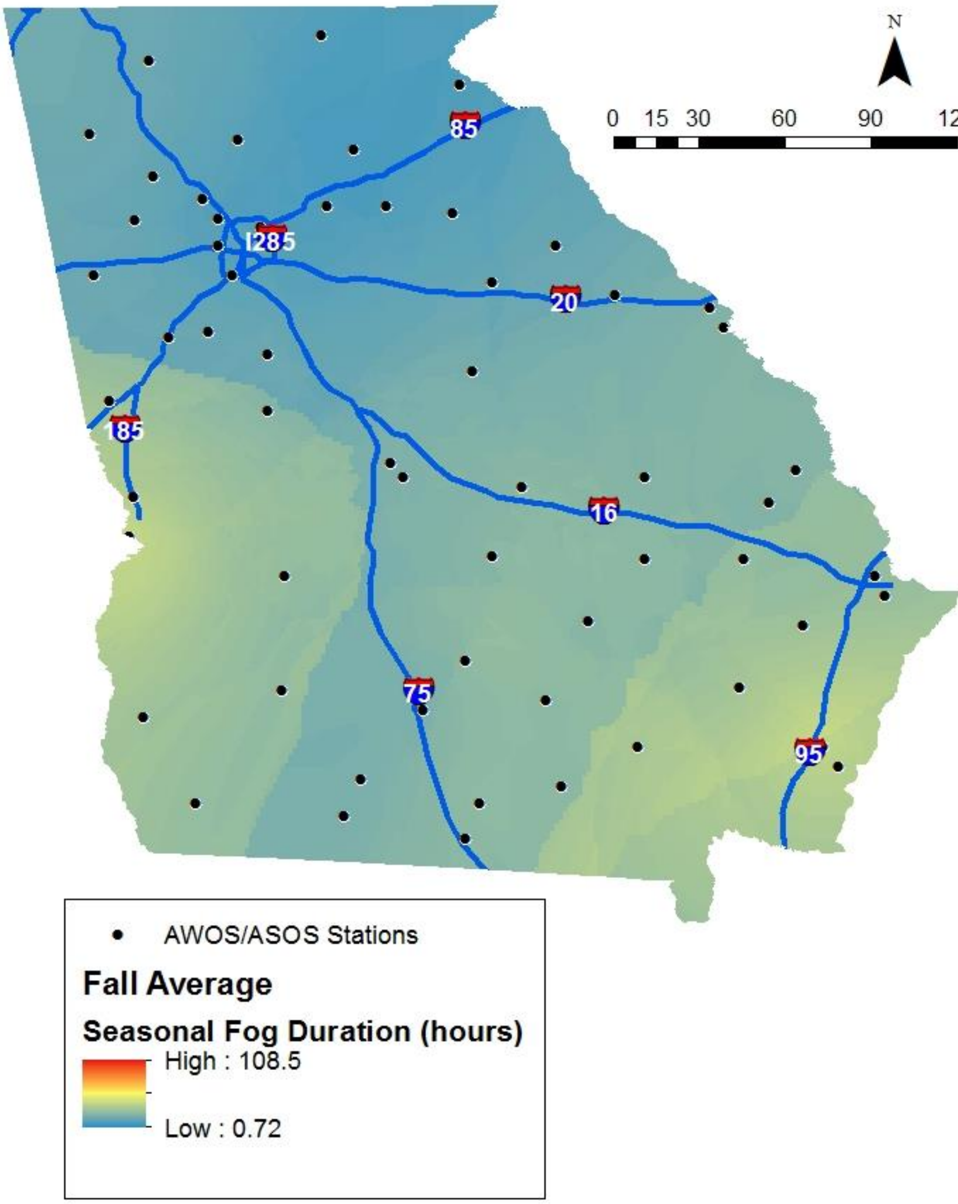

Figure 5: Seasonal Average Fog Duration Fall (2014–2016)

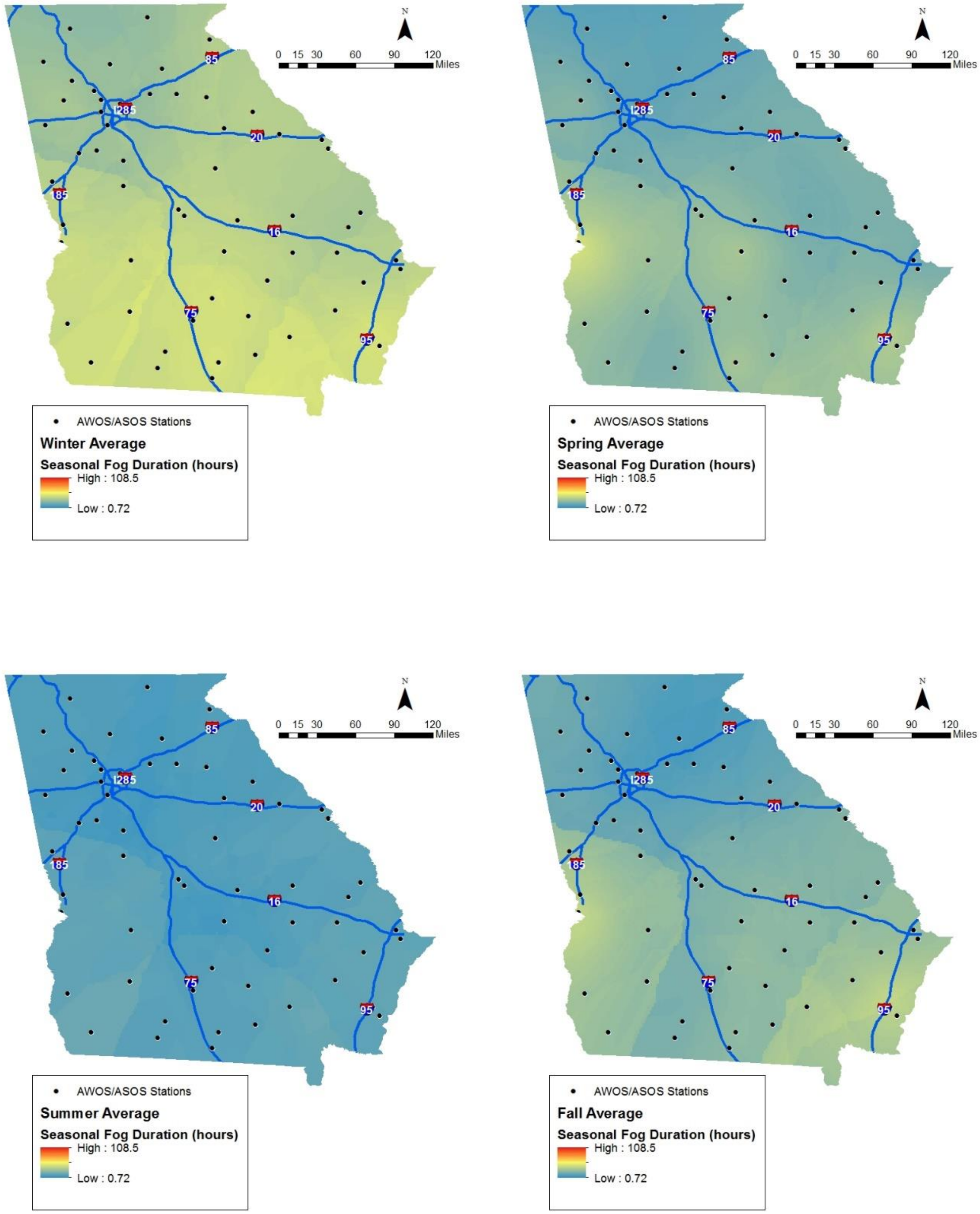

Figure 6: Average Seasonal Fog Duration

Relationship between Fog Occurrences and Highway Visibility

The research team predicted the average visibility along major highways in Georgia using the created fog frequency maps. The visibility percentage was determined using the Zonal Statistics tool in ArcGIS based on the fog duration rasters created through Kriging interpolation. From the mean fog duration calculated along each corridor, the percentage of time each corridor experienced reduced visibility was calculated as a percentage of the total time in each season that fog was present along the corridor. Table 1 shows the percentage of time each interstate corridor experienced reduced visibility during each season. Winter had the highest percentage of time with reduced visibility of all of the seasons. Table 2 shows the average peak for the seasonal percentage of time each corridor experienced reduced visibility. The peak seasonal fog duration was also the highest for the winter season, as is expected based on existing meteorological conditions typical of this season. Figure 7 shows the average seasonal fog duration for each corridor. The figure also shows the average overall fog duration and the average peak fog duration. Summer and fall fog durations are typically closer to the average value, whereas winter and spring fog durations are typically closer to the peak fog duration. This trend can be explained by meterological conditions typical of these seasons.

Table 1: Average Seasonal Fog Duration (%)

Interstate	Winter	Spring	Summer	Fall
I-16	1.57	0.94	0.42	0.98
I-285	1.23	0.64	0.27	0.40
I-95	1.70	0.93	0.50	1.26
I-20W	1.15	0.68	0.35	0.53
I-75S	1.72	0.99	0.40	0.80
I-20E	1.43	0.72	0.37	0.59
I-85S	1.53	1.05	0.49	0.99
I-75N	1.16	0.65	0.51	0.57
I-85N	1.36	0.66	0.58	0.43

Table 2: Peak Seasonal Fog Duration

Interstate	Winter	Spring	Summer	Fall
I-16	1.86	1.13	0.62	2.05
I-285	1.36	0.71	0.31	0.82
I-95	2.07	1.24	0.64	3.62
I-20W	1.43	0.88	0.51	1.81
I-75S	2.19	1.36	0.57	2.20
I-20E	1.63	0.85	0.50	1.43
I-85S	1.79	1.28	0.64	2.32
I-75N	1.29	0.73	0.76	1.17
I-85N	1.51	0.76	0.75	1.06

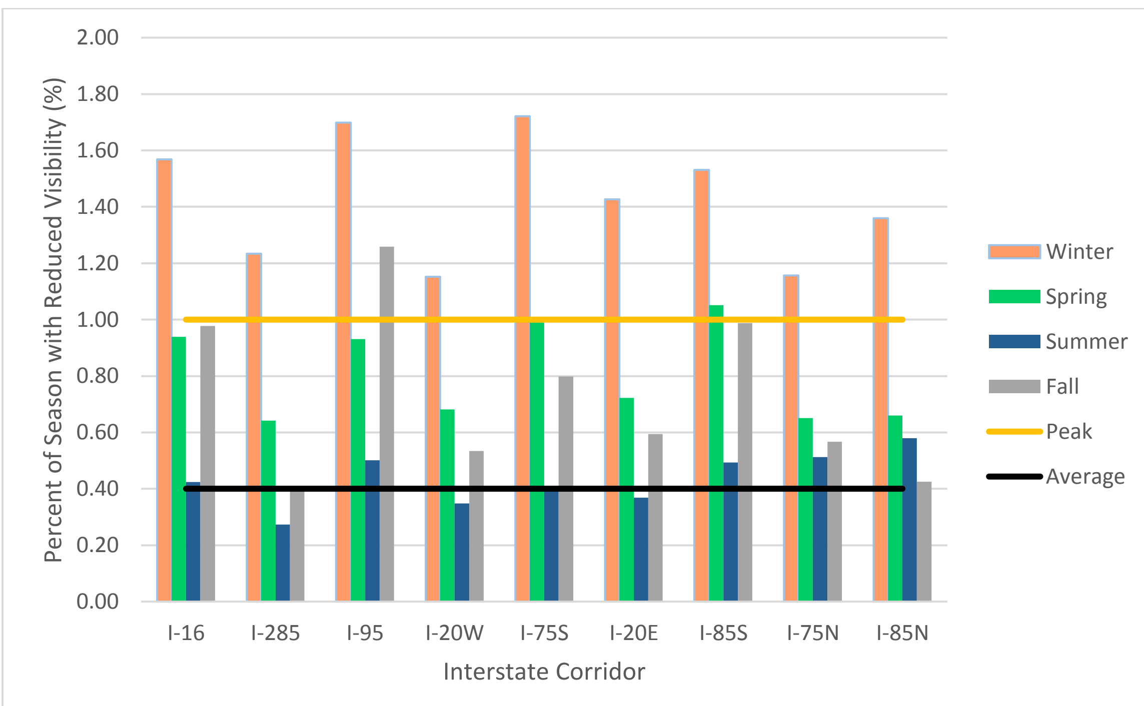

Figure 7: Percent of Season with Reduced Visibility

Fire and Smoke Frequency

The reseach team created a fire frequency map by averaging data reported by the Georgia Forestry Commission from 2014 to 2016. The average number of acres burned is displayed by county in Figure 8. More acres were affected by fires in the northwestern and southeastern regions of Georgia. The majority of counties averaged less than 50 acres of land burned per year and typically had little to no reduction in visibility due to smoke.

