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Creation of a Spatial Decision Support System as a Risk Assessment Tool Based on Kentucky Tornado Climatology

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CREATION OF A SPATIAL DECISION SUPPORT SYSTEM AS A RISK ASSESSMENT TOOL BASED ON KENTUCKY TORNADO CLIMATOLOGY FROM 1950 TO 2010

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Master of Science

By
Christopher Michael Blinn

May 2012

CREATION OF A SPATIAL DECISION SUPPORT SYSTEM AS A RISK ASSESSMENT TOOL BASED ON KENTUCKY TORNADO CLIMATOLOGY FROM 1950 TO 2010

Date Recommended May 9, 2012

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Dean, Graduate Studies and Research Date

I dedicate this thesis to my family. Without you all, I would have given up a long time ago. You have all have been my biggest supporters from the start, and I want you to know that your guidance and love has not been forgotten. I would never have been able to complete this degree without you all. Thank you!

I also want to make an individual dedication to my wife, Sam. All of my life I have tried to be my best, but you make me my best. You bring out the best of me in everything I do. You will never know how much you truly mean to me. Thank you so much!

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Christopher M. Blinn May 2012 97 Pages

Directed by: Dr. Stuart Foster, Dr. Jun Yan, Dr. Joshua Durkee, and Kevin Cary

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Tornadoes are one of Mother Nature's deadliest phenomena. They affect a large region of the United States. The risk of tornadoes is contingent on dynamic atmospheric conditions that are most likely during spring but which can occur anytime of the year, making the storms challenging to forecast. Using geographical information systems (GIS), a web-based spatial decision support system (SDSS) was created to help understand the spatial dimension of tornado risk assessment. The risk values are calculated using Tornado Days rather than taking a crude density measurement. The SDSS hosts GIS web services that are displayed on an Adobe Flex application. The web application allows users to view, research, query and extract information from the attributes of the GIS files. There is also a dynamic risk tool which gives users the ability to click anywhere inside the study area and get the percentage of risk that a tornado will occur within 25 miles of that very point. The web application eliminates users and viewers from conducting their own research and GIS work. In addition, automated updating models and macros were created to update the tornado database on an annual basis.

CHAPTER 1

INTRODUCTION

Many facets of life are determined and affected by the climate system. Climate is a factor in what crops we choose to grow, what activities in which people choose to participate, the type of clothing people wear, the architectural design of buildings, and the consumption of energy. The climate system defines not just the average temperature and precipitation patterns of an area, but also the range in weather and climate-related natural hazards people experience in a region. An aspect of climate that affects society negatively is severe weather. The American Meteorological Society broadly defines severe weather as any dangerous meteorological phenomena with the potential to cause damage, serious social disruption, or loss of human life (AMS n.d.).

In a broader sense, severe weather is a type of geophysical hazard (Royal Geographical Society 2011). Hazards refer to events that could occur due to environmental conditions of the area and pose a threat to people or property. However if there are no people or property in jeopardy, then there is no hazard (APA 2010). When a hazard becomes an actual event and has an ill effect on nature and/or society, it is then a disaster. A disaster can vary in impact based on both the natural intensity of the event and the location where it occurs. Even a weak tornado can cause extensive loss and damage in a densely populated urban area. In contrast, a strong tornado in a very rural area can have minimal impact. The probability of a hazard becoming a disaster is termed risk (Godschalk 2003). Risk is a function of the likelihood that a hazardous event will occur. The exposure of people and property to the event, and the resistance (affected by mitigation) to potential impacts of the event are all factors when quantifying risk.

Hazards for an area demand planned mitigations, or hazard mitigations. According to the FEMA (2010), mitigations are efforts put in place to reduce casualties and property damage in the event of disasters. In the proceeding moments after a disaster, planned mitigations become necessary and difficult to implement. Without mitigations, people in affected areas are forced to adapt to the changed environment. Socioeconomic and psychological issues arise when people are forced to adapt (Burton 1997). The first step in implementing mitigation for natural hazards is through risk analysis (FEMA 2010). The risk component quantifies the probability of a hazard becoming a disaster. Since risk is calculated on two scales, spatial and temporal, quantifying accurate assessments can be difficult.

There are difficulties in quantifying the risk of severe weather. One obstacle is that severe weather varies over both space and time. The atmosphere is a fluid and dynamic system in a constant state of change. Conducting risk assessment and implementing mitigation efforts become increasingly difficult when concerning convective weather systems. These systems develop extremely fast and have the potential to cause significant damage, especially in the event of a tornado, where the average lead time for a tornado warning is only 13 minutes (NOAA 2007). Tornadoes can strike with little or no warning and leave behind damage to both communities and agriculture (Balluz, et al. 2000). The area within which tornadoes occur in the United States is very extensive, and due to the natural intensity of these storms, having accurate risk assessments is important. However, in order to implement the right mitigation for an area, the proper resources for risk analysis must be put in place. Research on the components of tornadoes such as intensity, occurrence by date and time, and duration can be targeted on a spatial scale. From here, patterns can be identified which lead to better decision making for hazard mitigation. This is achieved only through better understanding of the components that quantify the risk assessment for a given area. It is important for individuals and communities to acknowledge the threat of severe weather and take appropriate action to understand and mitigate the risk.

There is a need for accurate risk analysis of natural hazards. With accurate risk assessments proper mitigations can be put in place to save more lives and protect more property in the event of a natural disaster. Resources can be better allocated to meet the demands of mitigations. Effective preparation can reduce the overall impact of a disaster thereby decrease the inevitable risk of the hazards affecting both people and property. To meet this demand, technology such as geographic information systems (GIS) are used to create an assortment of products used by the stakeholders to better determine and understand the risk of tornadoes. Risk assessments are used by stakeholders such as emergency management agencies to apply mitigation plans and best prepare for the inexorable destruction left behind from natural hazards. By not acknowledging the imminent threat of severe weather, a community increases their vulnerability of struggling to prepare and recover when these events occur (Comfort, Mosse and Znati 2009). The overall mission of an emergency management agency is to promote safer, less vulnerable communities with the capacity to cope with hazards and disasters (Blanchard, et al. 2007). To promote safer, less vulnerable communities, risk assessments need to be accurate and readily on hand. There is an obvious importance and responsibility in the field of risk assessment to base calculations off accurate data.

In addition to creating dependable risk assessments, the information needs to be available to all stakeholders including the general public. These stakeholders include emergency managers and other first responders, elected officials, and resource allocation planners. As of June 2010, there were over 239 million people estimated using the internet in the United States alone (International Telecommunication Union 2010). Many users rely solely on the internet as a source for news. There is diminutive argument that the internet has become one of the most accessed mediums of news and information over the past decade. The internet also allows for the information to be used whenever needed, making the internet one of the most reliable platforms to access information (Althaus and Tewksbury 2001).

The quality of decisions can be expected to increase as more complete information is made available. The best decisions are made when more information is readily available. The decision making process can be difficult if unclear data is not perceived correctly. Time delays in the decision making process can be costly, especially when the decision is based around the safety of people. A product known as a spatial decision support system (SDSS) has the capabilities to display and share risk assessment data on the internet. A spatial decision support system is an integrated database management system that provides computerized support for decision making where there is a geographic or spatial component available (Forgionne and Gupta 2003, 28). Compiled into the system, developers can create spatial tools for client-side interaction, data evaluation, analysis and extraction. Providing these services on the internet increases the availability to all stakeholders and the general public. Also, developers of the SDSS can work within user-friendly GIS software interfaces such as the

Environmental Systems Research Institute's (ESRI) ArcGIS mapping software and technology, making database editing, managing and updating simple.

This project is based on the development and operationalization of a web-based SDSS for assessing the risk of tornadoes in and near the state of Kentucky by using a dataset of recorded tornado events from 1950 to 2010. Visually, figure 1.1 shows how the raw weather data is converted into useful information for decision makers.

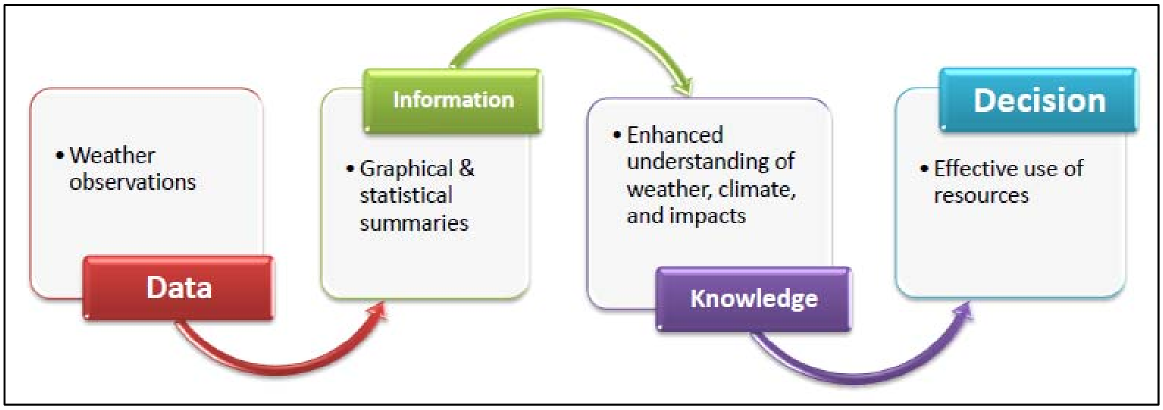


Figure 1.1. This diagram developed by the Kentucky Climate Center (2012) shows how the raw weather data can be converted to information for decision making. This graphic simplifies the methodology used in this study.

The SDSS is housed in a tornado database website that can be accessed by anyone with an internet connection. The SDSS eliminates the need for risk assessment stakeholders to purchase and understand GIS and web publishing technologies, while providing a platform for users to obtain usable and reliable information on Kentucky's tornado climatology. To do so, the website was designed to provide tools with dynamic capabilities that are visually pleasing and analytically powerful. Dynamic tools do not just perform a function but also adapt parameters of the function based on client-side criteria. For example, a search tool can provide useful information on an entity, but only delivers static results. If the tool was dynamic, the search results would use multiple queries to display certain information the client is interested in. The project also develops a series of updating tools and tutorials. Currently, the tornado dataset contains records from 1950 to 2010. When the annual data is released from the National Oceanic and Atmospheric Administration (NOAA), for the calendar year, the dataset will require updating. This goal was met by creating a series of tools which recreates the datasets used by the website.

CHAPTER 2

LITERATURE REVIEW

Tornadoes are capable of being extremely destructive and deadly. They have affected every state in the United States, including Alaska (Fathauer 1977) and Hawaii (Carbin 2010), resulting in extensive damages and for most states, loss of life. Not surprisingly, tornadoes have become one of the most feared phenomena of nature. Hence, it is important to understand when and where these storms may occur. Such information can lead to a better understanding of risk mitigation and preparedness efforts.

Tornadoes are enigmatic and difficulties arise when trying to predict them. Thunderstorms can be tornadic and show signs of tornadogenesis, but may never spawn a tornado. Tornadogenesis refers to the beginning processes in a storm which lead to the formation of a tornado (Steiner 1973, Kelly, et al. 1978, Church 1993, Concannon, Brooks and Doswell III 2000). This unpredictable nature of tornadoes makes them even more dangerous and life-threatening. With a better understanding on tornadogenesis, more accurate risk assessments can be calculated which can provide vital information to a variety of stakeholders including insurance companies, emergency management agencies, law makers, educators and the general public.

The key is to deliver information that is not only helpful but most importantly accurate. There are varying approaches to establishing a risk value for an area. Variables such as study area, temporal scale, analysis methodology, and result interpretation can all impact the resulting value. This section briefly reviews past approaches of calculating tornado risk and highlights the progressions made in those studies.

2.1 Previous Tornado Studies

Interest in tornadoes and tornado climatology has been reflected in studies published since the 1800s and early 1900s (Hare 1837, Finley 1884, Emery 1900). Many offer accounts of individual storms (Redfield 1841, Lloyd 1847, Clayton, Davis and Mils 1892). Most studies were limited in their geographic extent. While they may offer accurate local portrayals of tornado events, they do not place those events into a broader geographic context. One of the first extensive tornado datasets was created by Tom Grazulis (T. Grazulis 1993). It compiled tornado records from as early as 1680 and included records up to 1991. Grazulis continued to collect data on significant tornadoes (tornadoes with a Fujita scale rating of F2 or higher, or if the tornado resulted in any casualties) and he expanded the database to include records through 1995 (T. Grazulis 1997). In the 1970s, the National Severe Storms Forecast Center (NSSFC) removed nearly 20% of documented tornadoes from the national tornado log due to the reports being considered doubtful (Kelly, et al. 1978). The new dataset was used by Kelly et al. (1978) to derive a comprehensive tornado climatology. Studies including Thom (1963) and Schaefer et al. (1986) applied methodologies which calculated the mean annual area covered by the tornado paths in 1° of latitude and longitude resolution. More recently, Passe-Smith (2008) examined the effects of topography on tornado development. The study concluded that similar areas of topography, such as Oklahoma and Kansas, also experience similar diurnal temperature profiles and land usage, which may lead to similar storm development which leads to tornadogenesis.