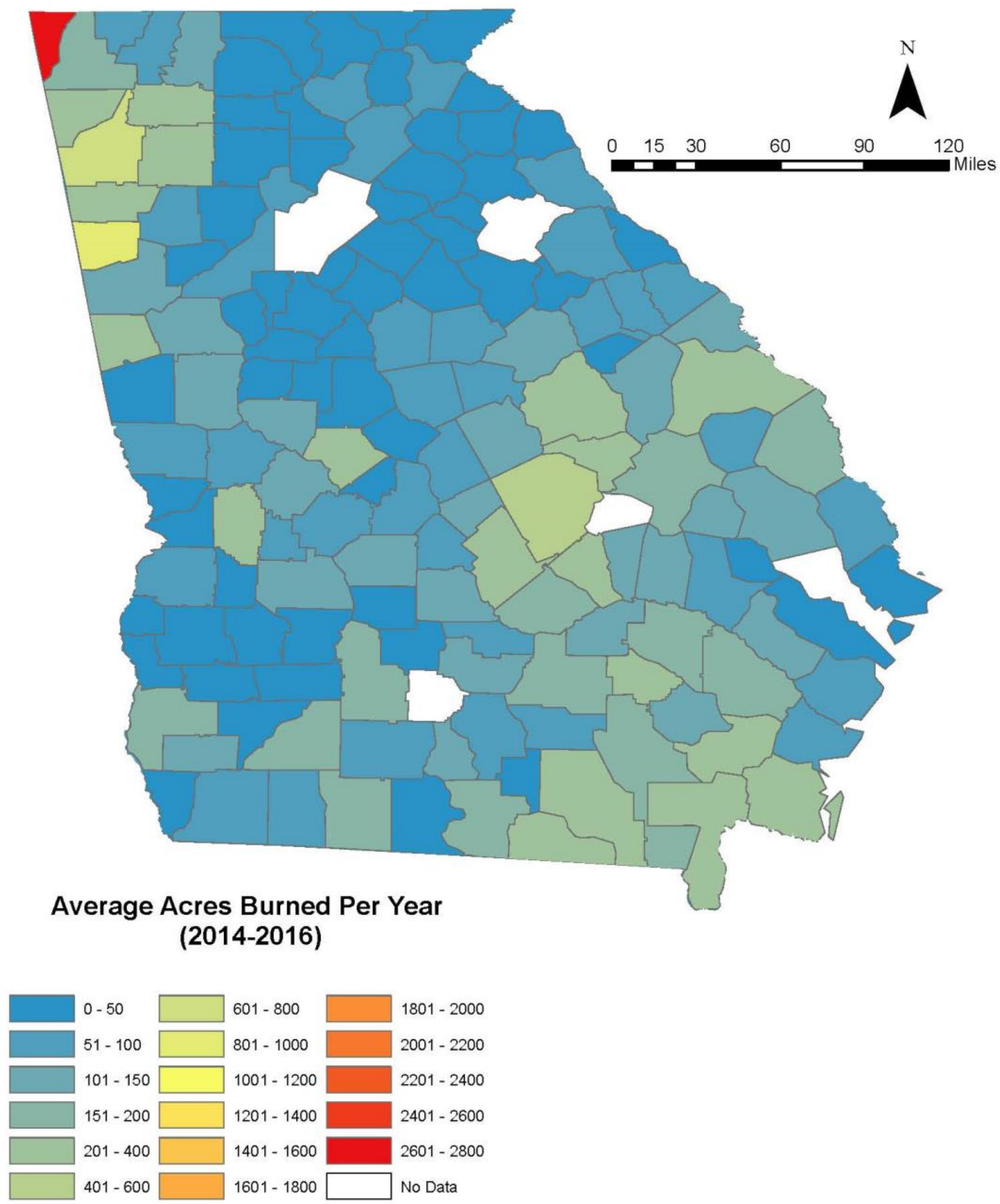

Figure 8: Average Acres Burned Per Year from 2014 to 2016

Similar to fog occurrence, fire frequency is dependent on the season. The average acres burned from 2014 to 2016 were also mapped by season to demonstrate the dependency on time of year. Figure 9 to Figure 12 display the seasonal averages for acres burned. The four seasons are categorized as specified previously. The maps are illustrated together in Figure 13. According to data retrieved from the Georgia Forestry Commission, the most acres were burned during the fall. The acres burned in the fall accounted for 30.8 percent of the total average acres burned from 2014 to 2016. Summer experienced the fewest acres burned (17.9 percent of total average acres burned). The majority of counties experienced less than 50 acres burned on average for each of the four seasons. The white regions on the maps represent counties that did not have available data.

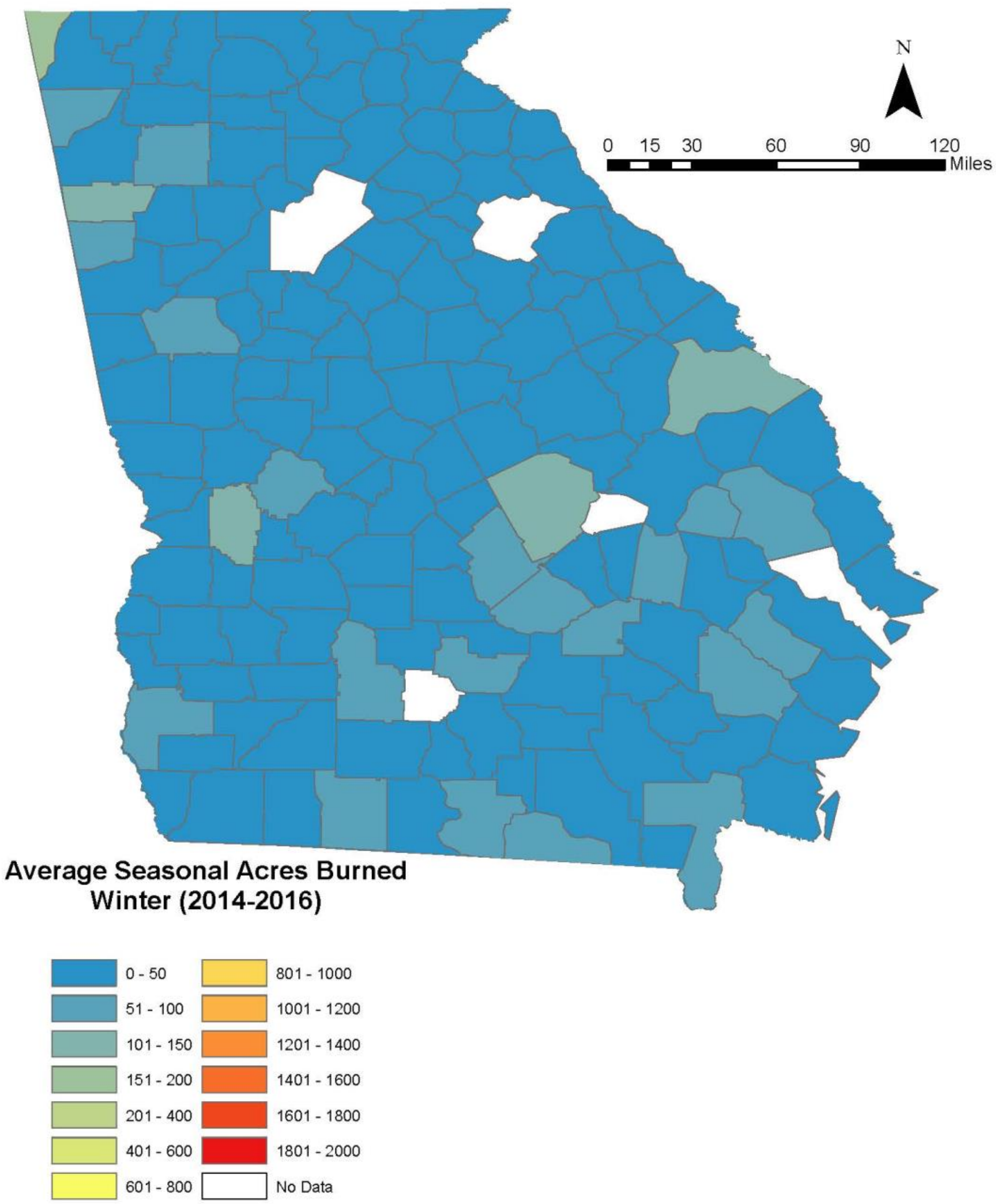

Figure 9: Average Seasonal Acres Burned Winter (2014–2016)

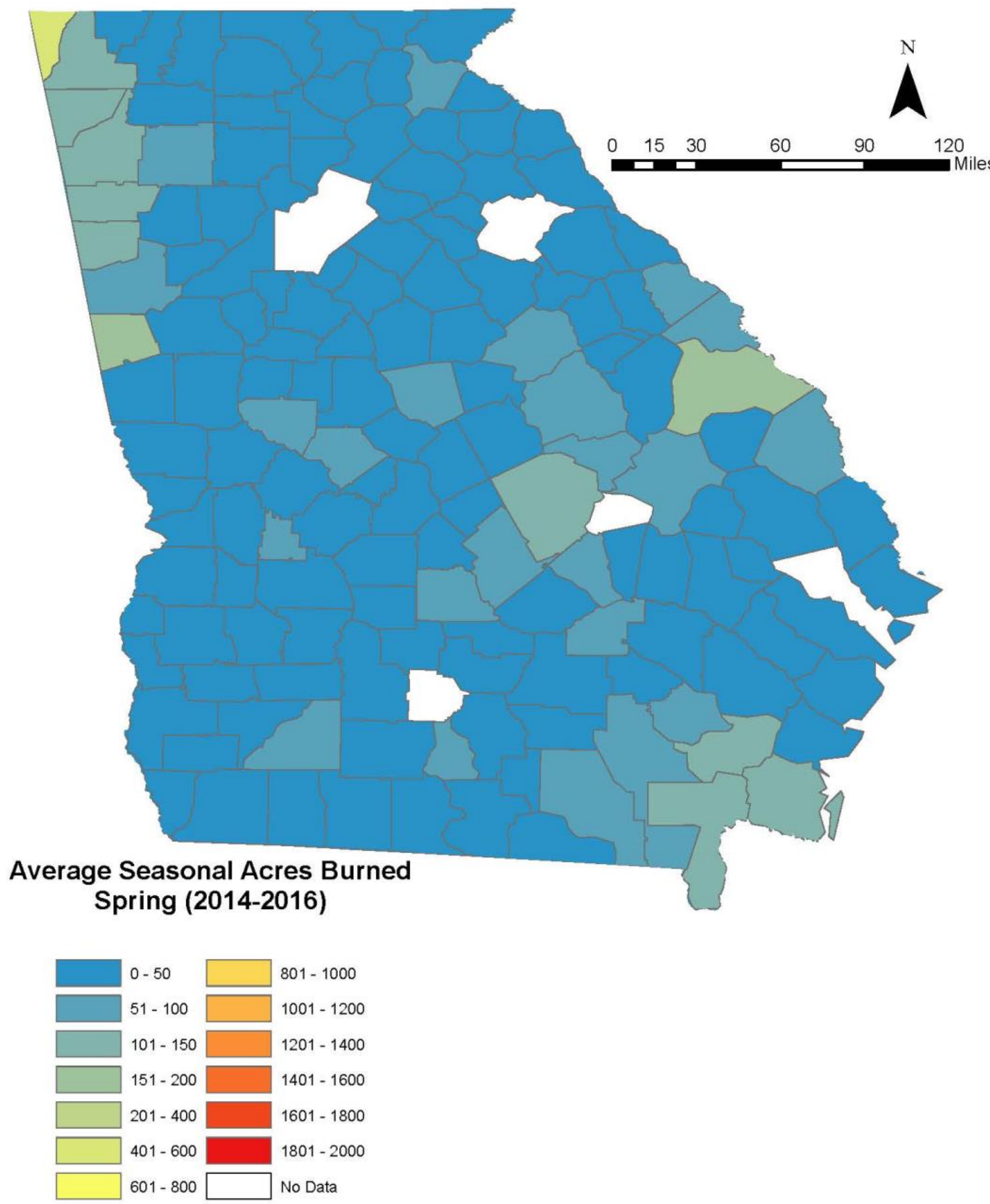

Figure 10: Average Seasonal Acres Burned Spring (2014–2016)

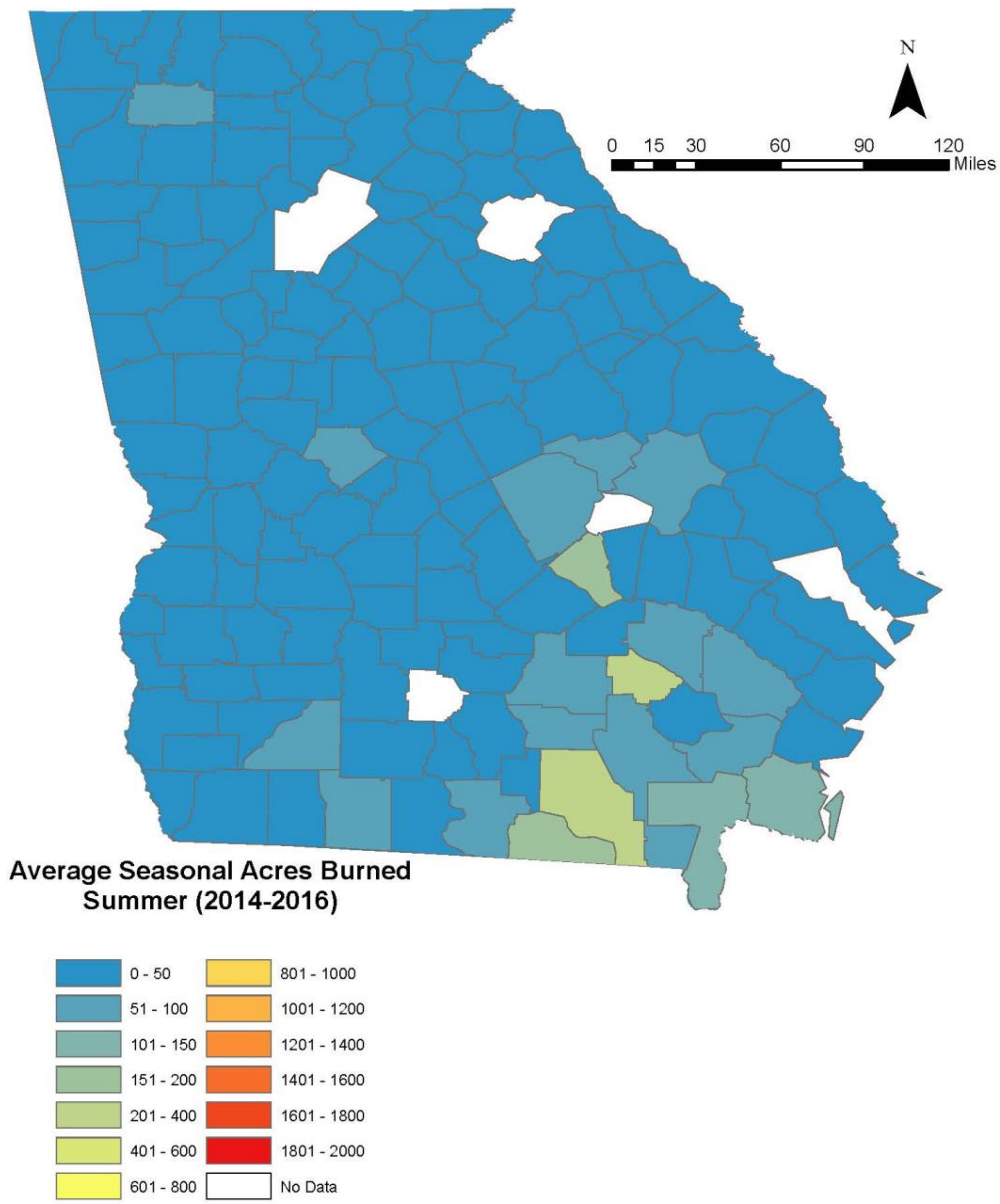

Figure 11: Average Seasonal Acres Burned Summer (2014–2016)

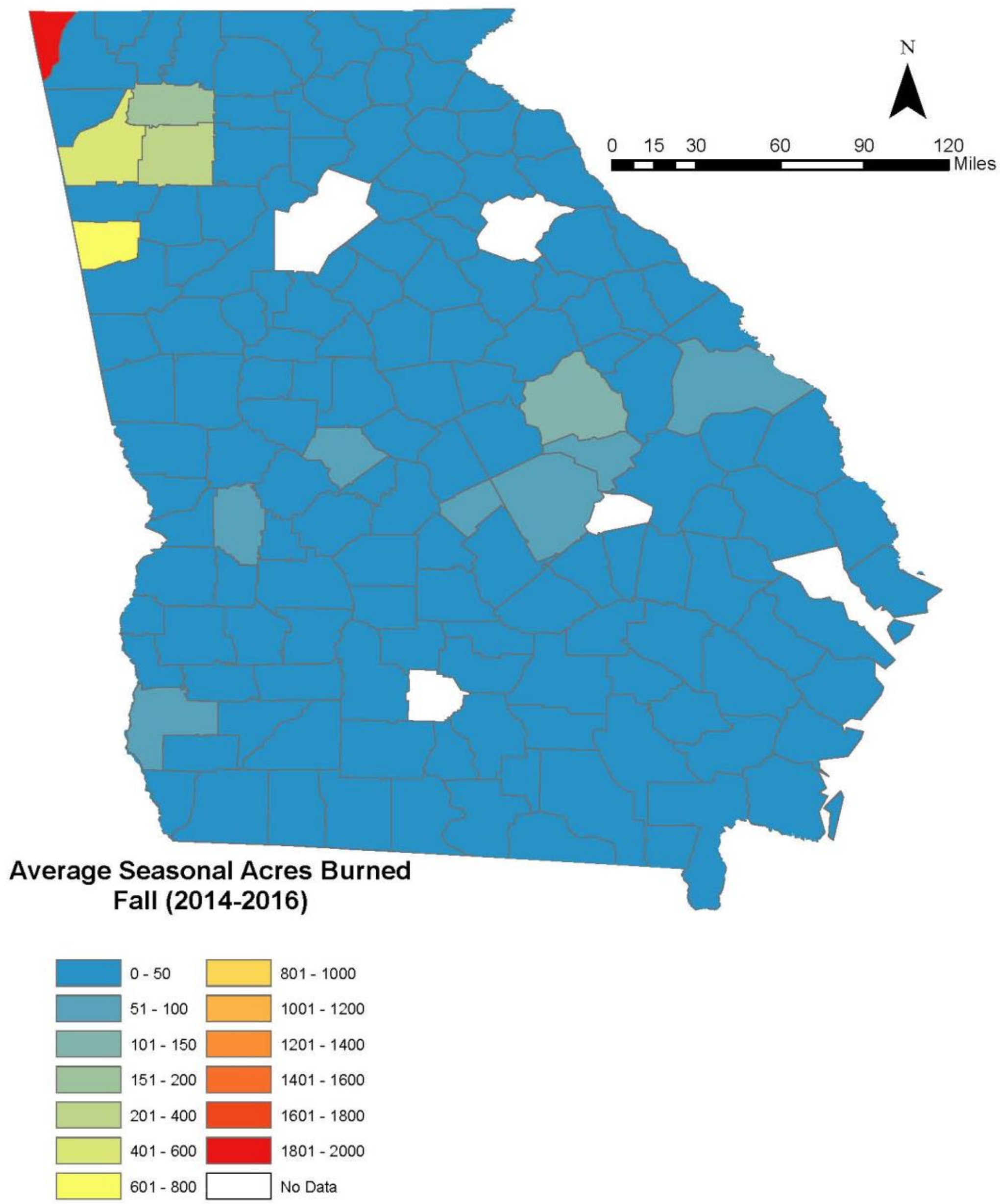

Figure 12: Average Seasonal Acres Burned Fall (2014–2016)

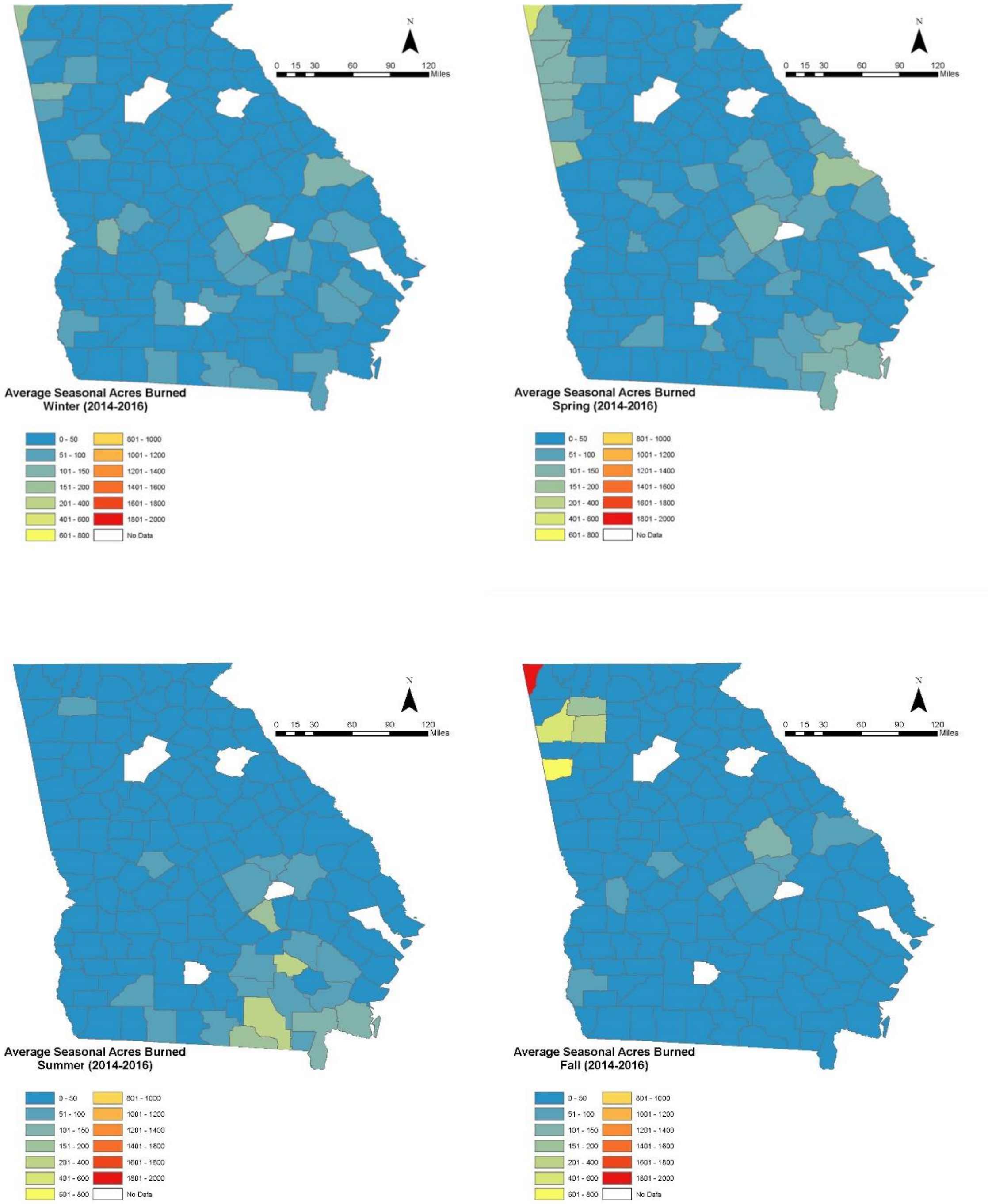

Figure 13: Average Seasonal Acres Burned from 2014 to 2016

Maps displaying the cause of the fires were also created. The causes were categorized into prescribed, natural, and human factors as shown individually in Figure 14 to 16 and shown combined in Figure 17. Prescribed causes are the leading cause of fires in Georgia. On average, approximately 8800 acres were burned per year by prescribed causes (51.8 percent of total acres burned per year). Naturally caused fires were more prominent in the southeastern region of the state near the Florida/Georgia border, whereas fires started by humans were more likely in the northwestern region. Human-caused fires account for an average of 34.7 percent of the total acres burned per year. Only 13.4 percent of total acres burned were started by natural causes. The white regions on the maps represent counties that did not have available data.