Analysis of tornado datasets has been limited by concerns with the accuracy of recorded attribute data of tornadic storms. Questions exist regarding the accuracy of tornado path length, path width and Fujita rating. The most reliable data are the date and absolute coordinate locations recording the location of tornadoes. Still uncertainty can exist when differentiating between a single tornado that produces an intermittent path and multiple tornadoes. With the advent of DOPPLER radar technology in 1988, meteorologists are better able to pinpoint crucial areas of the storm where tornadic circulation is occurring; thereby helping to identify tornadoes that might have previously gone undetected (NWS 2010). Verbout et al. (2006) addresses how over time, tornado datasets have become more accurate and reliable for tornado analysis.

Tornado days have become popular units of analysis. A tornado day is simply defined as a day when one or more tornadoes occurred within a defined area. Early work such as Showalter and Fulks (1943) created maps of tornado days for each state. While these maps were useful, they did not adjust the tornado day counts to reflect differences in the size of individual states. All things being equal, larger states in terms of area are more likely to have more tornado days than smaller states. Tornado days have since been used as a variable for analysis in many studies (1943) (Changnon Jr. 1982, Concannon, Brooks and Doswell III 2000, Brooks, Doswell and Kay 2003, Raddatz and Cummine 2003, Trapp et al. 2004, C. Doswell III 2007, Dixon et al. 2011). Using tornado days, rather than a raw dataset of tornado events assists in addressing an error in the number of reported tornadoes each year, when the same tornado is reported multiple times. As noted by Brooks et al. (2003), using the tornado day methodology reduced the apparent doubling in the number of tornadoes reported since 1950, to an increase of only about 10 to 15 percent.

With better analysis, tornado day methodologies started to become the choice for many researchers. According to Changnon (1982), different spatial patterns are evident when using tornado days instead of counts of tornadoes. Rather than just analyzing the location of the events, analysis of tornado days addresses the risk of a tornado occurring within an area on any given day of the year. This approach helped atmospheric scientists identify the location of seasonal variances in tornado frequencies (Church 1993). Brooks et al. (2003) later took this approach and calculated the probability of a tornado occurring within an 80 km by 80 km cell on any day of the year for the lower 48 states. Dixon et al. (2011) then conducted both tornado event and tornado day density analyses, noting their differences. There are some issues when using tornado days rather than attributed data of the events. Dixon et al. (2011) pointed out how using tornado days weights each event the same, exemplifying how a short-lived tornado bears the same attribute weight of a very long track. However, if a study is focusing only on the occurrence of tornadoes and not their strength or other characteristics, then this approach is appropriate.

2.2 GIS and Spatial Analysis

The ability to analyze the spatial distribution of tornado events has been aided by advancements in geographic information systems (GIS). According to the Environmental Systems Research Institute (ESRI) (2009), GIS is a technology that integrates both hardware and software to capture, manage, analyze and display spatial data. GIS software and application tools make operational methods of spatial analysis possible that otherwise would be too difficult to implement on a large scale. When the technological breakthrough in GIS occurred in the 1960s with the first mainframe computers housing spatial information, the ability to conduct analysis or even display the data was very challenging (M. Goodchild 2000).

The development of GIS has gone through four phases since the early 1960s. Beginning with the pioneering phase, which lasted from the early 1960s to approximately 1975, the first theoretical ideas for map-making by using computers were developed more so by individuals than industrial companies. The second phase, the governmental phase lasting from around 1973 to the early 1980s, saw an increase in governmental agencies and local government agencies using mapping and spatial analysis technologies. Such agencies included the U.S. Census Bureau and the U.S. Geological Survey. The third phase was the commercial phase. It began around 1982 and lasted until the late 1980s. This phase was dominated by commercial GIS software firms in competition with each other. The commercial phase was replaced by the current user-dominated phase. This phase reflects the evolution of desktop GIS software in conjunction with that of the internet (Coppock and Rhind, 1991).

GIS has created a new approach to cartography or map-making. On the forefront of cartography software in the United States, ESRI has evolved with the many phases to emerge as a global leader in geographic information services (GI Services). ESRI, started by current company president Jack Dangermond in 1969, was created to help support decision makers, including land use planners and resource managers, by providing them with the capability to create, manage, analyze, and display geographic data (Esri 2009) Since then, ESRI has evolved to create and supply products for an array of industries. As part of being a global leader, ESRI has created software that led the phase change from commercial-based products to user-based in the 1980s. ArcGIS software was developed in the late 1990s when ESRI joined two mainframe ideas: a complete desktop GIS software and enterprise capabilities. Desktop GIS software offers a user-friendly interface with a suite of programs and extensions that allow for numerous analysis operations and a complete cartographic design program. The enterprise capability refers to a network environment that allows for efficient communication between servers and clients in a network (Martin-Flatin et al, 1999). In terms of GIS, the servers house the data, tools and software, and the clients access the server. Communication is necessary in any network, and enterprise communication within ArcGIS software allows for maximum connectivity with all servers and clients (Dueker and Butler, 1997).

Apart from the networking abilities of ArcGIS, what makes the software a strong tool in geographic studies is the collection of advanced extensions and functions the software offers. Collectively, these extensions house hundreds of operations that are used for specialized purposes. For example, the Network Analyst extension for ArcGIS software provides tools for navigation analysis, routing, service area calculations, and deriving turn-by-turn directions. As technology started to change the direction of GIS at the beginning of the new millennium, the functionality of extensions began to focus on statistical operations. There are now multiple tools that allow users to conduct statistical operations within the same GIS software that they are using to conduct their spatial analysis. This flexibility greatly enhances the functional value of the software (McCoy and Johnston, 2001).

2.3 Internet GIS

The latest generation of GIS adds internet-based functionality for GIS. Due to the overwhelming increase in the popularity of the internet, there was an inevitable increase in ready availability of data that could be shared and manipulated (Peng and Tsou, 2003). The internet allows for decisions to be made based on the analysis of server-housed data, either spatial or nonspatial.

The architecture between the client, or user, and the server can be quite complex, however there are fundamental components that must be addressed (Berson 1996). The first component is that there must be a provider, known as a server, for a service and a request for the service from a client. The second component is that there must be a connection, known as a network, between the client and the server. The third and most important requirement is that the client and server must be able to communicate fluidly. This refers to the necessity that the software platform that generates the request and the software platform that receives the request must speak the same programming language and abide by the same protocols (Sun Microsystems 2009).

The internet started working with spatial data in the 1970s when the Department of Defense (DOD) created a decentralized network system known as ARPANET (Peng and Tsou, 2003). The goal of ARPANET was to develop a telecommunications system that was capable of surviving a nuclear attack. Spatial data was necessary for programming the telecommunication system for numerous locations across the United States. However, in 1983, ARPANET adopted a new protocol known as the Transmission Control Protocol/Internet Protocol (TCP/IP) which laid the foundation for communication from other networks. This communication is what enabled people outside the DOD to obtain the spatial data within the ARPANET project (Dragicevic 2004). When the internet boom occurred in the late 1990s, the possible uses of the internet for GIS began to increase.

The first internet map was the Xerox PARC Map Viewer (Palo Alto Research Center 1997). The map viewer was created in June 1993 by Steve Putz, and was created to promote information retrieval via the internet. The map viewer hosted static or non-interactive maps of the world. Since then maps have migrated from static viewers to fully integrated data-driven applications that not only allow the end user to view, but also interact with the spatial data.

The internet has changed GIS in three major areas: GIS data access, spatial information dissemination, and GIS modeling/processing (Peng and Tsou, 2003). . Internet websites now exist specifically to house GIS-ready data. Increased access to spatial data creates greater opportunity for spatial analysis by both the general public and geographic educators (Peng, 2001). The increase in public view and use are due to the spatial information dissemination that the internet has made possible. Further, GIS applications are becoming more user-friendly, so more people without extensive spatial analysis education or computer programming skills are using GIS to analyze spatial data. (Dragicevic 2004). Companies can now access tools provided over the internet that offer a user-friendly interface to conduct spatial analysis. There is no need for many of these companies to obtain a full suite of GIS software or to hire personnel that are trained in using GIS, because internet applications have been created to specifically work for certain industries (Maguire 1996). The growth of internet applications helps to further stimulate the increase of GIS data accessibility and the dissemination of spatial information (Peng and Tsou, 2003).

2.4 GIS and Spatial Decision Support Systems

Rapid growth in the availability of spatial data has spurred the development of spatial decision support systems (SDSS). A SDSS is a customized software application that processes spatial data to provide information designed to aid decision makers. A well designed SDSS is easy to use and summarizes results in a manner that is easy to interpret. (Sprague and Carlson, 1982). Decision support systems (DSS) were first designed in the 1970s, when studies at Massachusetts Institute of Technology began explaining the role of calculus-based decisions in model building, and how the information systems community can use those decisions (Gorry and Morton, 1971). For the next ten years, many publications on DSS (Alter, 1980, Little, 2004 & Sprague, 2008) highlighted the strengths of DSS. This led to an expansion in use of DSS from the business spectrum to the entire information technology community. As computers became more powerful, and more spatial data was being collected, advancements were made in computer models to analyze data (Sprague, 2008). An early example of how DSS began using spatial data is the Geodata Analysis and Display System (GADS) (Grace 1977).

It wasn't until the 1990s that the practicality of SDSS was finally realized on a larger scale in the GIS community (Muller 1993). SDSS applications are now widely used in transportation, water management, demographic, and resource management industries (Walsh, 1993; McKinney and Cai, 2002; Turoff et al, 2002; Ray, 2007). The use of GIS in SDSS applications has grown over the past decade, with many systems today using the internet to run user-interactive services (Power 2000).

GIS and the use of SDSS has particularly become a handy tool for emergency management agencies over the past decade. Work done at Pennsylvania State University has identified that a major problem with emergency management is that real-time spatial data is not available to work with when faced with an emergency situation (Rauschert et al. 2002). The idea of real-time data refers to how the internet can be used as a medium for both housing and collecting data. The work at Pennsylvania State University (2002) and work from the University of Kansas (Gunes and and Kovel, 2000) points out how GIS can improve disaster preparedness, mitigation, and response of emergency management agencies. These three areas are highlighted in the conceptual model of societal response to disaster (Kreps, 1985, Cutter, 1996, Lindell and Prater, 2003 & NRC, 2006). This model breaks down the actions of the hazards and disaster management system pre-impact, trans-impact, and post-impact. Using GIS can chronologically assist in each of these phases during the emergency event (NRC, 2006). Although GIS can be used in all phases, scholars believe that GIS plays a much larger role in the pre-impact with risk assessments and mitigations, and the post-impact with recovery and emergency activities (Cutter, 2003).

Four types of data need to be collected to properly prepare risk assessment information. The first is the actual event data, such as tornado or earthquake data. Both the spatial and the nonspatial attributes of the events need to be collected. Second, these data need to be integrated with supporting data, such as census data, topography data, geological data and infrastructure data. The third type of data needed is ground truth data of the area, such as imagery and aerial photography. The fourth and final type of data is the network and communication links. These data can be used both for the infrastructure and network databases and as the linkup data to make the information available to the stakeholders and the public (Esri 2000). All of these data are analyzed to generate information and support decision making.

CHAPTER 3

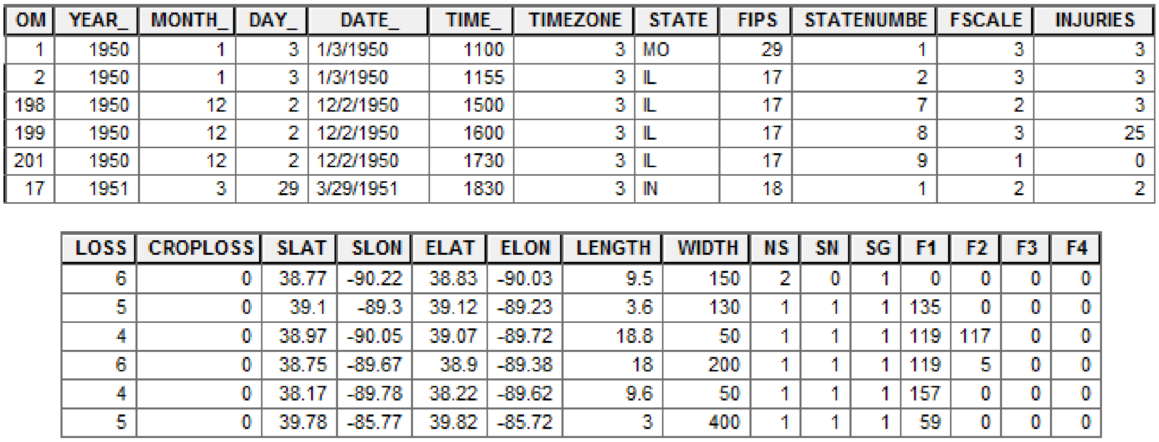
DATA SOURCES AND METHODOLOGY

Past research on tornado densities has utilized spatial analysis tools within ArcGIS to map the density of tornado occurrence across the United States (Hossain, et al. 1999, Brooks, Doswell and Kay 2003, C. Doswell III 2007, C. B. Doswell III 2009, Dixon, et al. 2011). Each study has displayed different results based on parameters chosen during the analysis. This study will introduce a methodology of spatial analysis that combines two popular approaches.