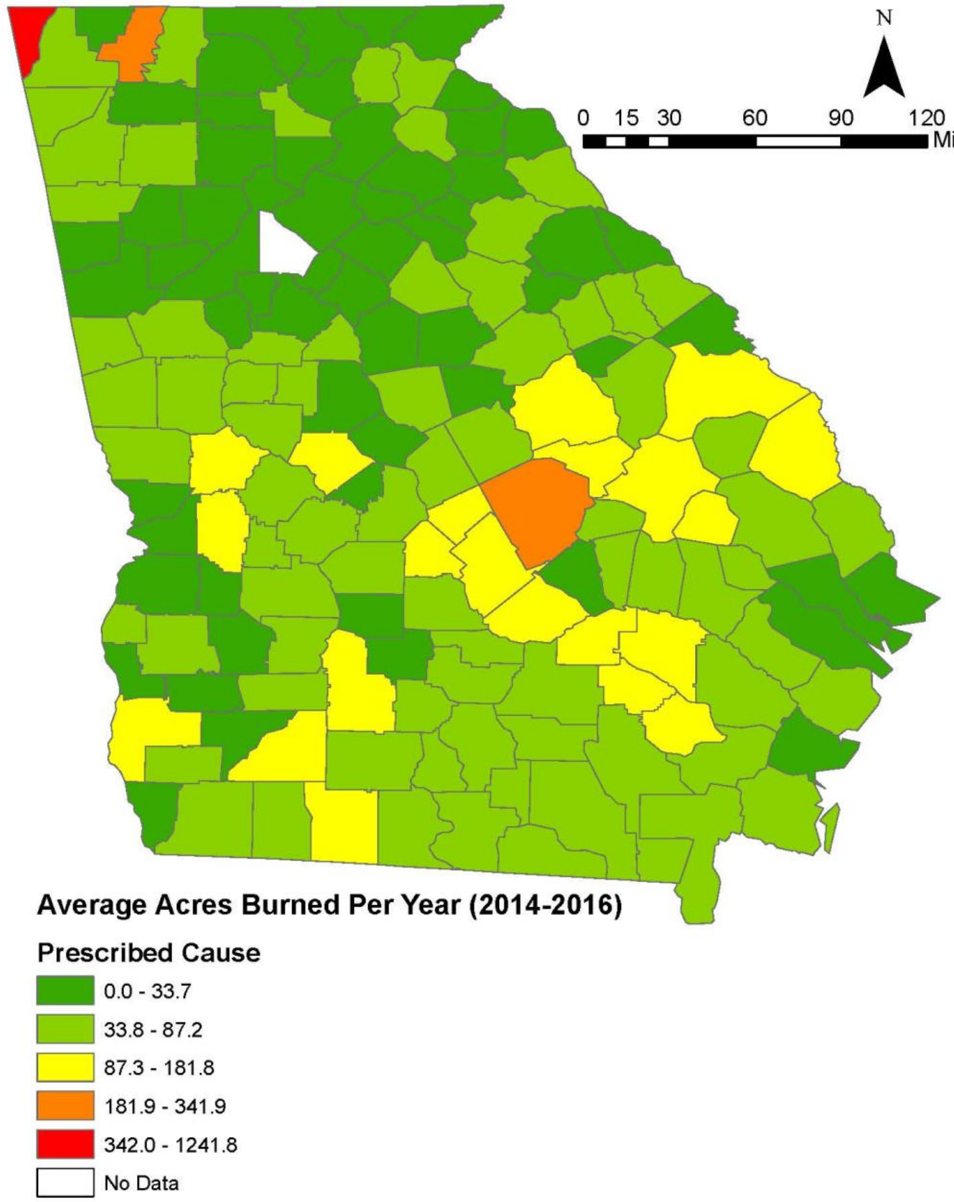

Figure 14: Average Acres Burned Per Year (2014–2016) Prescribed Cause

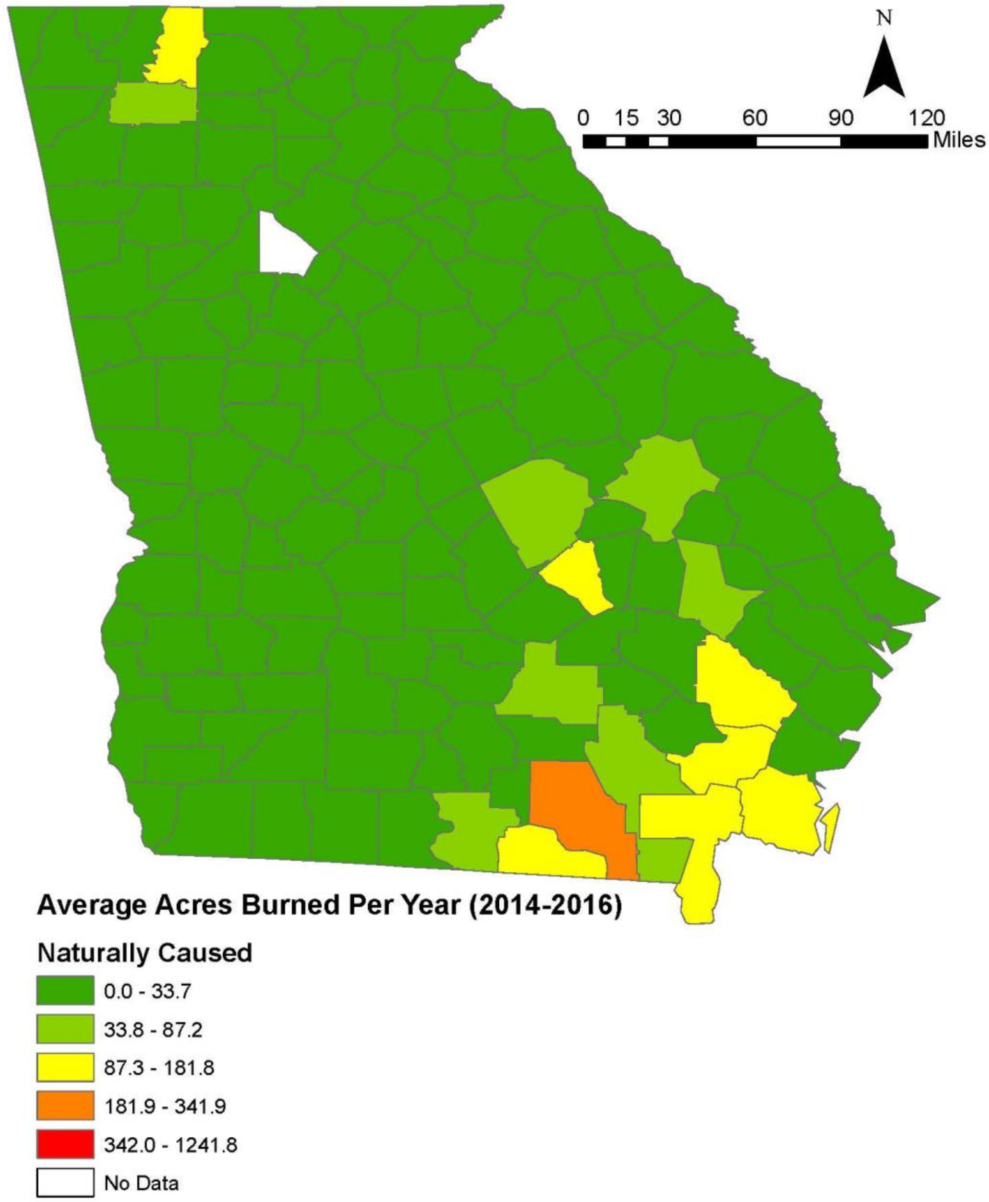

Figure 15: Average Acres Burned Per Year (2014–2016) Naturally Caused

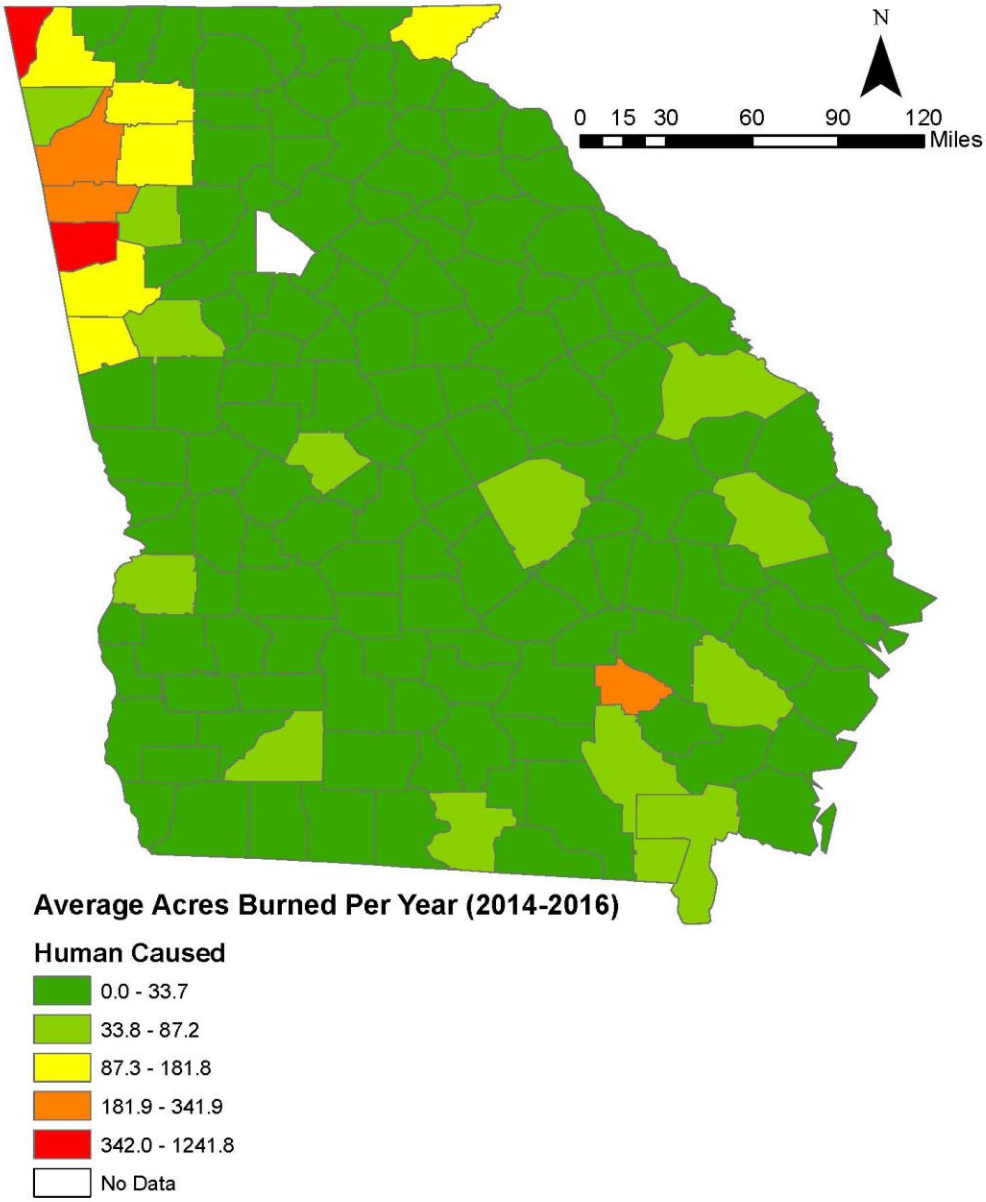

Figure 16: Average Acres Burned Per Year (2014–2016) Human Caused

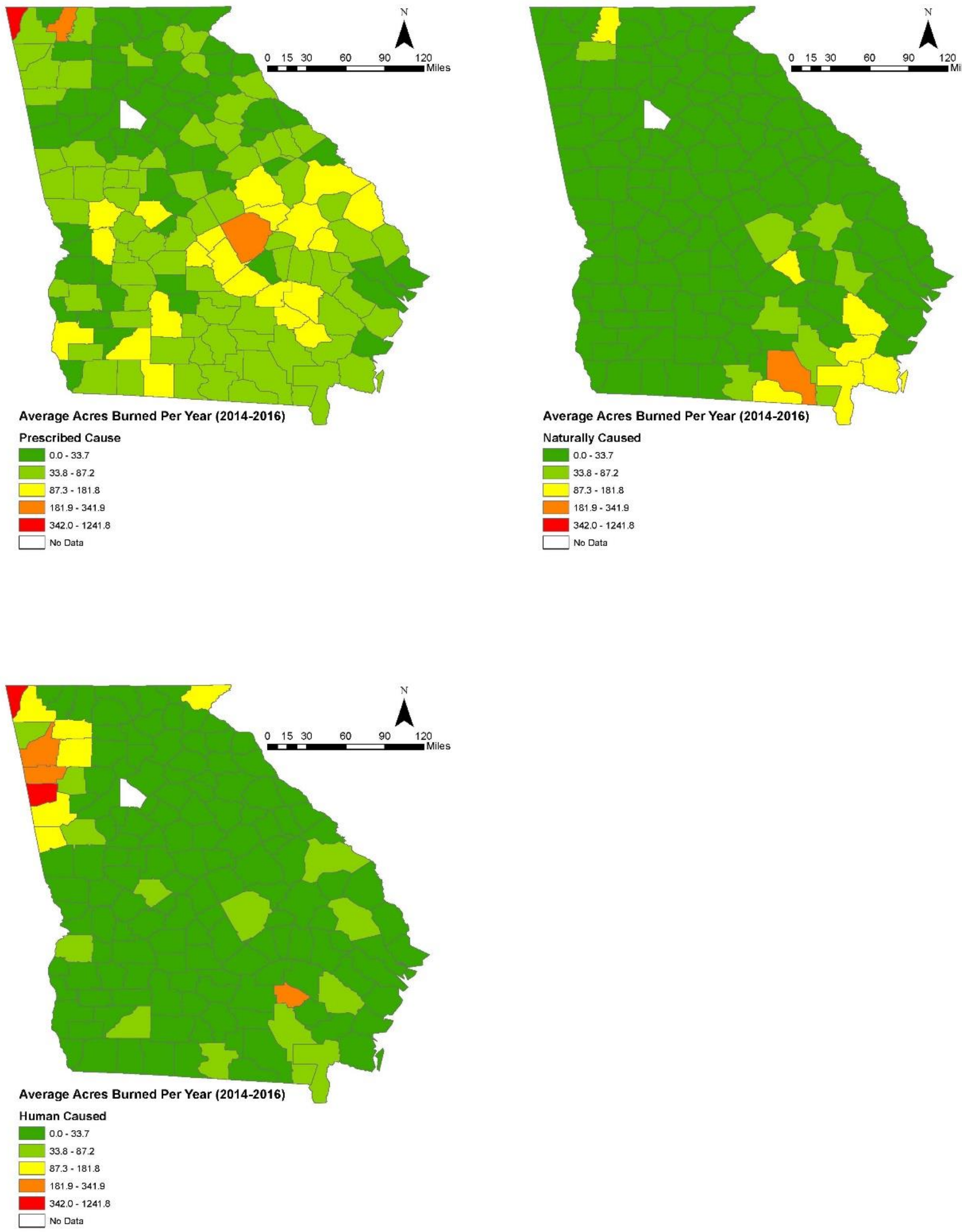

Figure 17: Average Acres Burned Per Year from 2014 to 2016 Categorized by Cause

CONCLUSIONS & RECOMMENDATIONS

The major goal of this research study is to determine the fog and smoke frequency in Georgia in relation to driver visibility. This report presents three major findings: fog frequency of all regions, fog frequency on interstates, and fire frequency in Georgia.

From the study, the researchers concluded that the visibility hazards, fog and fog enhanced with smoke, are dependent on region and season. Fog is more prevalent in the northern mountainous region and the southeastern coastal portion of Georgia. Additionally, more acres of land were affected by fires in the northwestern and southeastern regions. Fog occurrences were more prominent during winter months and more acres of land were burned during the fall. ArcGIS® was used as an analytic tool that helped to infer patterns between fog and state topography. These results were concluded from climatology maps based on visibility data from AWOS/ASOS units and fire records from the Georgia Forestry Commission.

Collectively, these results show that conditions of reduced visibility vary widely across Georgia with Southern and Coastal Georgia being the most signicantly impacted especially during the fall and winter months. Both the average and peak-season frequencies of reduced roadway visibility in Georgia are high enough to warrant consideration of countermeasures and safety treatments in vulnerable areas. While this study broadly identified areas of the state where such treatments may be desirable, additional study is required to locate the specific locations and types of treatments that will provide the most cost-effective improvements in highway safety. Specifically, GDOT should consider the following recommendations:

1. *GDOT should undertake a higher spatial-resolution evaluation of reduced visibility along selected corridors and regions to identify specific roadway segments and locations for which visibility-related safety treatments would be cost-effective. This study should include both a specific analysis of roadway crashes and fatalities associated with reduced visibility in the study areas and an analysis of the likely effectivess of potential treatments, both active and passive, in reducing visibility-related risks in these area. The corridors and areas recommended for this study include:*

    a. *I-95 in Coastal Georgia*

    b. *I-16 from Savannah to Metter (or Macon) including state routes serving the Port of Savannah*

    c. *State Routes in the North Georgia Mountains*

    d. *Interstate and selected State Routes crossing reserviors and major rivers.*

2. *Based on the results of the study recommended above, GDOT should consider revisions to its design policy to include provisions for reduced-visiblity treatments in designated locales and/or corridors during the design process.*

The rationale for the selection of the locations in recommendation 1 is based on both the frequency of reduced visibility and the likely impact this reduced-visibility on highway safety both now and into the future. While both I-85 and I-75 in south Georgia also have a relatively high rate of reduced visibility during portions of the year, the continued growth in the Port of Savannah associated with the opening of the new Panama Canal and the associated deepening of the Savannah Ship Channel is likely to result in significant additional heavy duty truck activity on both the I-95 and I-16 corridors as well as State Routes servicing the port itself. As truck volumes increase, visibility related treatments are likely to prove increasingly cost-effective.

In the case of the north Georgia, mountain roads typically have more limited sight distance than those on level terrain and thus any level of reduced visibility is likely to have a more adverse safety impact. Likewise, river and reservior crossing represent a different type of hazard where visibilty may reduced quickly from otherwise normal conditions.

The second recommendation focuses on identifying the potential need for treatments during the design process and thus avoiding subsequent retro-fitting. Implementing these recommendations will allow GDOT to significantly reduce the adverse impacts of reduced-visibilty conditions in Georgia.