Spatial analysis relies heavily on the the input data. Without understanding the input data completely, difficulties may arise when trying to interpret the analytical results. The input data used in this study are tornado track records provided by the SPC. The tornado track records date from the beginning of the year 1950 to the end of 2010, a total of 61 years. The tornado data are analyzed using a variety of spatial analysis tools in ArcGIS. Based on previous tornado risk analysis studies, the tornado data are reformatted to reflect tornado days rather than raw tornado events. The tornado day data are formatted into classes of risk and then structured to be published on the internet. The entire process can be broke into three phases: 1. Data Collection, 2. Data Analysis, and 3. Data Formatting

3.1 Description of SPC Database

The first phase of data collection involves collecting tornado information for the study area. The Storm Prediction Center (SPC) within the National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA) prepares and maintains the Storm Data publication (NOAA 2010) database. The data and related material are also published through the National Climate Data Center (NCDC), within the National Environment Satellite, Data and Information Service (NESDIS) of NOAA. These centers are providing a variety of data and information about severe weather and maintain a warehouse of data on tornadoes, hail and wind events (Schaefer and Edwards 1999). The National Tornado Database is compiled from Storm Data publications. Storm Data publications contain only confirmed information on storms, and are printed "as is" reported by the NWS. The publications include 28 storm event categories, including reported wall clouds and waterspouts (McCarthy 2003). When the data are forwarded to the SPC, the wall clouds and waterspouts are filtered out before the information is added to the National Tornado Database. The SPC reformats the data into 27 different attribute fields (**Table 3.1**.)

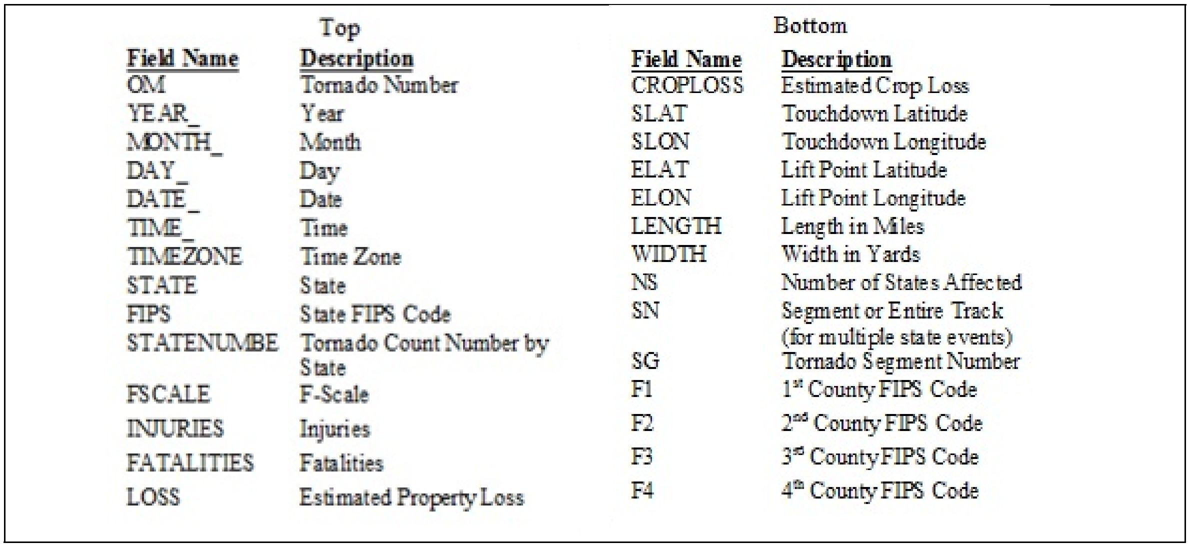


OM	YEAR_	MONTH_	DAY_	DATE_	TIME_	TIMEZONE	STATE	FIPS	STATENUMBE	FSCALE	INJURIES
1	1950	1	3	1/3/1950	1100	3	MO	29	1	3	3
2	1950	1	3	1/3/1950	1155	3	IL	17	2	3	3
198	1950	12	2	12/2/1950	1500	3	IL	17	7	2	3
199	1950	12	2	12/2/1950	1600	3	IL	17	8	3	25
201	1950	12	2	12/2/1950	1730	3	IL	17	9	1	0
17	1951	3	29	3/29/1951	1830	3	IN	18	1	2	2

LOSS	CROPLOSS	SLAT	SLON	ELAT	ELON	LENGTH	WIDTH	NS	SN	SG	F1	F2	F3	F4
6	0	38.77	-90.22	38.83	-90.03	9.5	150	2	0	1	0	0	0	0
5	0	39.1	-89.3	39.12	-89.23	3.6	130	1	1	1	135	0	0	0
4	0	38.97	-90.05	39.07	-89.72	18.8	50	1	1	1	119	117	0	0
6	0	38.75	-89.67	38.9	-89.38	18	200	1	1	1	119	5	0	0
4	0	38.17	-89.78	38.22	-89.62	9.6	50	1	1	1	157	0	0	0
5	0	39.78	-85.77	39.82	-85.72	3	400	1	1	1	59	0	0	0

Figure 3.1. (top) Snippet of tornado database table provided by the SPC. (bottom) Remaining fields in the tornado database table.

Table 3.1. SPC fields of criteria in the National Tornado Database



Top		Bottom	
Field Name	**Description**	**Field Name**	**Description**
OM	Tornado Number	CROPLOSS	Estimated Crop Loss
YEAR_	Year	SLAT	Touchdown Latitude
MONTH_	Month	SLON	Touchdown Longitude
DAY_	Day	ELAT	Lift Point Latitude
DATE_	Date	ELON	Lift Point Longitude
TIME_	Time	LENGTH	Length in Miles
TIMEZONE	Time Zone	WIDTH	Width in Yards
STATE	State	NS	Number of States Affected
FIPS	State FIPS Code	SN	Segment or Entire Track (for multiple state events)
STATENUMBE	Tornado Count Number by State	SG	Tornado Segment Number
FSCALE	F-Scale	F1	1st County FIPS Code
INJURIES	Injuries	F2	2nd County FIPS Code
FATALITIES	Fatalities	F3	3rd County FIPS Code
LOSS	Estimated Property Loss	F4	4th County FIPS Code

In addition to keeping records of storm events, the SPC releases GIS-ready files on their SVRGIS website (B. Smith 2011). This is the initial dataset that will be used in this study. It should be noted that not every record in the SVRGIS file represents an entire tornado event. Some records only exemplify a segment of a tornado, while others contain the information for the entire event. For multi-state tornadoes and tornadoes that lift and touchdown numerous times, there are multiple records to breakdown each segment. Multi-state tornadoes have records for each state the tornado affected and also a full event record. Users of this dataset must recognize this point and remember to account for this when conducting analysis. This study only looks at records that contain the entire event information within the study area.

3.2 Study Area

The study area for this project consists of the Commonwealth of Kentucky surrounded by a 25-mile buffer. The buffer, created using a simple process in ArcMap (figure 3.2), is needed to eliminate edge effects in the study. Edge effects, also known as boundary effects, arise in spatial analysis when entities of measurement exist beyond the area boundary but are not included in the analysis. This creates bias in results of spatial analysis operations (Esri 2012). In this study, tornado tracks lying outside the state of Kentucky, but within the buffer area, impact the risk assessment analysis. Therefore, it is important to include those tracks within Kentucky and those within 25 miles of the state.

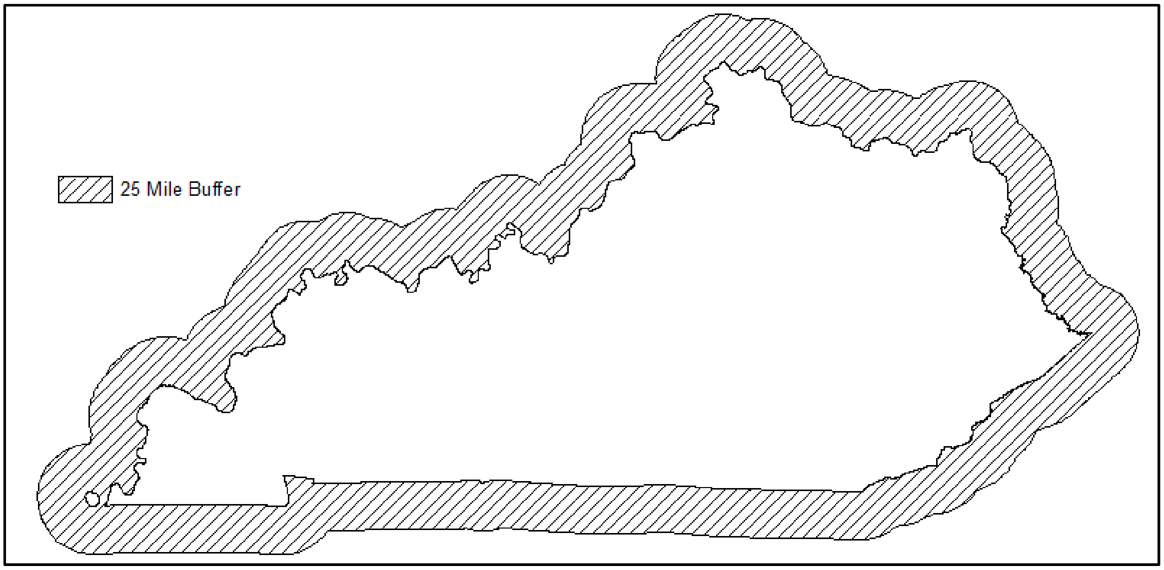
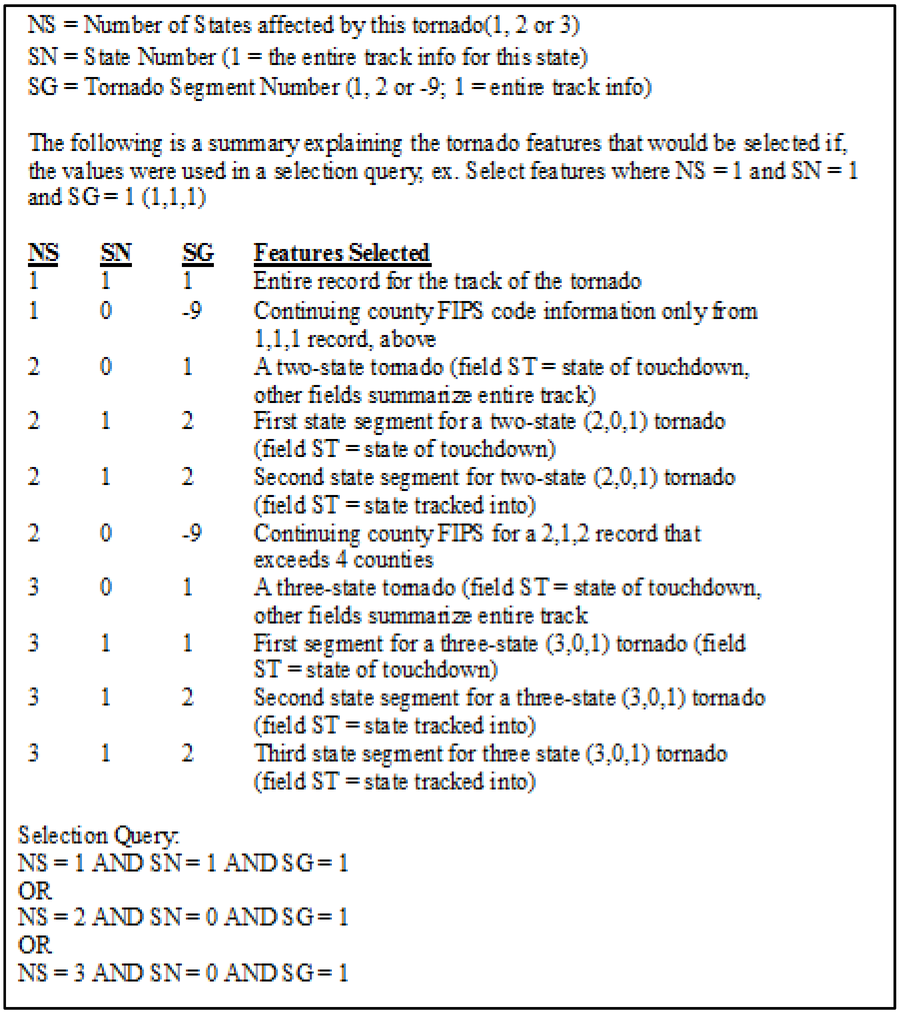


Figure 3.2. A 25 mile buffer of the state of Kentucky created using the Buffer tool in ArcGIS 10.

3.3 Selection of Tornado Records

Before any analysis can take place, the dataset requires cleaning. The dataset includes a record for each state through which a multi-state tornado passes, and also a record for the entire storm. In total, a multi-state tornado then has at least three records in the database. However, by selecting the records of the entire tornado event, the remaining tornadoes can be removed from the dataset. This removal changed the number of tornadoes in the national dataset from 28,916 to 28,111 (a decrease of 2.78%). This task is performed by creating a selection query that searches the tornado dataset fields for a specific arrangement of values indexed in the NS, SN, and SG fields of the dataset (**Table 3.2**).

Table 3.2. Selecting entire tornado event records from dataset



NS = Number of States affected by this tornado(1, 2 or 3)
SN = State Number (1 = the entire track info for this state)
SG = Tornado Segment Number (1, 2 or -9; 1 = entire track info)

The following is a summary explaining the tornado features that would be selected if, the values were used in a selection query, ex. Select features where NS = 1 and SN = 1 and SG = 1 (1,1,1)

NS	SN	SG	Features Selected
1	1	1	Entire record for the track of the tornado
1	0	-9	Continuing county FIPS code information only from 1,1,1 record, above
2	0	1	A two-state tornado (field ST = state of touchdown, other fields summarize entire track)
2	1	2	First state segment for a two-state (2,0,1) tornado (field ST = state of touchdown)
2	1	2	Second state segment for two-state (2,0,1) tornado (field ST = state tracked into)
2	0	-9	Continuing county FIPS for a 2,1,2 record that exceeds 4 counties
3	0	1	A three-state tornado (field ST = state of touchdown, other fields summarize entire track
3	1	1	First segment for a three-state (3,0,1) tornado (field ST = state of touchdown)
3	1	2	Second state segment for a three-state (3,0,1) tornado (field ST = state tracked into)
3	1	2	Third state segment for three state (3,0,1) tornado (field ST = state tracked into)

Selection Query:
NS = 1 AND SN = 1 AND SG = 1
OR
NS = 2 AND SN = 0 AND SG = 1
OR
NS = 3 AND SN = 0 AND SG = 1

After selecting the tornado records with the entire track data, the tornadoes need to be extracted based on their location with respect to the study area. Rather than just using the tornado records that intersected with the study area, tornado records that intersected or were within 25 miles of the edge of the study area are extracted (figure 3.3). The 25-mile buffer is needed to control for boundary effects that would otherwise bias results when calculating the densities of both tornado events and tornado days. This reduced the dataset size from 28,111 to 675 (a decrease of 97.6%).

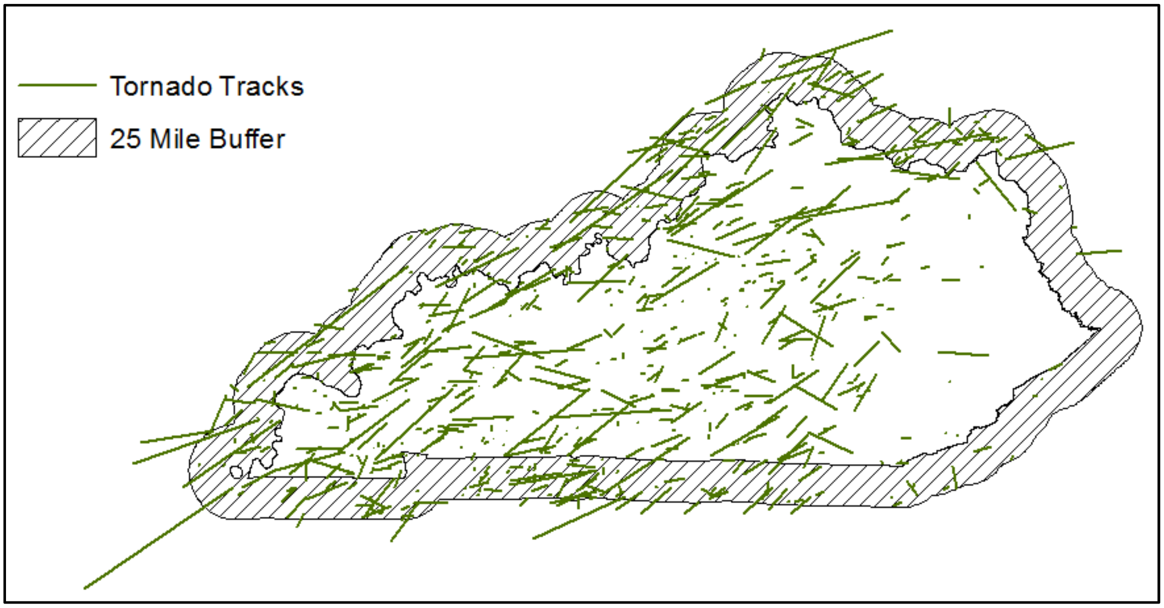


Figure 3.3. All tornado tracks that intersect with the 25 mile buffer and the state of Kentucky

3.4 Spatial Smoothing

The next step involves establishing the risk assessment levels and creating the risk classes using GIS operations. The risk assessment levels are based on historical data portraying the occurrence of tornadoes in proximity to a given point of interest. A point of interest is defined as the centroid of a grid cell, where the grid cell is 0.0625 square mile. The grid is created using density tools.

There are three types of density tools offered within the Spatial Analyst Extension of ArcGIS software: point, line and kernel. Point and line density differ from kernel density. Point and line density apply a binary function when calculating values. Given a point of interest, a buffer with a specified radius, commonly referred to as bandwidth, is generated around the point. Point features within the buffer are then selected (figure 3.4).

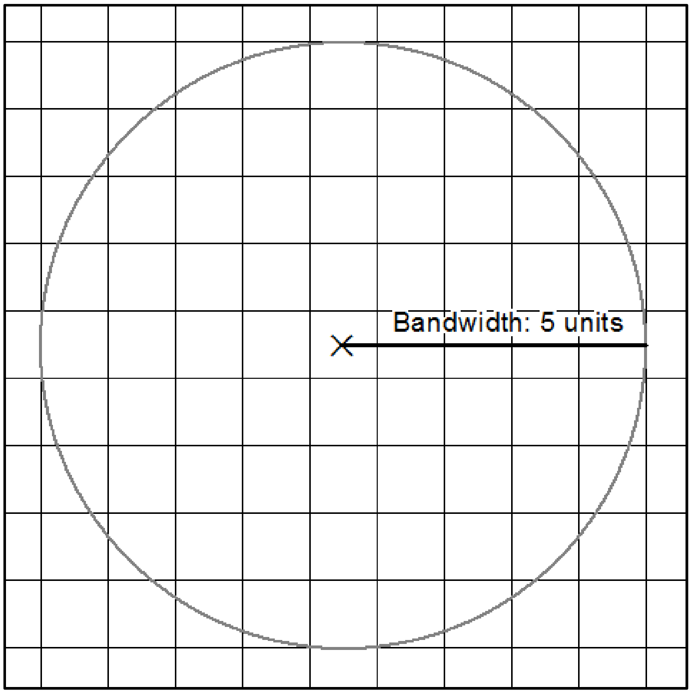
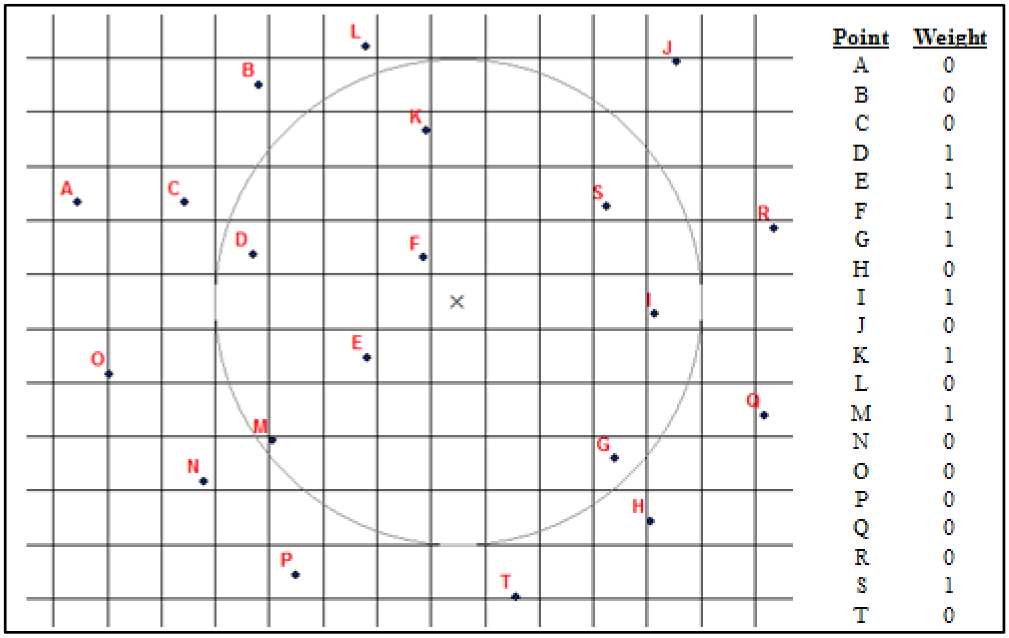


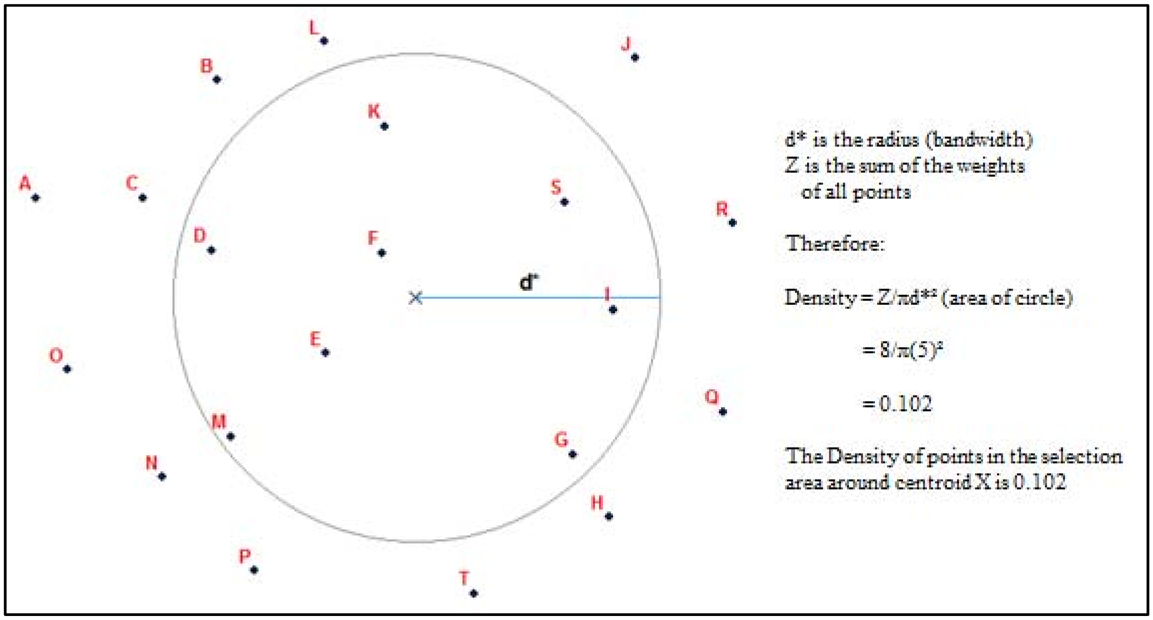
Figure 3.4. A selection area (area within grey outline) around a centroid (x label), created with a 5 unit bandwidth.

A binary weighting system is then used to calculate the density value of the point features relative to the point of interest. If a point is within the selection area, it receives a weight value of one, whereas a point that lies outside of the selection area receives a weight value of zero (figure 3.5). The binary weights are then summed, and the sum is divided by the area of the buffer. The result is a measure of the density of points relative to the point of interest (figure 3.6).