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APPENDICES

APPENDIX A: SEASONAL FOG DURATION

Seasonal Fog Duration for 2014

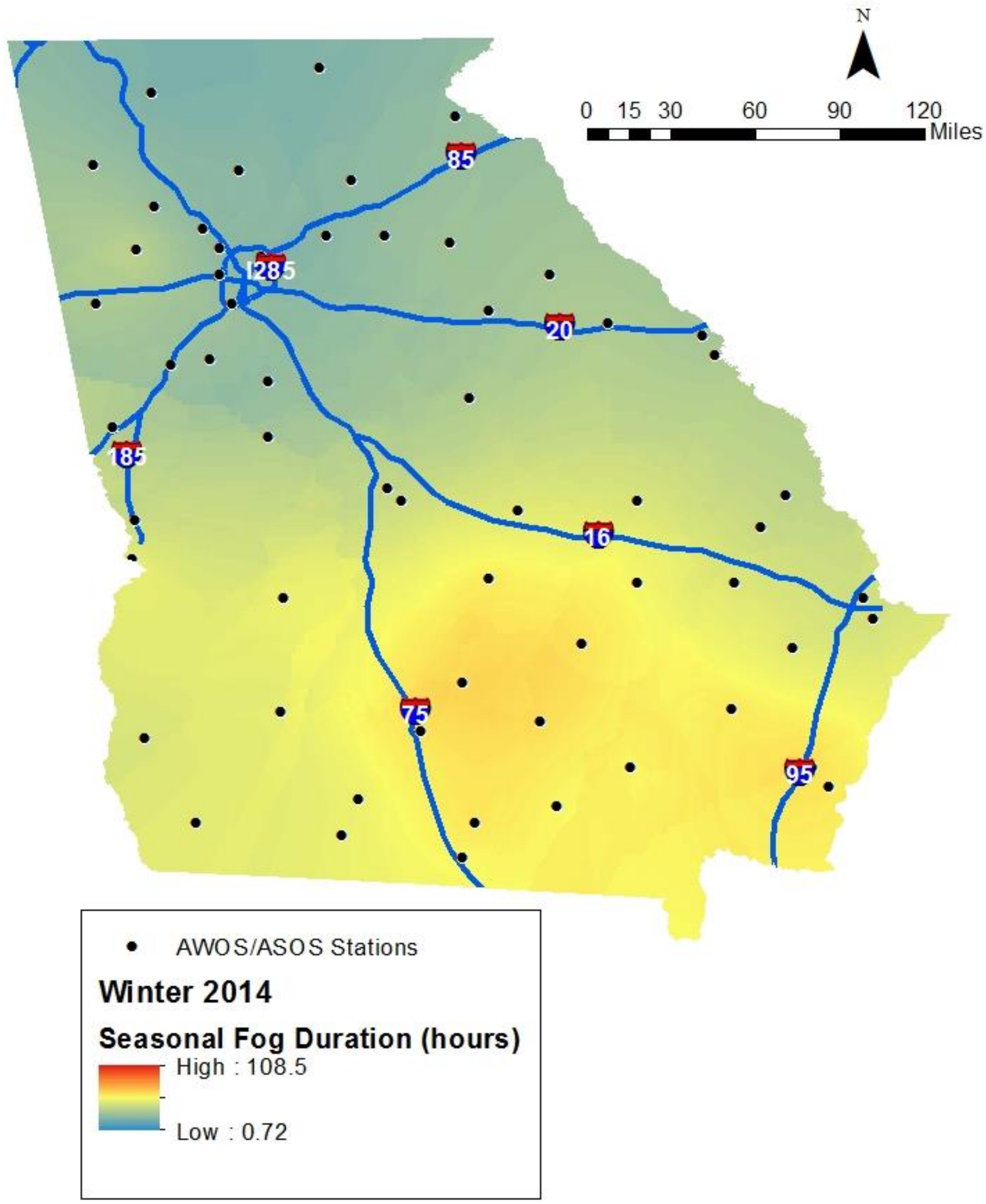

Figure 18: Seasonal Fog Duration Winter 2014

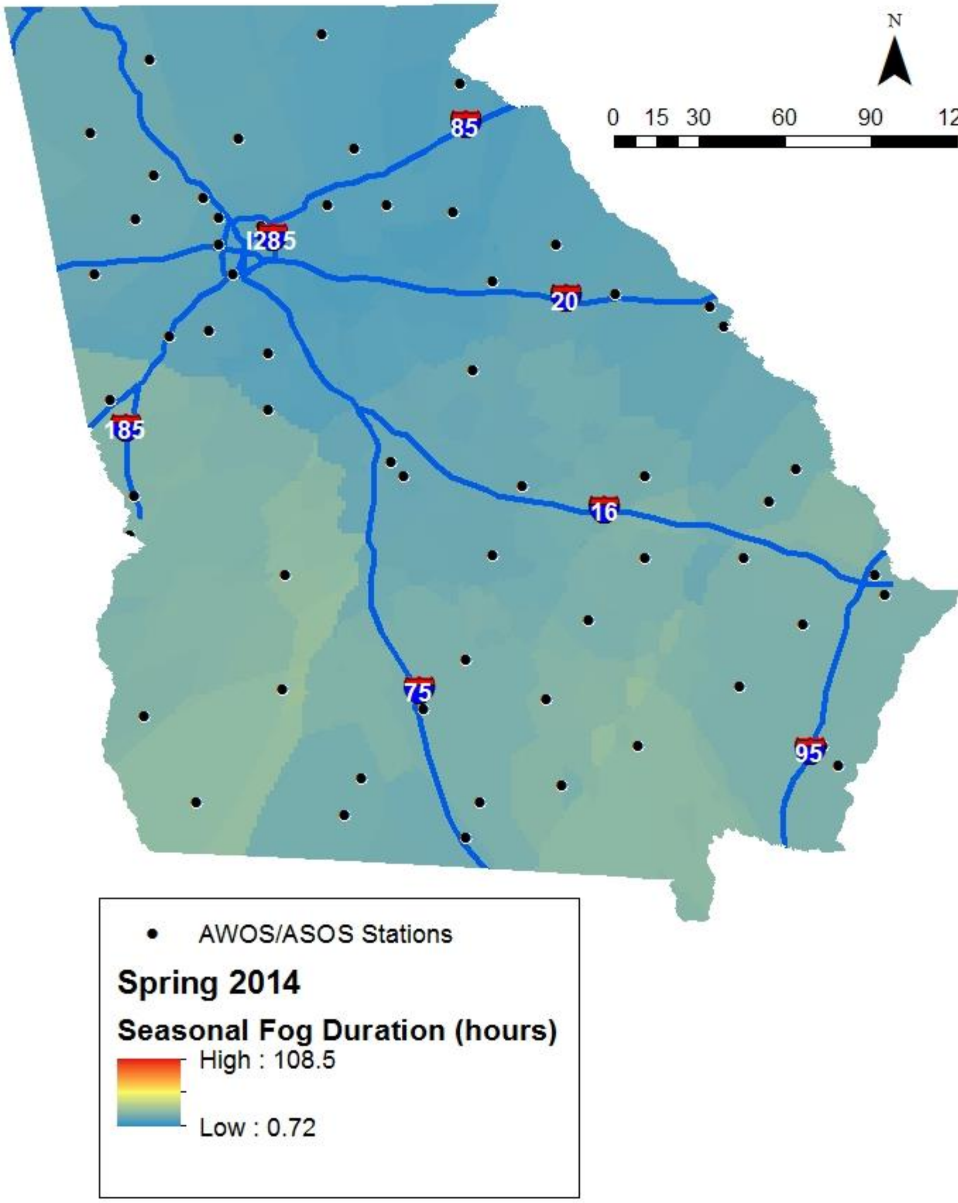

Figure 19: Seasonal Fog Duration Spring 2014

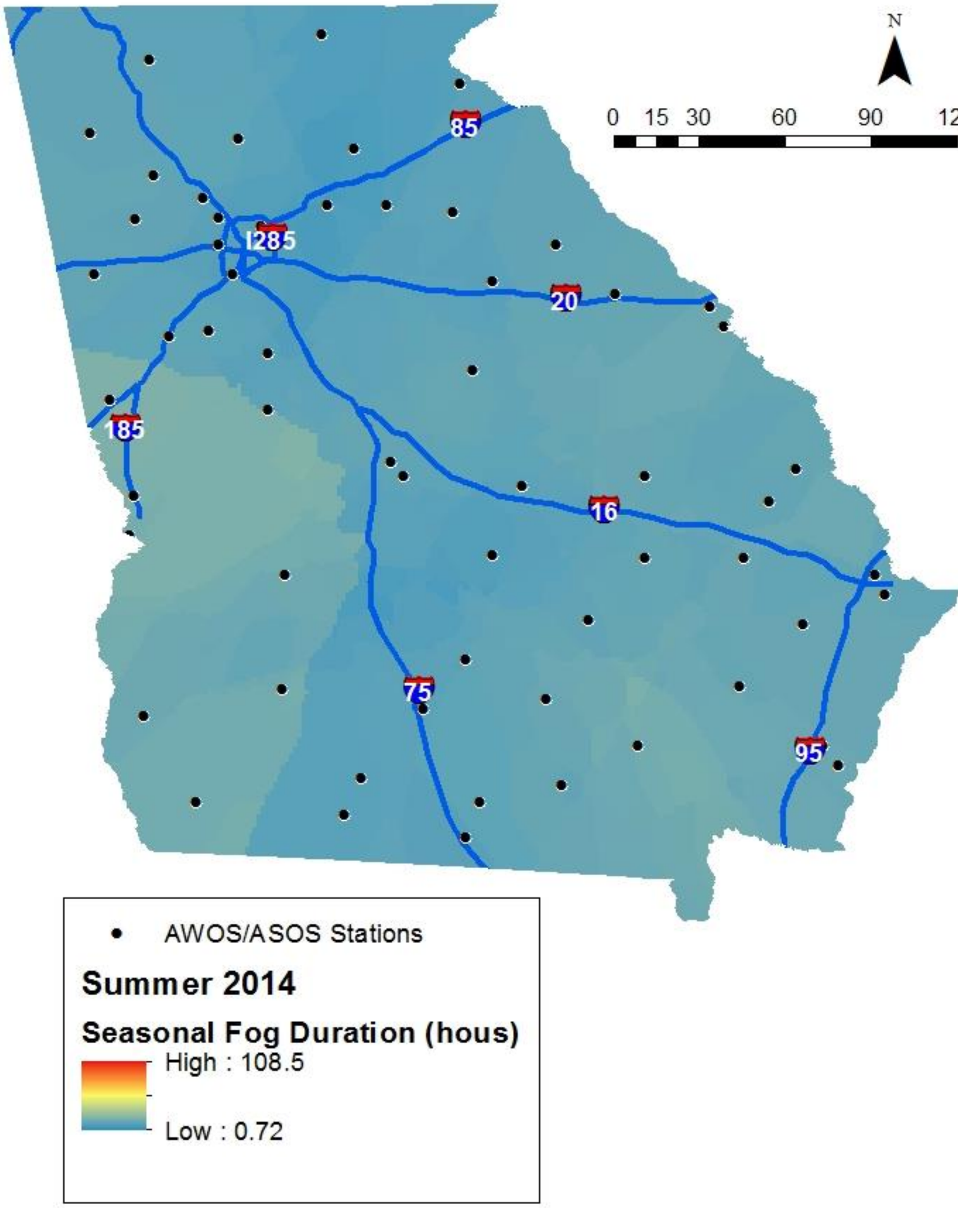

Figure 20: Seasonal Fog Duration Summer 2014

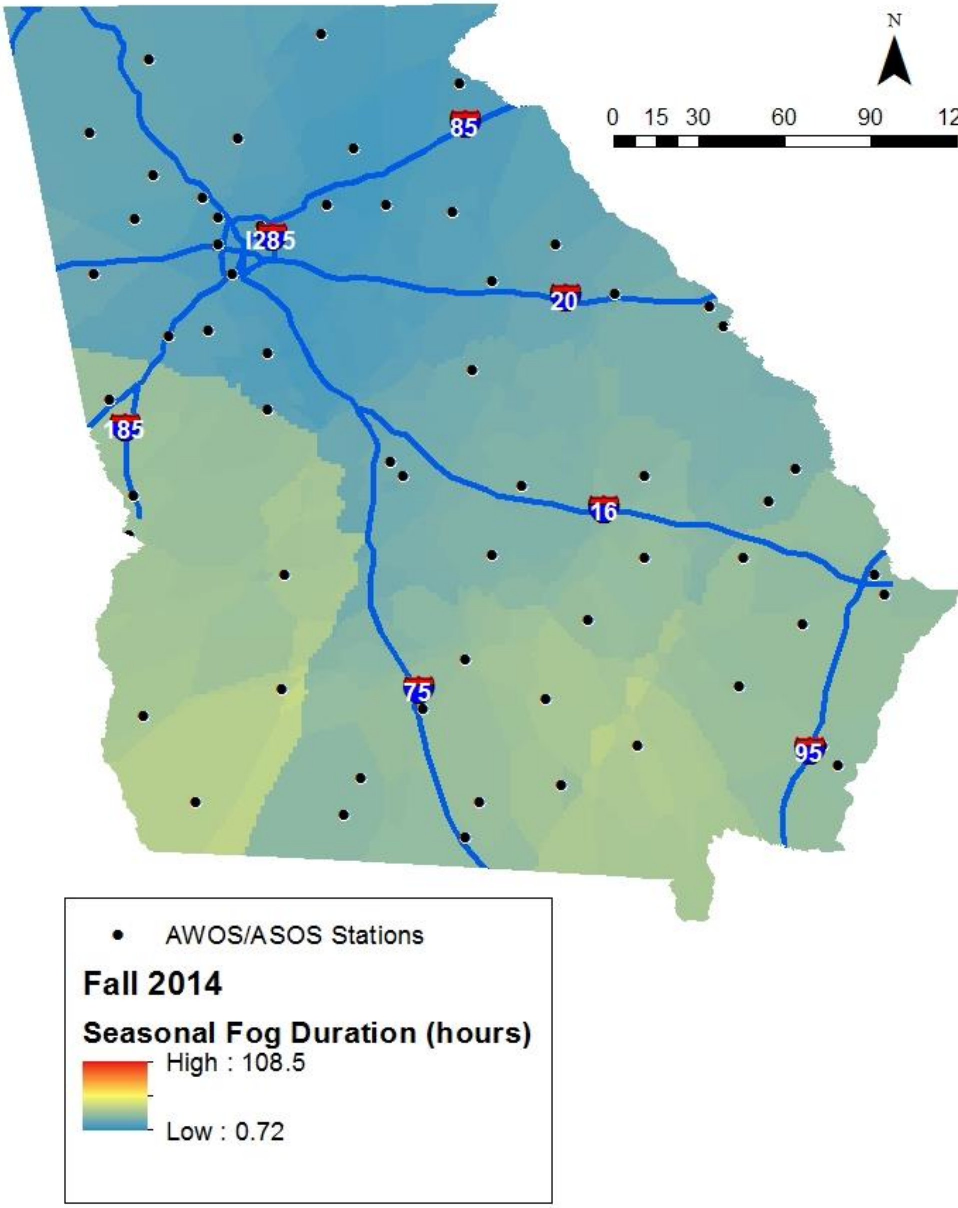

Figure 21: Seasonal Fog Duration Fall 2014

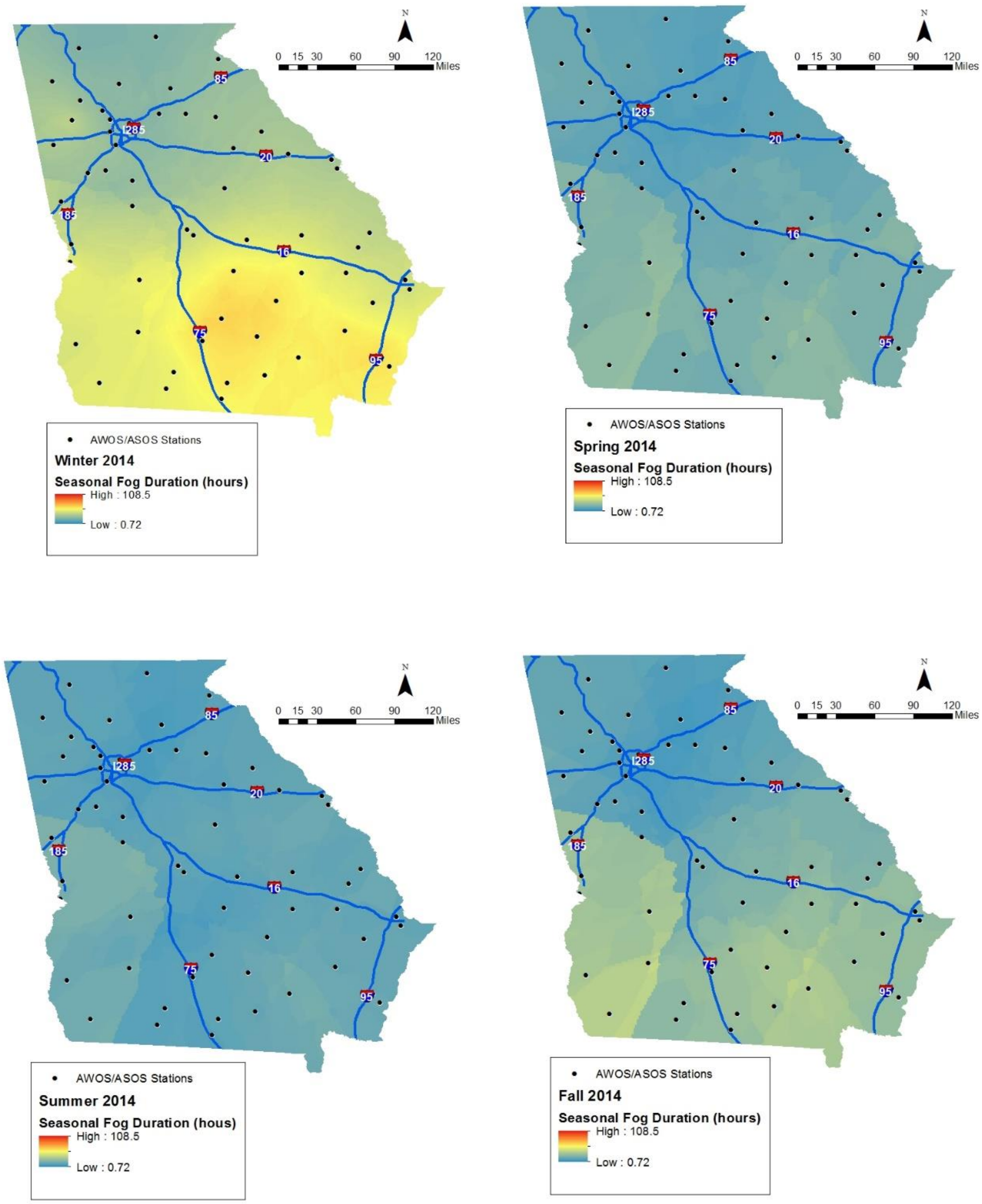

Figure 22: Seasonal Fog Duration 2014

Seasonal Fog Duration for 2015

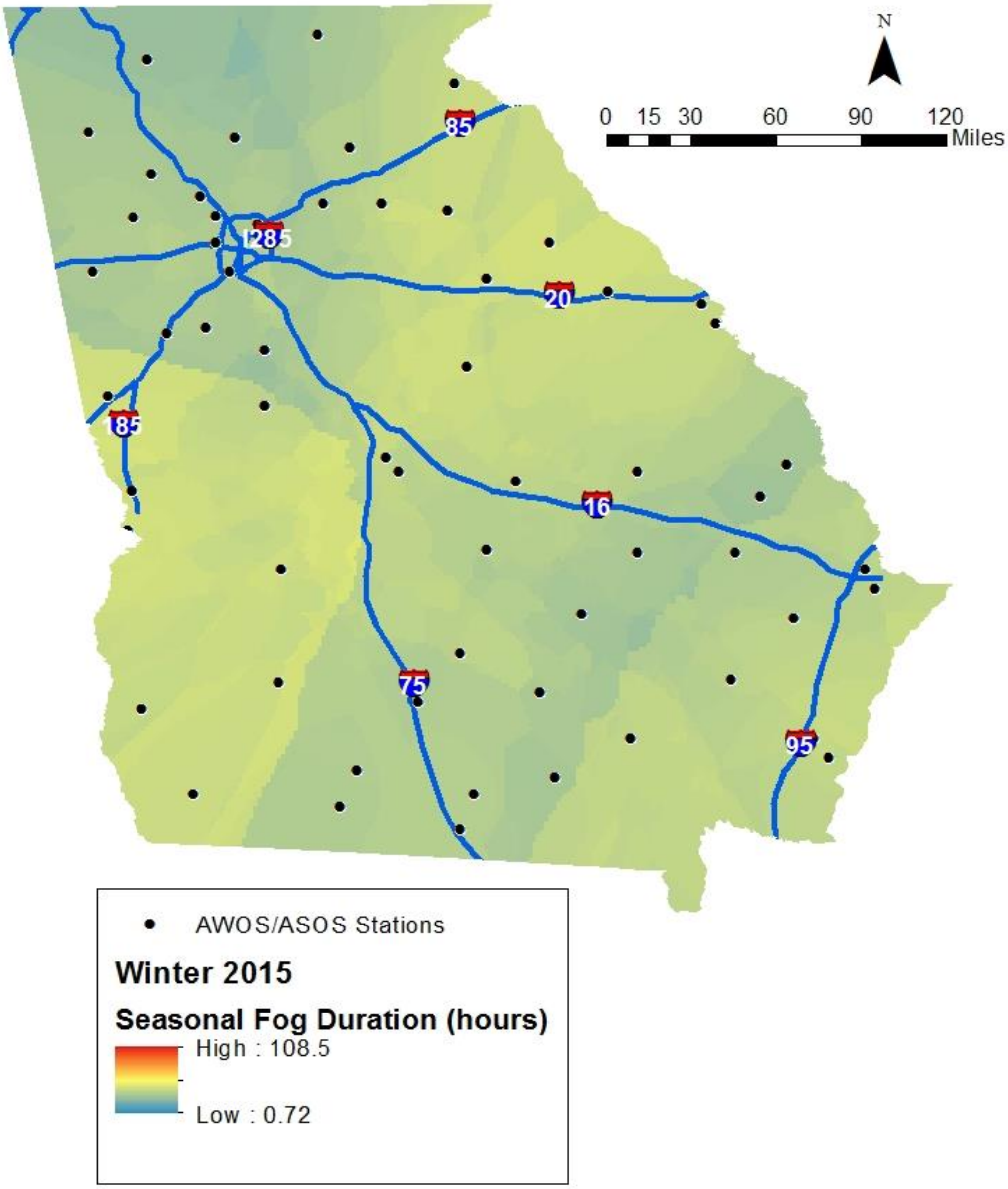

Figure 23: Seasonal Fog Duration Winter 2015

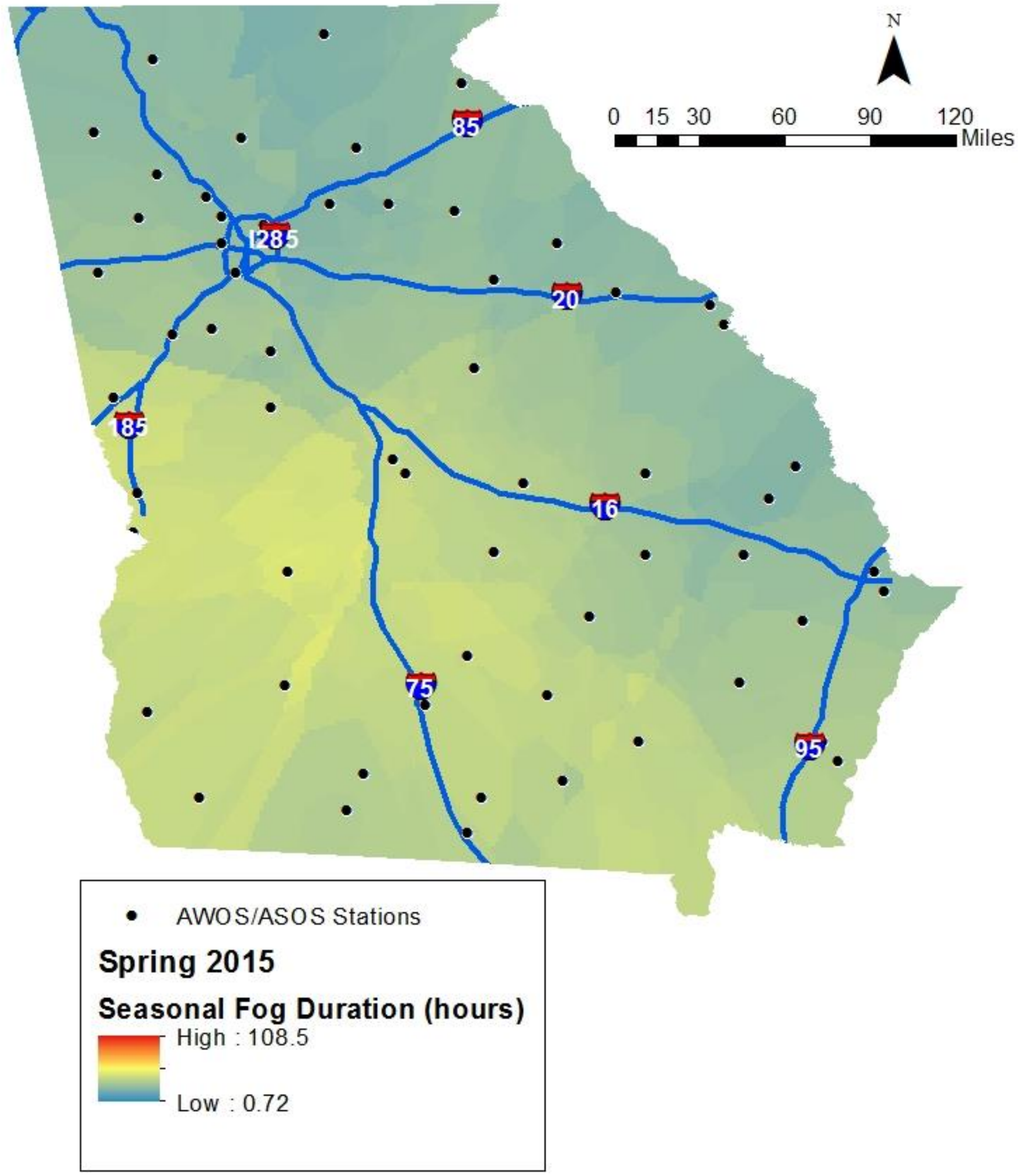

Figure 24: Seasonal Fog Duration Spring 2015

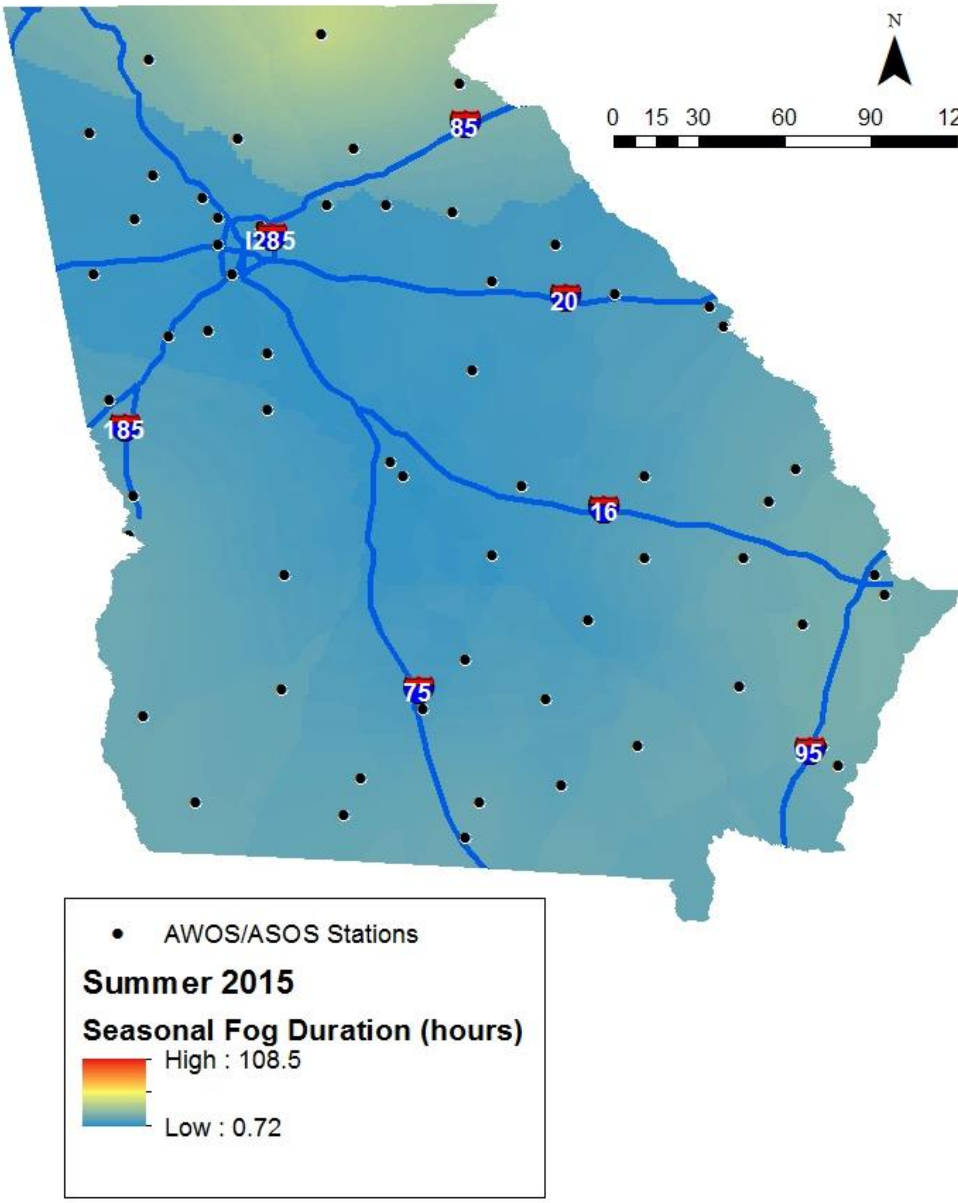

Figure 25: Seasonal Fog Duration Summer 2015

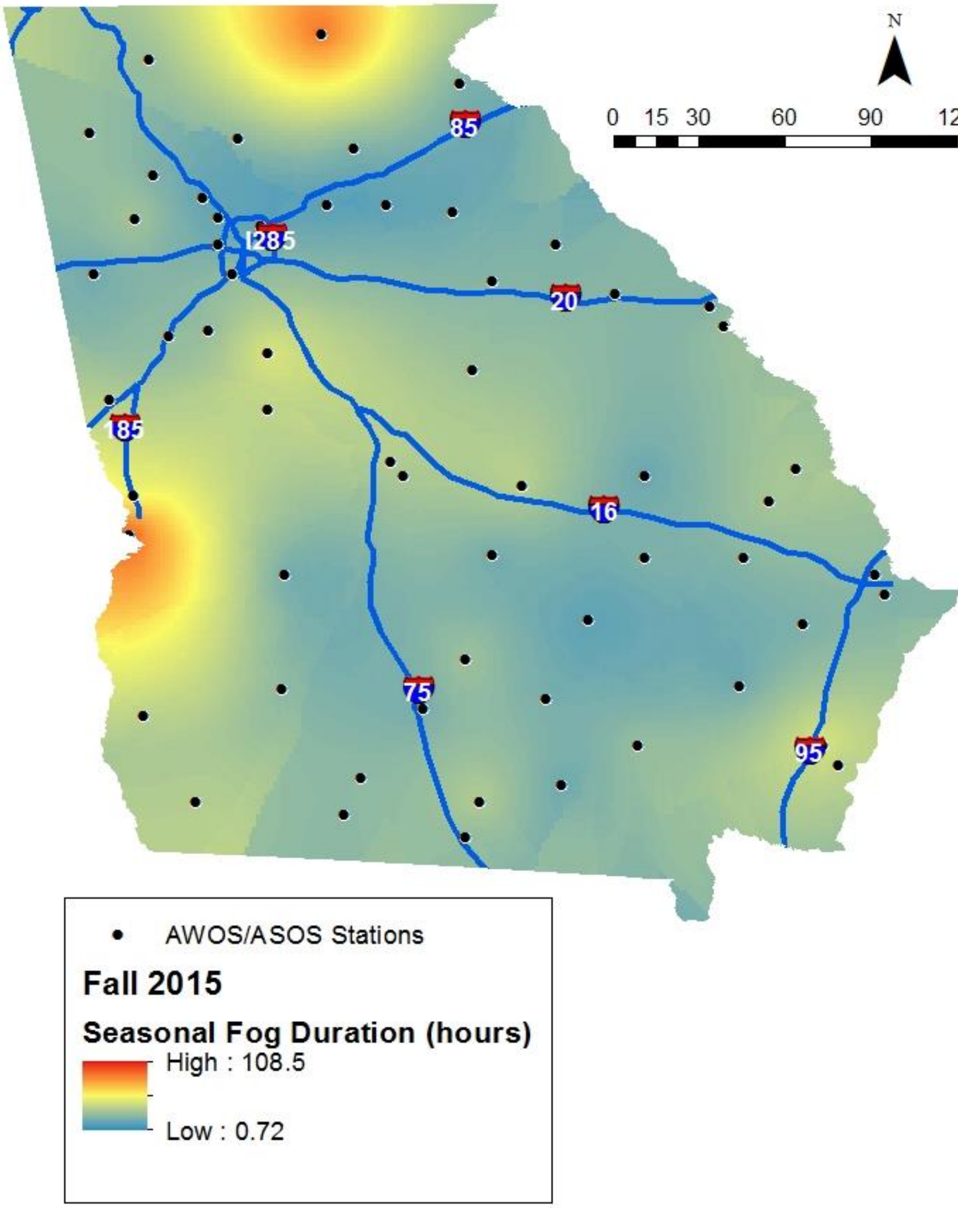

Figure 26: Seasonal Fog Duration Fall 2015

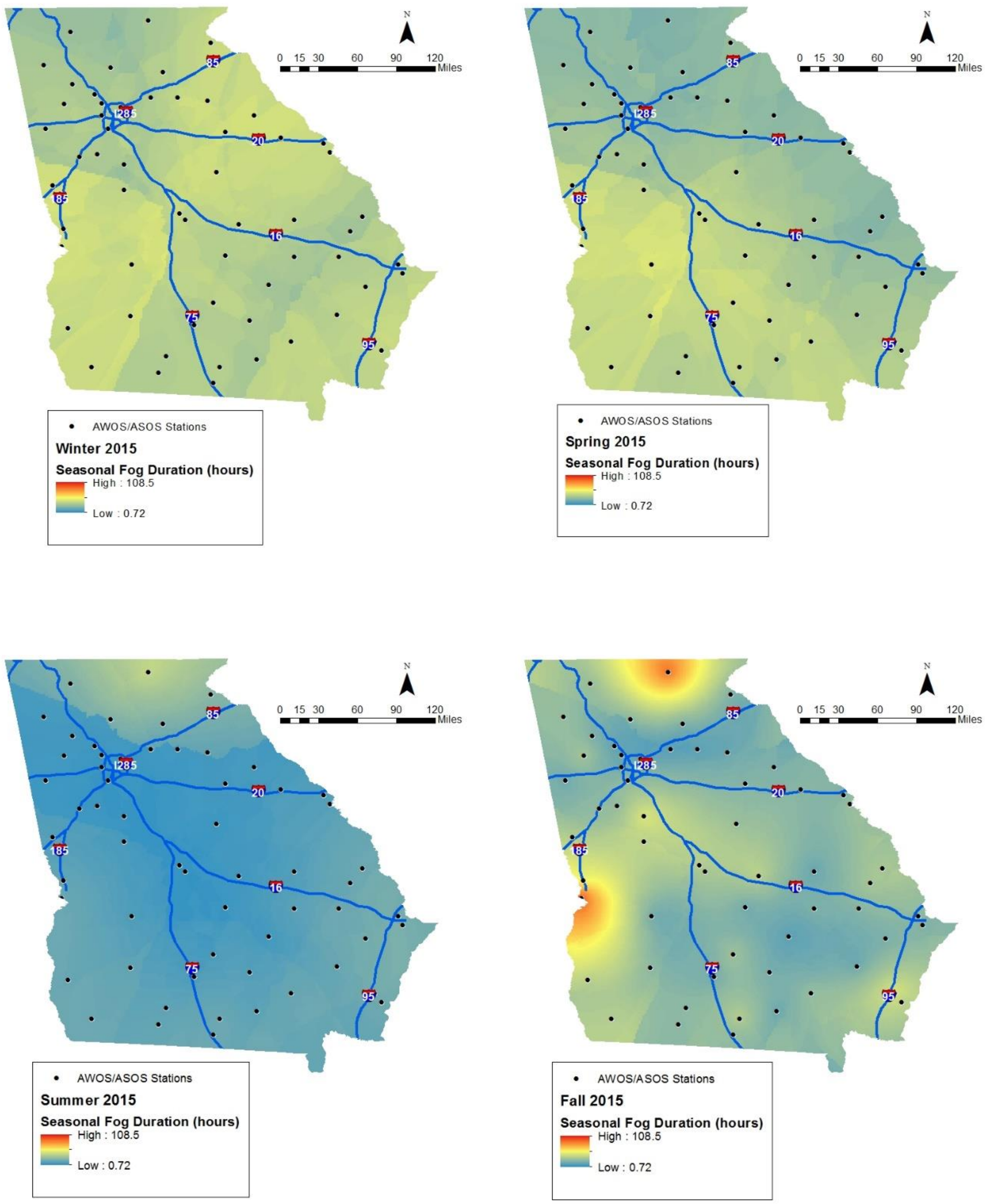

Figure 27: Seasonal Fog Duration 2015

Seasonal Fog Duration for 2016

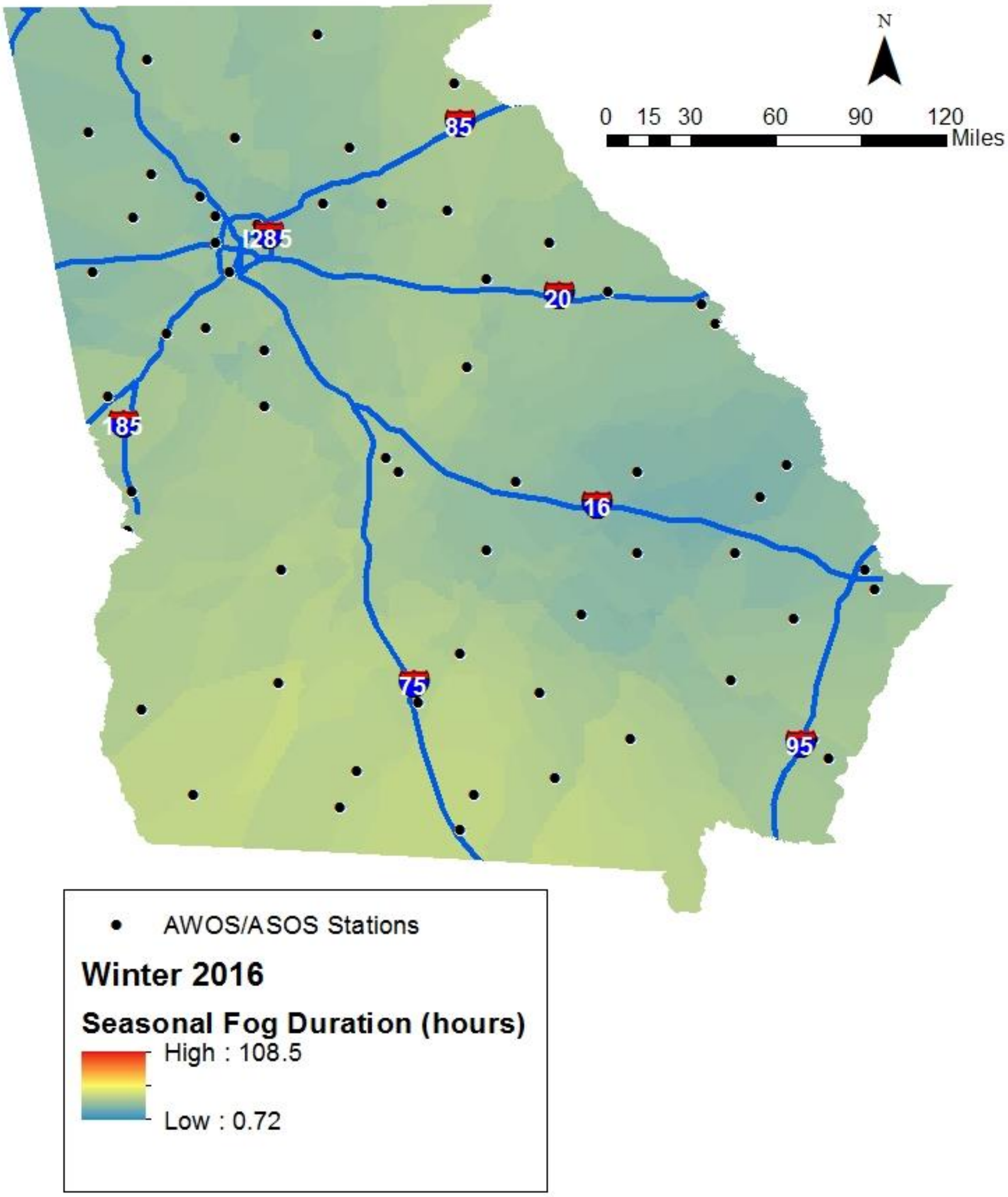

Figure 28: Seasonal Fog Duration Winter 2016

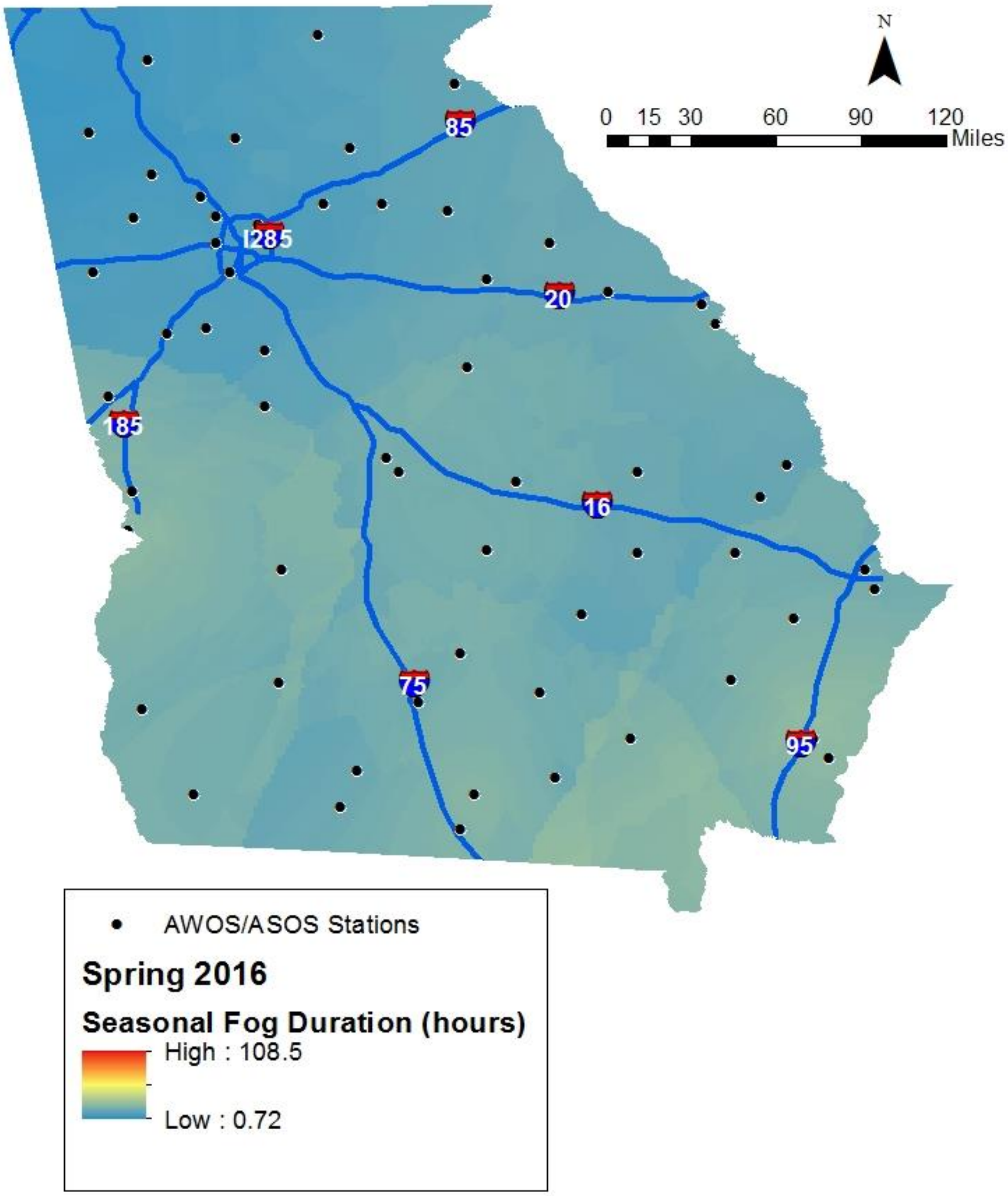

Figure 29: Seasonal Fog Duration Spring 2016