Point	Weight
A	0
B	0
C	0
D	1
E	1
F	1
G	1
H	0
I	1
J	0
K	1
L	0
M	1
N	0
O	0
P	0
Q	0
R	0
S	1
T	0

Figure 3.5. Calculating the weight value of points when conducting a point density analysis. Points within the selection area receive values of one and points outside receive values of zero.



d* is the radius (bandwidth)
Z is the sum of the weights
of all points

Therefore:

Density = $Z/\pi d^{*2}$ (area of circle)

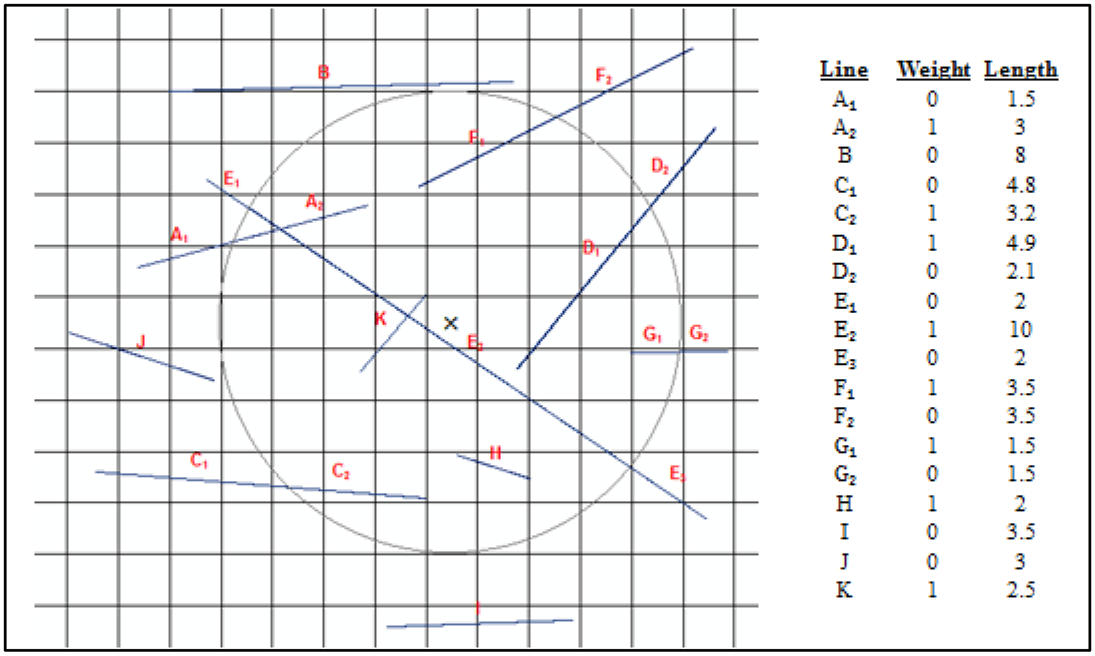
$= 8/\pi(5)^2$

$= 0.102$

The Density of points in the selection area around centroid X is 0.102

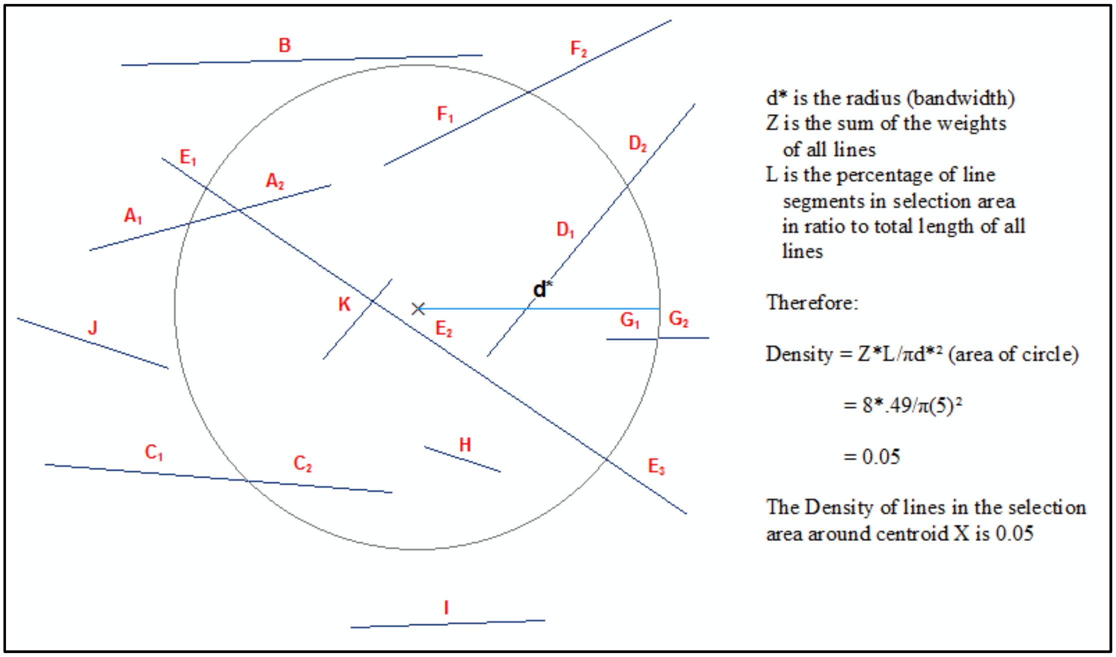
Figure 3.6. The point density for the selection area around centroid x.

Similar to point density, line density also applies a binary weighted system. However, since lines are two-dimensional and have a length, it is possible for a line feature to be both inside and outside the selection area. Instead of weighting an entire line feature, line density snips the line at the points where the line intersects the selection buffer. For the portion of the line within the selection area, it is valued with a weight of one. Outside of the selection area, the line segment is given a weight of zero. Each positive weight is then multiplied by the length of the line within the selection buffer. These resulting products are then summed and divided by the area of the buffer to produce a measure of the line density relative to the point of interest (figure 3.7 and 3.8).



Line	Weight	Length
A_1	0	1.5
A_2	1	3
B	0	8
C_1	0	4.8
C_2	1	3.2
D_1	1	4.9
D_2	0	2.1
E_1	0	2
E_2	1	10
E_3	0	2
F_1	1	3.5
F_2	0	3.5
G_1	1	1.5
G_2	0	1.5
H	1	2
I	0	3.5
J	0	3
K	1	2.5

Figure 3.7. Calculating the weight value of lines when conducting a line density analysis. Line segments within the selection area receive values of one and line segments outside receive values of zero.



d* is the radius (bandwidth)
Z is the sum of the weights of all lines
L is the percentage of line segments in selection area in ratio to total length of all lines

Therefore:

Density = $Z*L/\pi d*^2$ (area of circle)

$= 8*.49/\pi(5)^2$

$= 0.05$

The Density of lines in the selection area around centroid X is 0.05

Figure 3.8. The line density for the selection area around centroid x.

Unlike the binary weighting used to calculate point and line density, kernel density estimation (KDE) uses a continuous distance-decay function to calculate weights. Based on the distance from the center of the selection area, the function yields values between zero and one. If the value is zero that means the location of the object in regards to the center of the selection area is at a distance greater than or equal to the bandwidth from the point of interest. A value of one would indicate that the location of a feature coincided with the point of interest. A variety of distance-decay functions can be used to assign weights, including a Gaussian function (figure 3.9 and 3.10).

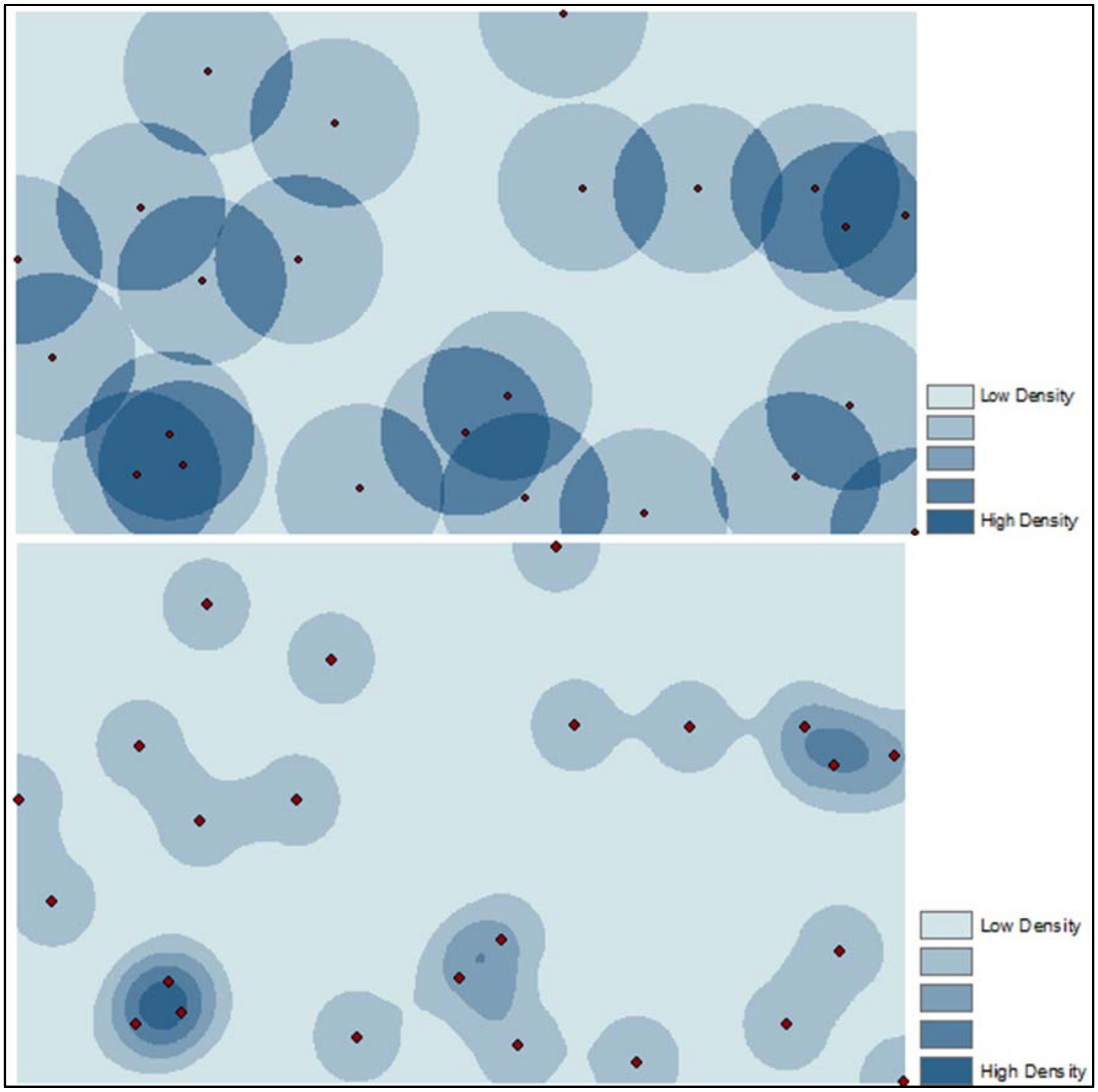


Figure 3.9. Point density (top) measures the density value for each cell value using a binary weighting method. KDE (bottom) applies a weighting kernel function which creates a smoother output.

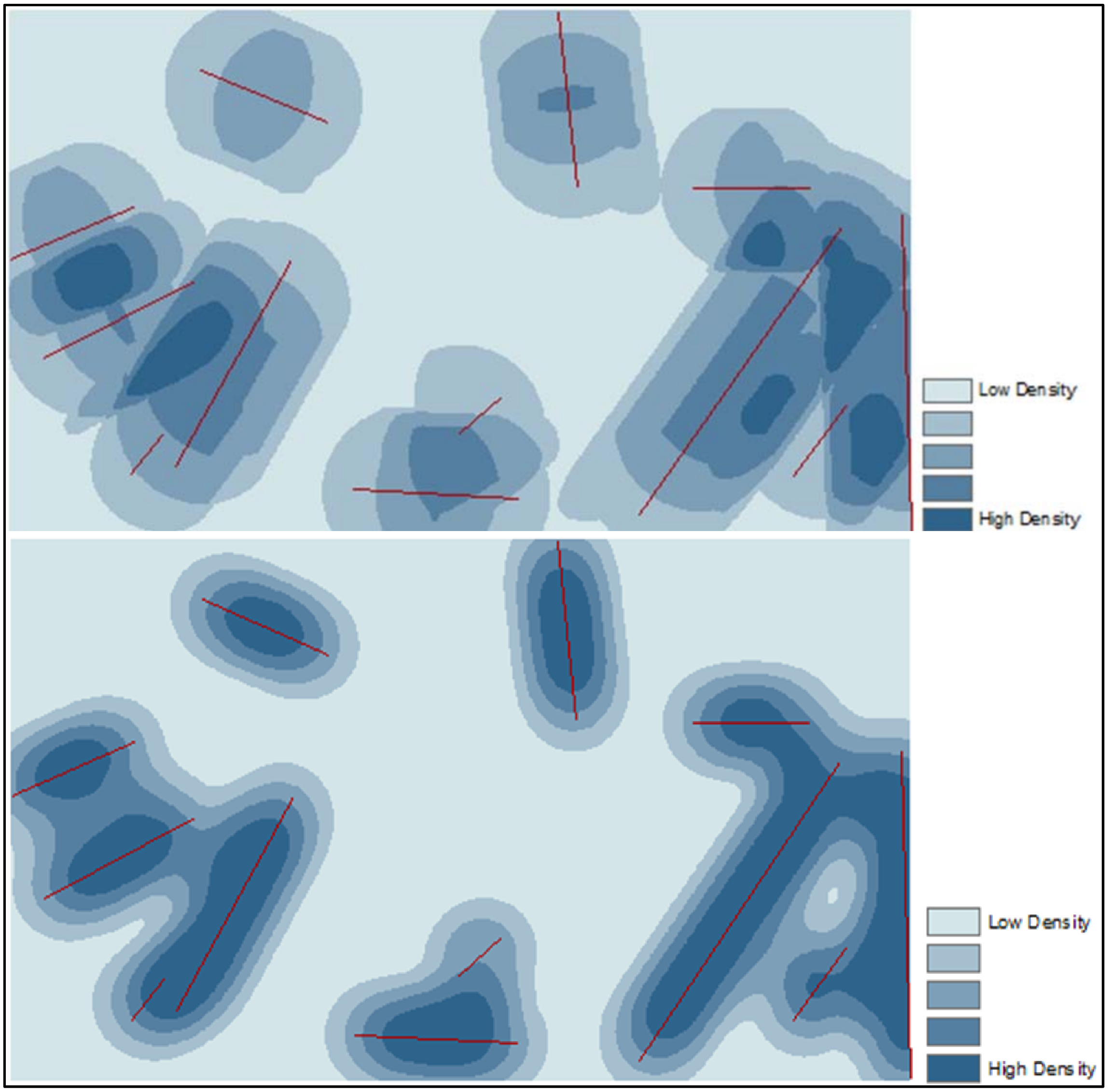
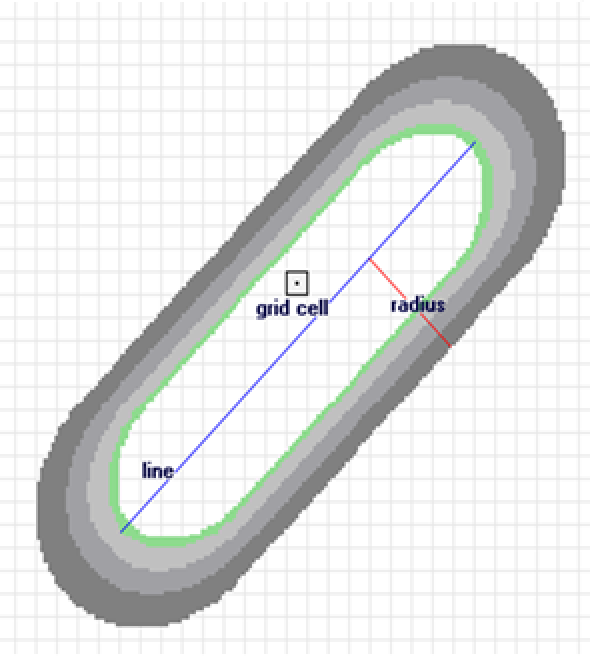


Figure 3.10. Line density (top) works similar to point density and calculates the density value using the binary weighting system. KDE (bottom) can work on both point and line features to create a smooth, easy to interpret output.