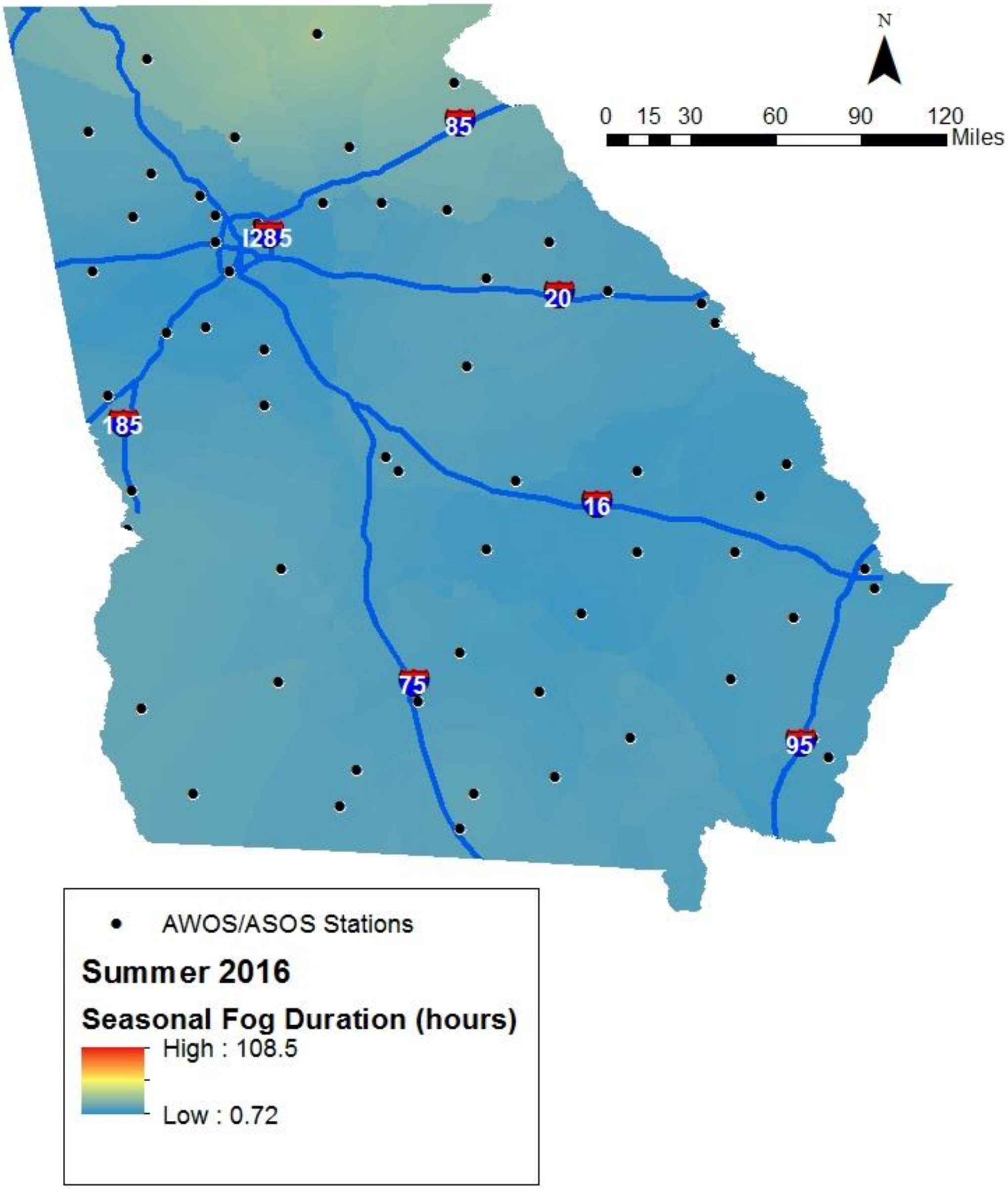

Figure 30: Seasonal Fog Duration Summer 2016

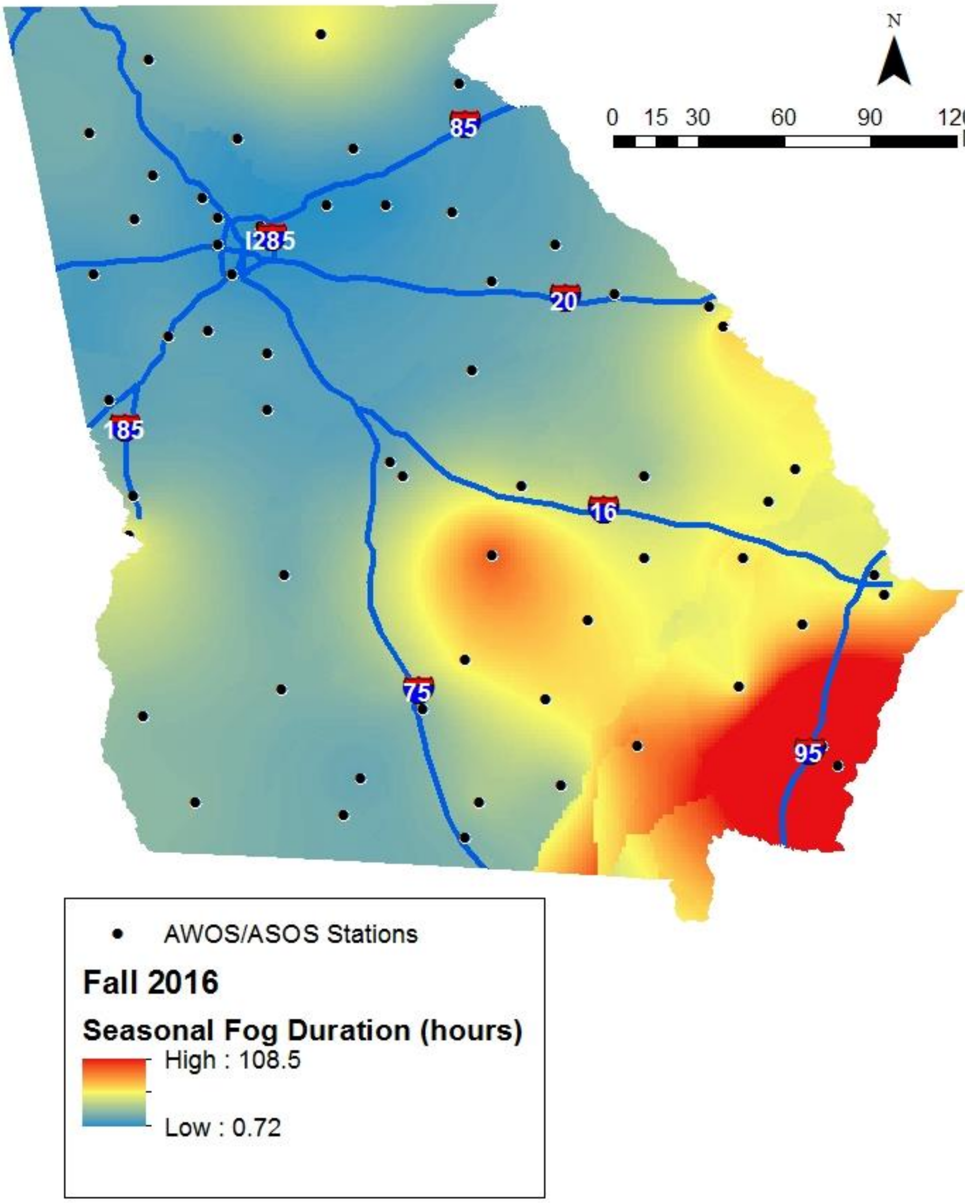

Figure 31: Seasonal Fog Duration Fall 2016

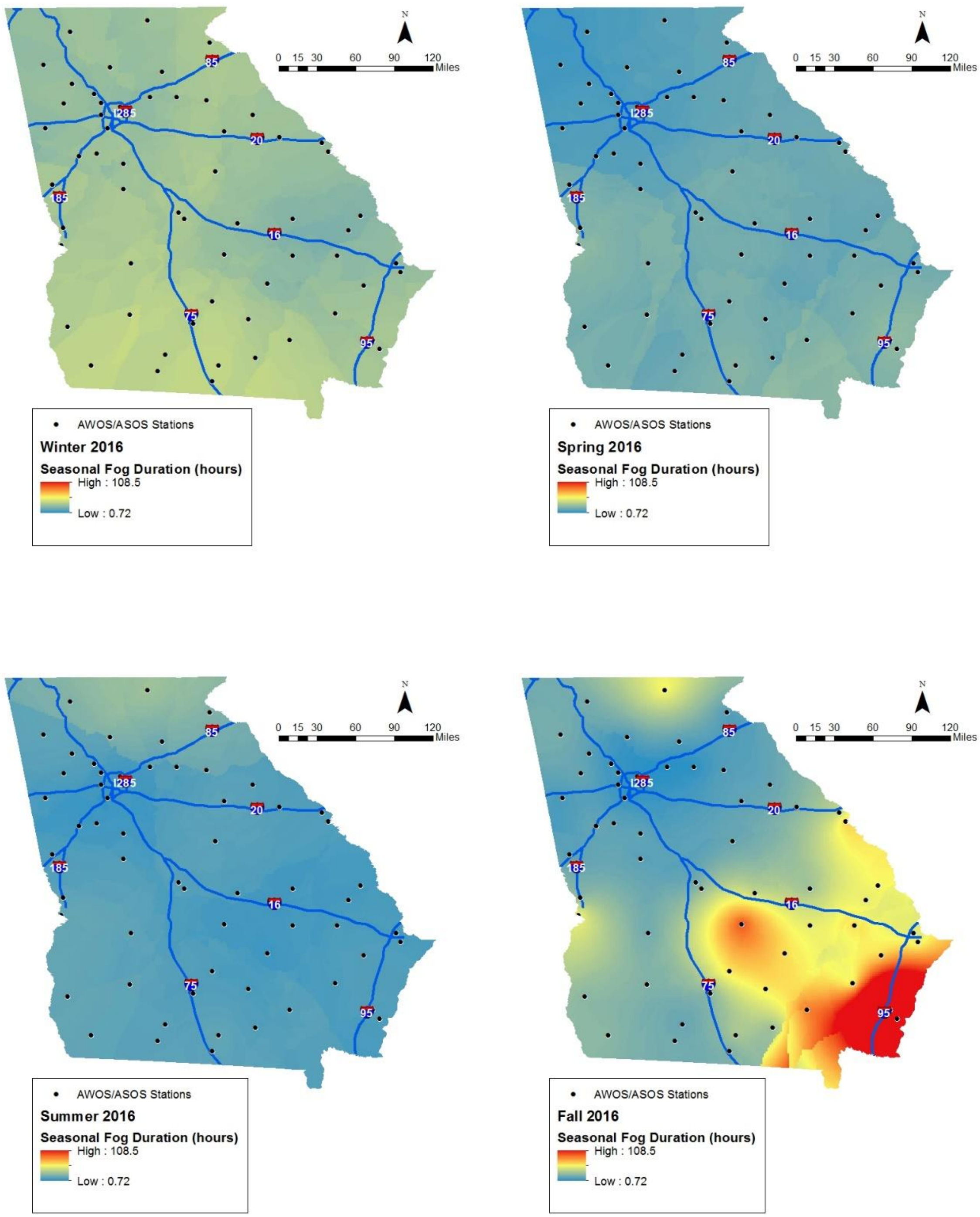

Figure 32: Seasonal Fog Duration 2016

APPENDIX B: SEASONAL INTERSTATE VISIBILITY

2014 Seasonal Interstate Visibility

Table 3: 2014 Visibility (%)

Interstate	Winter 2014	Spring 2014	Summer 2014	Fall 2014
I-16	2.03	0.77	0.53	0.95
I-285	1.04	0.46	0.41	0.36
I-95	2.14	0.80	0.59	1.05
I-20W	1.16	0.60	0.54	0.63
I-75S	2.06	0.69	0.47	0.86
I-20E	1.26	0.49	0.49	0.53
I-85S	1.50	0.79	0.74	1.01
I-75N	0.98	0.63	0.49	0.53
I-85N	1.08	0.45	0.43	0.38

2015 Seasonal Interstate Visibility

Table 4: 2015 Visibility (%)

Interstate	Winter 2015	Spring 2015	Summer 2015	Fall 2015
I-16	1.59	1.35	0.43	1.14
I-285	1.47	1.12	0.18	0.78
I-95	1.68	1.24	0.61	1.12
I-20W	1.33	1.14	0.22	0.76
I-75S	1.59	1.57	0.35	1.14
I-20E	1.76	1.12	0.25	0.96
I-85S	1.79	1.68	0.39	1.61
I-75N	1.35	1.06	0.47	0.95
I-85N	1.69	1.04	0.67	0.73

2016 Seasonal Interstate Visibility

Table 5: 2016 Visibility (%)

Interstate	Winter 2016	Spring 2016	Summer 2016	Fall 2016
I-16	1.08	0.70	0.31	0.84
I-285	1.19	0.35	0.23	0.07
I-95	1.27	0.75	0.30	1.61
I-20W	0.97	0.30	0.28	0.21
I-75S	1.52	0.71	0.37	0.39
I-20E	1.26	0.56	0.37	0.29
I-85S	1.31	0.68	0.35	0.34
I-75N	1.14	0.26	0.58	0.22
I-85N	1.31	0.49	0.64	0.17

APPENDIX C: STATION LOCATIONS AND COORDINATES

Table 6: Station Information

Station Name	Latitude (N)	Longitude (W)	USAF Code
GREENSBORO	33.6	−83.1333	720347
GRIFFIN-SPALDING	33.23333	−84.2667	720966
ALBANY	31.53333	−84.2	722160
AMERICUS	32.11667	−84.1833	720948
AUGUSTA/BUSH	33.36667	−81.9667	722180
ATHENS	33.95	−83.3333	723110
ATLANTA	33.63333	−84.45	722190
WAYCROSS/WARE CO	31.25	−82.4	722130
HAZELHURST	31.88333	−82.65	721035
BAINBRIDGE	30.96667	−84.6333	720268
BLAKELY EARLY C	31.4	−84.9	720257
BRUNSWICK/GLYNCO	31.25	−81.4667	722136
CANTON/CHEROKEE	34.31667	−84.4167	722109
COLUMBUS	32.51667	−84.95	722255
CARROLLTON/GRAY	33.63333	−85.15	720674
CLAXTON/EVANS CO	32.2	−81.8667	722691
DUBLIN	32.56667	−82.9833	722217
AUGUSTA/DANIEL	33.46667	−82.0333	722181
DALTON	34.71667	−84.8667	722154
DOUGLAS MUNI	31.48333	−82.8667	722062
EASTMAN	32.21667	−83.1333	720962
PEACHTREE CITY	33.35	−84.5667	722197
ATLANTA/FULTON	33.78333	−84.5167	722195
FITZGERALD	31.68333	−83.2667	721033
GAINESVILLE	34.26667	−83.8333	722185
HOMERVILLE	31.05	−82.7833	720392