The The Gaussian kernel function appears as a symmetric bell-curve shape on a graph, except that the value of the function at positive or negative the bandwidth value equals zero instead of infinity or negative infinity respectfully. At the peak of the curve, the value is one. The KDE using the Gaussian kernel then sums the values of every cell in the analysis extent. The values are calculated based on the KDE value generated by the Gaussian kernel over each input entity (figure 3.11). The continuous weight function logically generates a much smoother output than either the point or line density tools.



Kernel Density Estimation

$$f_h(x) = \frac{1}{n}\sum_{i=1}^{n} K_h(x - x_i)$$

which equals…

$$\frac{1}{hn}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right)$$

where

K = kernel
h = bandwidth (must be greater than 0)
$x_1, x_2 \ldots x_i$ = input entities
n = number of entities
i = index from 1 to n

Gaussian Kernel Weight

$$K(x) = ae\frac{(x-b)^2}{2c^2}$$

where

K = kernel weight
$x_1, x_2 \ldots x_n$ = input entities
a, b, c = real constants
$e \approx 2.718281828$ (Euler's number)

Figure 3.11. KDE example and equations. Image Source: Kernel Density (Esri 2010)

In all density measures available in ArcGIS, there are two very important parameters. The more important of these determines the area in which the density will be measured. This is called the bandwidth. The bandwidth value can be either automatically configured by the software, or it can be determined by the user. Having flexibility to choose the bandwidth allows the user to configure the output raster surface to meet desired criteria. The other important parameter is the cell size. The output of density operation is stored in a raster, a rectangular grid of cells. The cell size determines the resolution of the grid. By assigning a color to each cell based on its value, the raster is viewed as an image. Each value is given a color or tone value which allows the user to visually see the distribution of density values.

3.5 Preparing the Tornado Day Data

In order to conduct the analysis using tornado days, the dataset first needs to be converted from vector format to raster format. Many of the processes involved in this conversion require iterative application of a sequence of operations. This is possible through the ModelBuilder application in ArcGIS (figure 3.12).

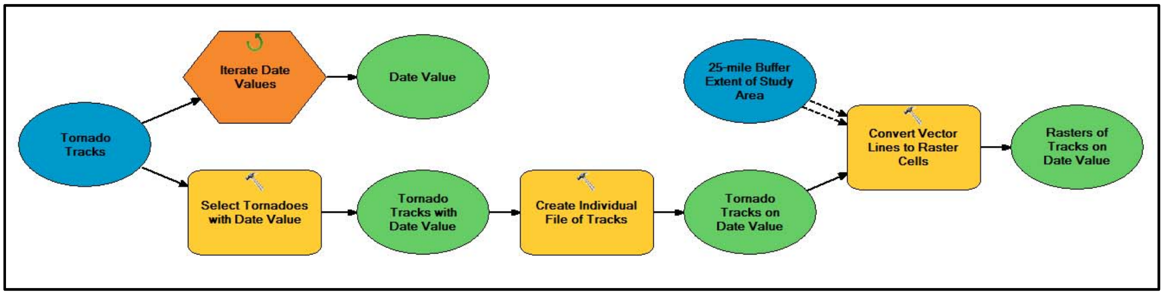


Figure 3.12. Model to iterate tornado track records by their date value and create raster files from the vector tornado track records.

ModelBuilder allows the user to construct models as sequential sets of operations which contain as few or many tools as needed to complete a process. Models are very useful when multiple tools are needed to analyze and process a dataset in order to produce the required output. For calculating tornado days, tools must be used to complete six different processes for each individual date value in the dataset. ModelBuilder displays a sequential script as a flow chart. In the background of ModelBuilder, a python script is created to execute the proper functions and operations.

The first step is to create a separate binary raster of the tornado day values for each day on which a tornado occurred somewhere within the study area raster. This requires that the 61-year tornado dataset (records from 1950-2010) be broken down into individual files, each containing all of the tornado records from a particular date. This results in a total of 267 files. The next step is to convert each file from a vector format to a raster format, in which each cell has a resolution of 0.25 miles. Binary values will be assigned to the cells, with a value of one (indicated by the shaded cells in figure 3.13 if a tornado track impacted a cell on the given day, and a value of zero, otherwise. Even if there are multiple tornado track records that intersect a raster cell on the same date, it is still counted as one tornado day. This also eliminates any duplicate records that may remain in the dataset.

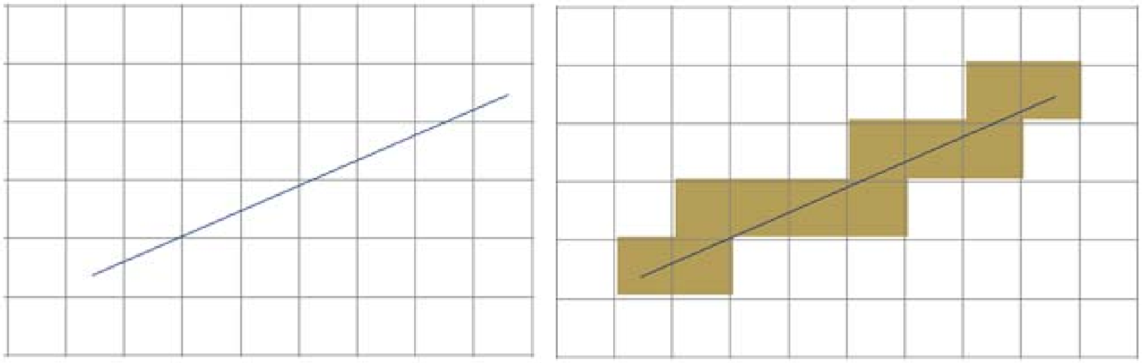


Figure 3.13. (Left) A line portraying a tornado track overlying a blank raster. (Right) The overlying cells pixelate to show the tornado track.

The process shown in figure 3.13 is run on each of the 267 separate files representing days on which at least one tornado occurred in the study area. In order to add all of the rasters together, each raster must have the same cell and extent size. Again, iteration was used to make sure each raster was formatted correctly (figure 3.14).

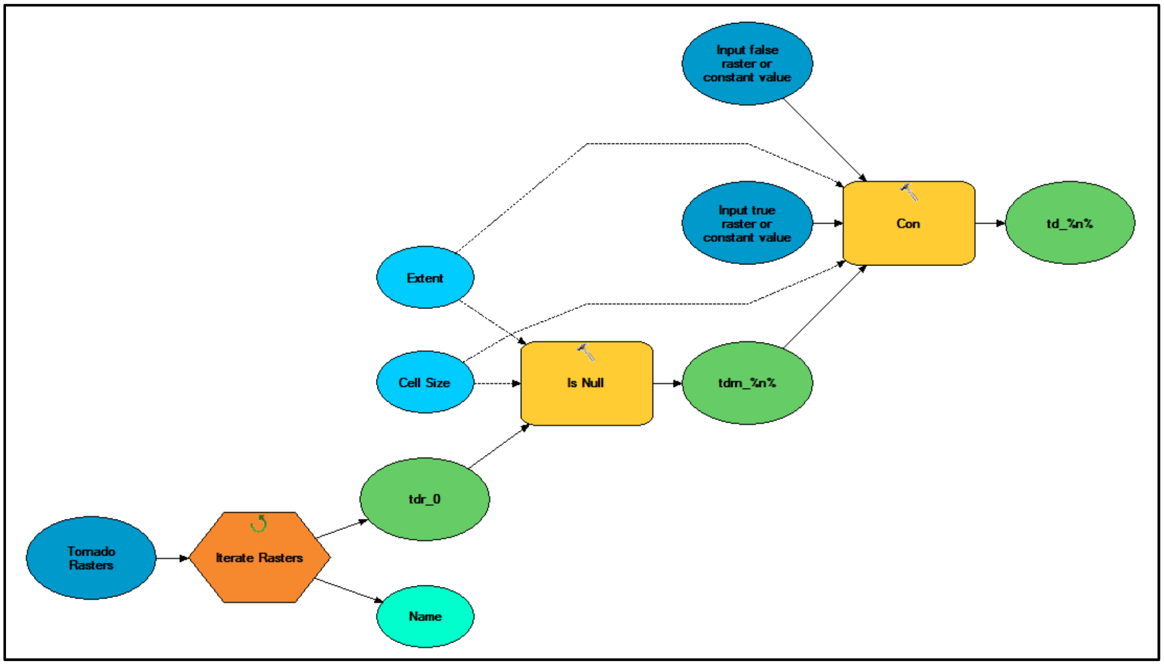


Figure 3.14. Model used to format rasters to calculate tornado days.

With all of the files converted to rasters, the Weighted Sum tool in ArcGIS is used to add all of the raster datasets together. Therein the values of the cells that overlay one another in the various files are added together. The result is a final raster with cell values reflecting the number of days on which a tornado track impacted the respective cells over the 61 years of the dataset. These values are then be divided by the number of years in the dataset. Given that no cell was impacted by more than three tornadoes over the period, the remaining values are very small.

The goal of the project is to calculate the tornado impact density which is the total area (number of cells) impacted by tornadoes within 25 miles of a point of interest per year divided by the area of the 25-mile buffer. Calculating the risk of a location based on the previous tornado events within 25 miles, is consistent with current NWS practices (Dixon, et al. 2011). Therefore, a Focal Statistics function is used in the Raster

Calculator of ArcGIS. This function first creates a neighborhood around each cell. The neighborhood has a specified shape (circle) and size (radius = 25 miles). Then a calculation is done to add all of the values of cells that intersect the neighborhood. Recall that the study area includes a 25-mile buffer around the Kentucky, and this eliminates any potential edge effect in the calculation for cells within the boundary of Kentucky. The cells lying outside of Kentucky are then clipped and removed from any further processing.

The final step involves spatial smoothing of the tornado impact values. Given the degree of uncertainty in determining the actual paths of historically documented tornadoes, the tornado impact density values are inexact. Further, when mapping these values, the resulting image shows discrete changes in density. This can result in misinterpretation of the actual precision with which risk can be determined. Thus spatial smoothing is used to produce a more effective visual display of risk.

This is done using two operations. First, the tornado impact density raster is converted into a vector format as a layer of points. The cell values from the raster are then associated with the corresponding points in an attribute table. Each point value is the sum of cell values within the buffered area around that point. As such it is the total number of tornado days summed over all cells within the 25-mile buffer. These points are then input into the Kernel Density tool, and the raster cell value field is used as the weight. The KDE tool applies a 25-mile bandwidth, and uses the same output cell size as the weighted sum raster. The KDE output is then clipped to fit inside the study area (figure 3.15).

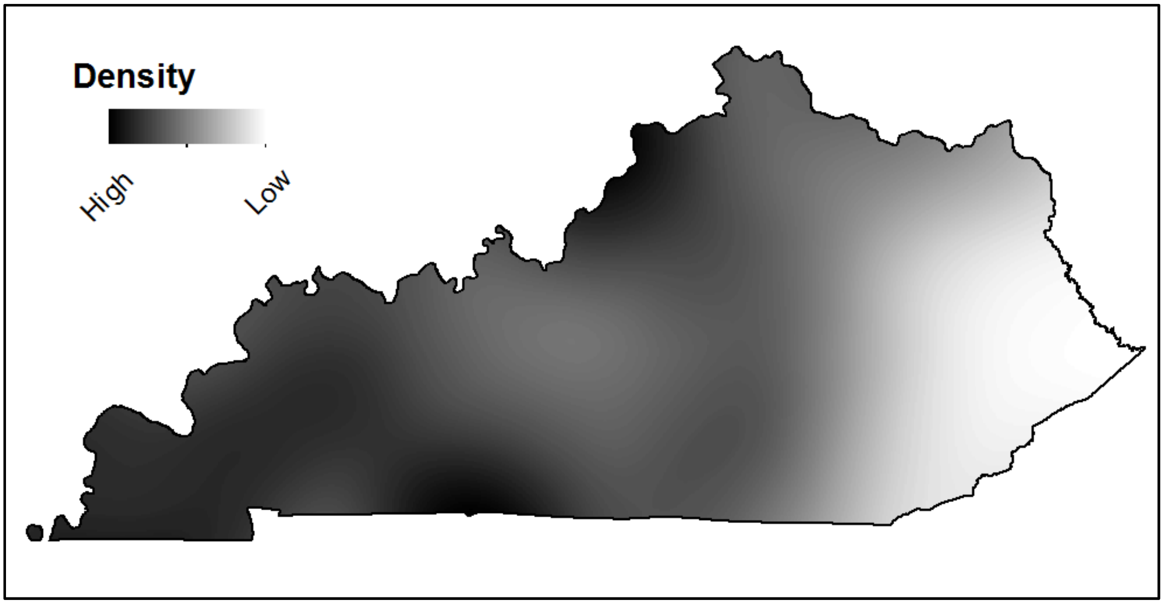


Figure 3.15. KDE output of tornado days in Kentucky.

3.6 Identification of Risk Zones

Risk is by definition a calculation of likelihood of a disaster occurring. Inevitably, tornadoes are not completely predictable, and therefore quantifying a value of risk becomes difficult. However, using the approach above, nearby areas are compared against a constant value, such as an average, to determine if the area has greater or less risk than others based on historical tornado events. By definition of the term risk, if areas are calculated to have higher tornado impact densities within 25 miles than the state average, then that area in question has an above average risk. Likewise, areas lower than the state average are deemed to be areas below the average amount of occurrences.

Understanding the variability in the tornado day values is important for creating the class breaks that will define the risk zones. To statistically determine these zones, the standard deviation is used as the variability factor. Standard deviation is a measure of the dispersion of values from the mean of a distribution. By using the mean minus the standard deviation and the mean plus the standard deviation as break values, three value categories are created. The category containing the smallest values is deemed the low risk classification. The category containing the largest values is deemed the high risk classification. The remaining values are considered average risk since they fall within one standard deviation from the mean value (table 3.3). Using these class values, the risk zones create an intuitive symbology of the tornado day events (figure 3.16).

Table 3.3. Breakdown of the value thresholds for risk zones of tornado days

Value	**Risk Description**
Below Average	This zone experiences less than average amount of Tornado Day occurrences within 25 miles of a given point.
Average	This zone experiences an average amount of Tornado Day occurrences within 25 miles of a given point.
Above Average	This zone experiences an above average amount of Tornado Day occurrences within 25 miles of a given point.

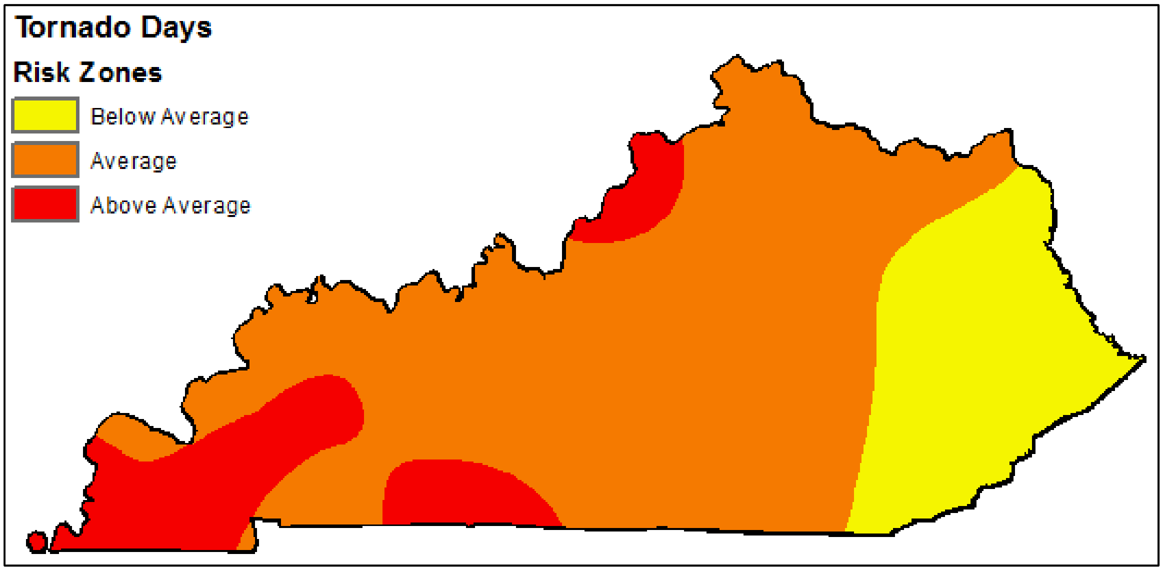
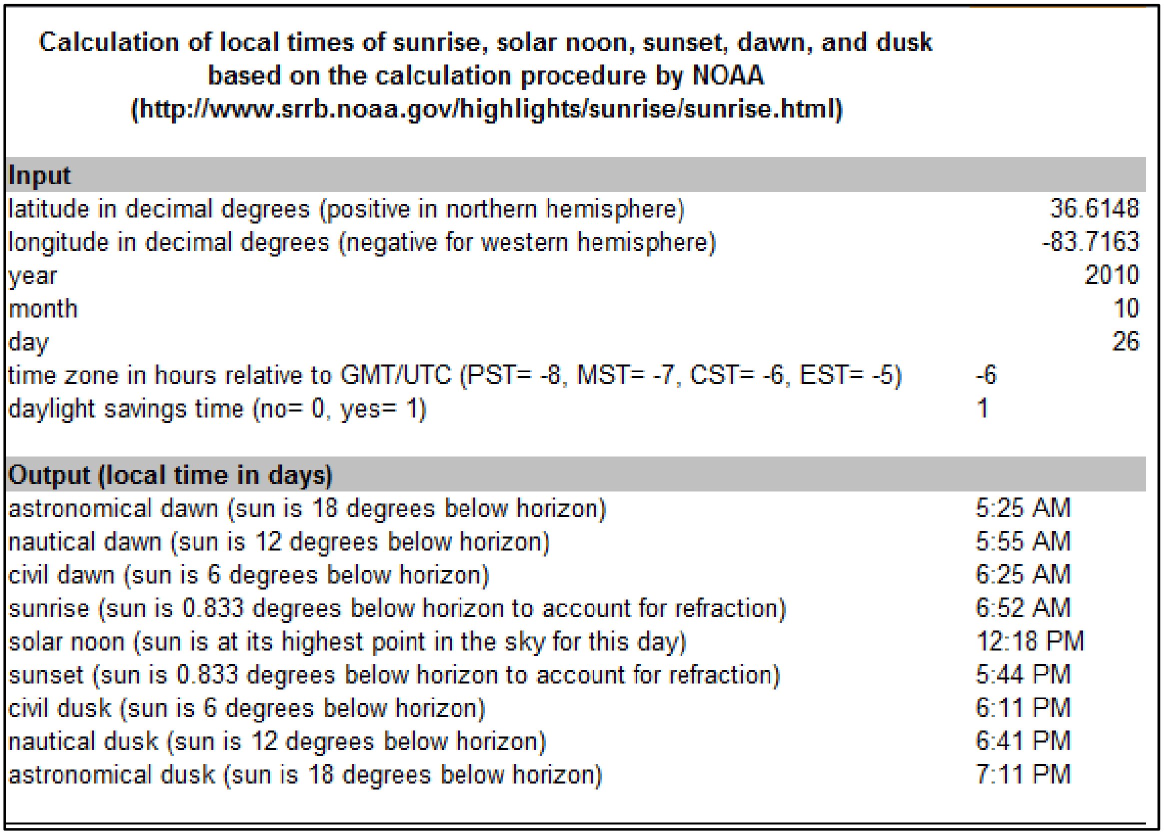


Figure 3.16. Risk zone classes of Tornado Day occurrences within Kentucky from 1950-2010.

3.7 Tornado Attribute Data

Some of the default attribute data provided by the SPC made it possible to create multiple tornado datasets. Datasets were created based on decade, season, and F-Scale. To create these, queries were made on the entire tornado dataset, and the selections were exported as a new feature class file. Another dataset that was created was based on if the tornado occurred during daylight or if it occurred at nocturnal. To achieve this, a function was used in Excel, developed by the State of Washington's Department of Ecology, Greg Pelletier (Department of Ecology, State of Washington 2011). The function calculates the sunrise/sunset time for any location on the planet on any day in history with an accuracy of +/- one minute (figure 3.17). The function requires seven input parameters; latitude, longitude, year, month, day, time zone, and a binary value representing daylight savings time (no=0, yes=1).



Calculation of local times of sunrise, solar noon, sunset, dawn, and dusk
based on the calculation procedure by NOAA
(http://www.srrb.noaa.gov/highlights/sunrise/sunrise.html)

Input	
latitude in decimal degrees (positive in northern hemisphere)	36.6148
longitude in decimal degrees (negative for western hemisphere)	-83.7163
year	2010
month	10
day	26
time zone in hours relative to GMT/UTC (PST= -8, MST= -7, CST= -6, EST= -5)	-6
daylight savings time (no= 0, yes= 1)	1

Output (local time in days)	
astronomical dawn (sun is 18 degrees below horizon)	5:25 AM
nautical dawn (sun is 12 degrees below horizon)	5:55 AM
civil dawn (sun is 6 degrees below horizon)	6:25 AM
sunrise (sun is 0.833 degrees below horizon to account for refraction)	6:52 AM
solar noon (sun is at its highest point in the sky for this day)	12:18 PM
sunset (sun is 0.833 degrees below horizon to account for refraction)	5:44 PM
civil dusk (sun is 6 degrees below horizon)	6:11 PM
nautical dusk (sun is 12 degrees below horizon)	6:41 PM
astronomical dusk (sun is 18 degrees below horizon)	7:11 PM

Figure 3.17. The *Twilight* function developed by Greg Pelletier to calculate sunrise/sunset times.

By creating a macro in Excel to loop through the tornado dataset the sunrise and sunset for each day is calculated. Then using another macro, the time of the tornado event in the dataset is compared to the sunrise and sunset times. If the time is between the sunrise and sunset, then it is given a value of 1 for daylight. If the time was between the sunset and sunrise of the next day, it is given a value of 0 for nocturnal. This calculation makes it possible to query all diurnal and nocturnal tornadoes into individual datasets.

CHAPTER 4

WEBSITE APPLICATION DEVELOPMENT

The goal of this project is to create a powerful website through which users can gather historical tornado data information to make constructive decisions. It is extremely important to make a website that has state-of-the-art functionality, an attractive look, and ease of use for a variety of end users. This phase creates the website and configures a server to distribute this information to the public and stakeholders. With the relationship between the internet and GIS becoming stronger, the development of using ArcGIS server to upload services is quite simple. By setting up the server/client architecture within ArcGIS Server the GIS feature classes the kernel density outputs, all of the tornado track files, Kentucky counties, bordering states, and a defined study area, are uploaded into a geodatabase. The geodatabase then works as the storage container for the server to create the web services. These services are then accessed via a URL that the web application will call.

ArcGIS can be configured to deploy desktop, mobile and web mapping applications. ArcGIS Server publishes both web services, which are systems that are designed to support communication between machines over a network (W3C 2011), and web applications, which are software programs that are accessible on a browser controlled environment (W3C 2011). Essentially, ArcGIS Server allows for geospatial data to be accessed, manipulated, edited and obtained via an internet or intranet.

Rather than using a default client-side web application, which can be less attractive and not as powerful, this study creates an Adobe Flex application. Flex was created as an open source, cross-platform application builder. Compared to the default

ArcGIS Server web application, Flex applications are more current in their design and interface (figure 4.1).