MCDUFFIE/THOMSON	33.53333	−82.5167	720289
WASHINGTON	33.78333	−82.8167	720294
JESUP/WAYNE CTY	31.55	−81.8833	720671
SYLVANIA	32.65	−81.6	720301
LA GRANGE	33	−85.0667	747807
FT STEWART/WRIGH	31.86667	−81.5667	722090

FT BENNING/COLUM	32.31667	−84.9667	722250
LAWRENCEVILLE	33.98333	−83.9667	747808
MACON	32.68333	−83.65	722170
DOBBINS AFB/MARI	33.91667	−84.5167	722270
MOULTRIE MUNI	31.08333	−83.8	722147
MILLEDGEVILLE	33.15	−83.2333	720348
THOMASTON UPSON	32.95	−84.2667	747806
ATLANTA DEKALB/PEACHTREE AIRPORT	33.876	−84.302	722196
DALLAS	33.91204	−84.9406	720714
ROME	34.35	−85.1667	723200
MARIETTA MCCOLUM	34.01667	−84.6	747812
SAVANNAH	32.11667	−81.2	722070
SWAINSBORO	32.61667	−82.3667	720951
BRUNSWICK	31.15	−81.3833	722137
SAVANNAH/HUNTER	32.01667	−81.15	747804
STATESBORO	32.48333	−81.7333	747805
TIFTON	31.43333	−83.4833	720712
TOCCOA	34.6	−83.3	725258
THOMASVILLE	30.9	−83.8833	720738
MOODY AFB/VALDOS	30.96667	−83.2	747810
VIDALIA MUNI	32.2	−82.3667	722134
VALDOSTA REGIONA	30.78333	−83.2667	722166
CARTERSVILLE	34.13333	−84.85	722156
WINDER/BARROW	33.98333	−83.6667	747809
ST AUGUSTINE	29.9556	−81.3383	722212
BIRMINGHAM	33.564	−86.752	722280
CHARLESTON	32.889	−80.041	722080
CHATTANOOGA	35.035	−85.204	723240