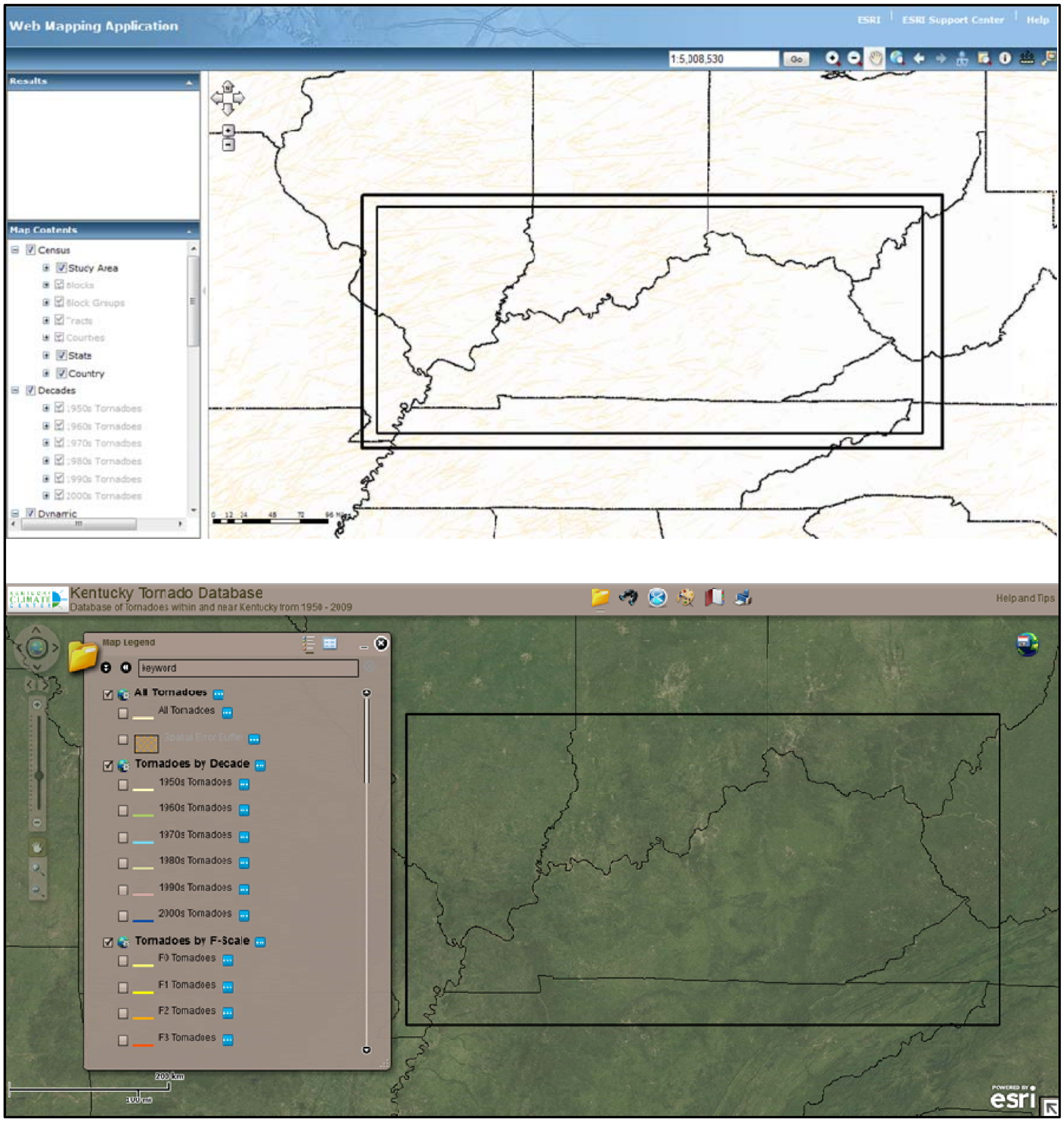


Figure 4.1. The ArcGIS Server application (top) and the Flex Viewer application (bottom) both showing the same services.

Configuring the web application requires no programming experience, however a basic understanding of computer applications is highly recommended. When the Flex Viewer application is downloaded, by default the application is deployable with sample data provided by ESRI (figure 4.2). There are two major steps that are taken before an application can be deployed; 1) Services must be created, and 2) The application interface needs to be customized.

Figure 4.2. Default settings of the Flex Viewer when downloaded and first deployed.

4.1 Service Creation

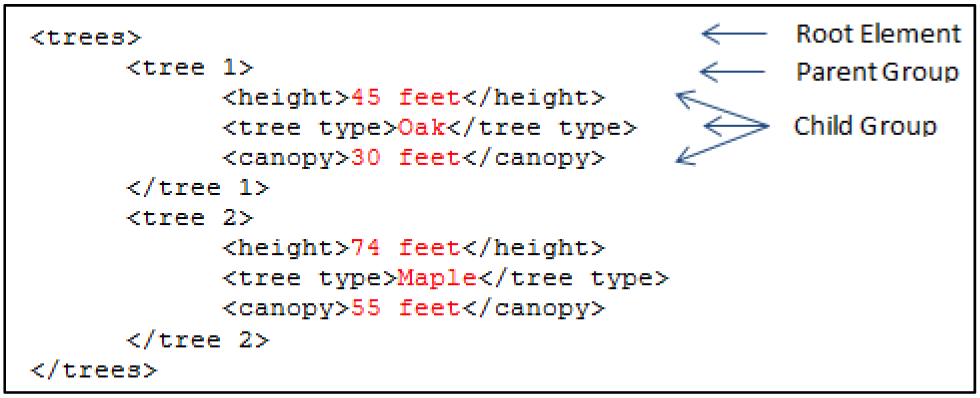
Creating services is the first step to adding unique data to the Flex Viewer and replacing the sample data provided. Services can be created using the ArcGIS Server Manager and published directly in ArcMap and ArcCatalog. Many types of services can be created, and each is used for different reasons. The user needs to choose the capabilities of their application prior to creating the services because the services are what govern the application capabilities. When choosing a resource for the services, there is the option to use either an ArcGIS map document (MXD) or a map service definition (MSD). An MXD contains the layers, layout, and tables of a map resource which can be used for hard copy or digital maps**Invalid source specified.**. An MSD file is used to publish high-performance ArcGIS map services**Invalid source specified.**. MSD files are created based on an MXD, but create a cache which breaks parts of the map down into images. These images can load much faster than MXD layers, since layers require dynamic properties for symbology purposes such as migrating labels.

The map on the website is made of separate services for each tornado dataset type: All Tornadoes, Tornadoes by Decade, Tornadoes by F-Scale, Tornadoes by Time of Day, and Tornado Day Rasters. There are two advantages to using multiple services. The first is if any dataset stops working correctly, that service can be repaired and the remaining services and website can run without issue. The second advantage to using multiple services is that if similar websites are developed on the same GIS server, then the same services can be shared by both, thus avoiding duplication and helping to optimize the server's performance.

4.2 Application Customization

ESRI incorporated Flex capabilities in the ArcGIS Flex Viewer product released in 2009. Flex Viewer is an easy, configurable, non-programming interface that deploys ArcGIS Server services on an Adobe Flash application. Flex products are known for their aesthetics and dynamic processing capabilities. Along with the Flex Viewer product, ESRI also created the Flex Viewer Resource Center, which houses tutorials, sample data, and a large collection of tools, widgets and sample code for users to customize their own Flex Viewer web applications for free.

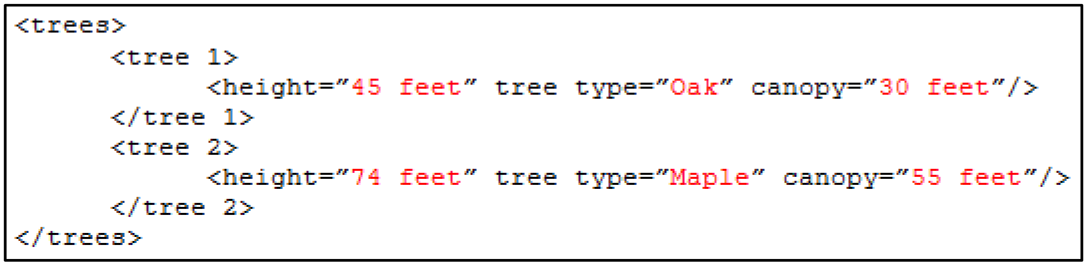
There are two stages of customizing the Flex Viewer. The first stage is to customize the appearance and functionality of the viewer, and the second is to configure the tools or widgets the application uses. For both stages, the customization process is done through configurable XML, or extensible markup language. XML simplifies customization of internet applications by using a grouping method (Liu, Novoselsky and Arora 2010). These are then broken into parent and child subgroups (figure 4.3). The groups and subgroups define parameters and then set the parameters by using a very simple syntax. The parent group contains one or more parameters. The parent group and child subgroups are within a root element. For example, if the root element is tree, then subgroups or children elements could be height, tree type, canopy size, etc. (W3C 1998).



```
<trees>
      <tree 1>
            <height>45 feet</height>
            <tree type>Oak</tree type>
            <canopy>30 feet</canopy>
      </tree 1>
      <tree 2>
            <height>74 feet</height>
            <tree type>Maple</tree type>
            <canopy>55 feet</canopy>
      </tree 2>
</trees>
```

Figure 4.3. This simple XML code shows the relationships between root elements, parent parameters and child parameters. Each parameter must close before the next can be started.

Root elements, parent parameters, and child parameters can consist of one or more parameters (figure 4.4). When multiple parameters inside of a single group are defined, each parameter is defined, and then the values are set by using quotation marks.



```
<trees>
      <tree 1>
            <height=”45 feet” tree type=”Oak” canopy=”30 feet”/>
      </tree 1>
      <tree 2>
            <height=”74 feet” tree type=”Maple” canopy=”55 feet”/>
      </tree 2>
</trees>
```

Figure 4.4. In this XML code snippet, the child groups become parent parameters. Note that the syntax for XML is the same as all programming languages where using indents to identify child and parent elements with the proper hierarchy.

4.2.1 Main Configuration File

The first configuration to the application is to the main interface of the website. This is done mostly though the main configuration file. In the Flex Viewer package, this file is called *conFigurexml*. The *conFigurexml* file can be opened and edited in any text viewer program such as *Windows Notepad*. The file is broken into three major sections (root elements): the main configuration, the map section, and the widget section (figure 4.5).

```
<configuration>
    <b><title>Kentucky Tornado Database</title></b>
    <subtitle>Database of Tornadoes within and near Kentucky from 1950 - 2010</subtitle>
    <logo>assets/images/kcc.png</logo>
    <style>
        <colors>0x000000,0xA8978D,0x7D6F54,0x6E6D37,0x464123</colors>
        <alpha>0.9</alpha>
    </style>

    <!-- UI elements -->
    <widget left="10"
            top="50"
            config="widgets/Navigation/NavigationWidget.xml"
            url="widgets/Navigation/NavigationWidget.swf"/>
    <widget right="-2"
            bottom="-2"
            config="widgets/OverviewMap/OverviewMapWidget.xml"
            url="widgets/OverviewMap/OverviewMapWidget.swf"/>
    <widget right="20"
            top="55"
            config="widgets/MapSwitcher/MapSwitcherWidget.xml"
            url="widgets/MapSwitcher/MapSwitcherWidget.swf"/>
    <widget left="0"
            top="0"
            config="widgets/HeaderController/HeaderControllerWidget.xml"
            url="widgets/HeaderController/HeaderControllerWidget.swf"/>
    <widget left="600"
            top="400"
            config="widgets/mySplash2.2.2/compiled_FV2.2/mySplash/SplashWidget.xml"
            url="widgets/mySplash2.2.2/compiled_FV2.2/mySplash/SplashWidget.swf"/>
    <widget right="25"
            top="60"
            config="widgets/ExportMap/exportMap.xml"
            url="widgets/ExportMap/exportMap.swf"/>
```

Figure 4.5 (a). The first part of the main configuration file includes setting the title, subtitle, logo, color scheme, transparency (alpha), and User- Interface (UI) elements. These widgets control the layout of the application, and require very little customization.

```
<map initialextent="-11725000 3851000 -8383000 5086000" fullextent="-11725000 3851000 -8383000 5086000" top="40">
    <basemaps>
        <layer label="Aerial"
               type="tiled"
               visible="true"
               alpha=".75"
               displaylevels="6,7,8,9,10,11,12,13,14,15,16,17"
               url="http://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer"/>
    </basemaps>
   <operationallayers>
       <layer label="Tornadoes by Season"
              type="dynamic"
              visible="true"
              url="http://ares/ArcGIS/rest/services/Season/MapServer"/>
       <layer label="Tornadoes by F-Scale"
              type="dynamic"
              visible="true"
              url="http://ares/ArcGIS/rest/services/FScale/MapServer"/>
       <layer label="Tornadoes by Decade"
              type="dynamic"
              visible="true"
              url="http://ares/ArcGIS/rest/services/Decades/MapServer"/>
       <layer label="All Tornadoes"
              type="dynamic"
              visible="true"
              url="http://ares/ArcGIS/rest/services/Tornadoes/MapServer"/>
    </operationallayers>
</map>
```

Figure 4.5 (b). The second part of the main configuration page adds the layers of your map. These layers call services created by ArcGIS Server.

```
<widgetcontainer layout="float">
    <widget label="Map Legend"
            x="100"
            y="60"
            preload="open"
            icon="assets/images/i_folder.png"
            config="widgets/Legend2/Legend2Widget.xml"
            url="widgets/Legend2/Legend2Widget.swf"/>
    <widget label="Advanced Search"
            right="50"
            top="100"
            icon="assets/images/i_search.png"
            config="widgets/Selection/SelectionWidget.xml"
            url="widgets/Selection/SelectionWidget.swf"/>
    <widget label="Extract Data"
            left="100"
            top="200"
            icon="assets/images/i_scissors.png"
            config="widgets/DataExtract/DataExtractWidget.xml"
            url="widgets/DataExtract/DataExtractWidget.swf"/>
    <widget label="Charts and Statistics"
            left="950"
            top="60"
            icon="assets/images/i_statistics.png"
            config="widgets/Chart/ChartWidget.xml"
            url="widgets/Chart/ChartWidget.swf"/>
    <widget label="Draw"
            left="800"
            top="300"
            icon="assets/images/i_draw2.png"
            config="widgets/eDraw2.2.4/compiled_FV2.2/eDraw/DrawWidget.xml"
            url="widgets/eDraw2.2.4/compiled_FV2.2/eDraw/DrawWidget.swf"/>
</widgetcontainer>
```

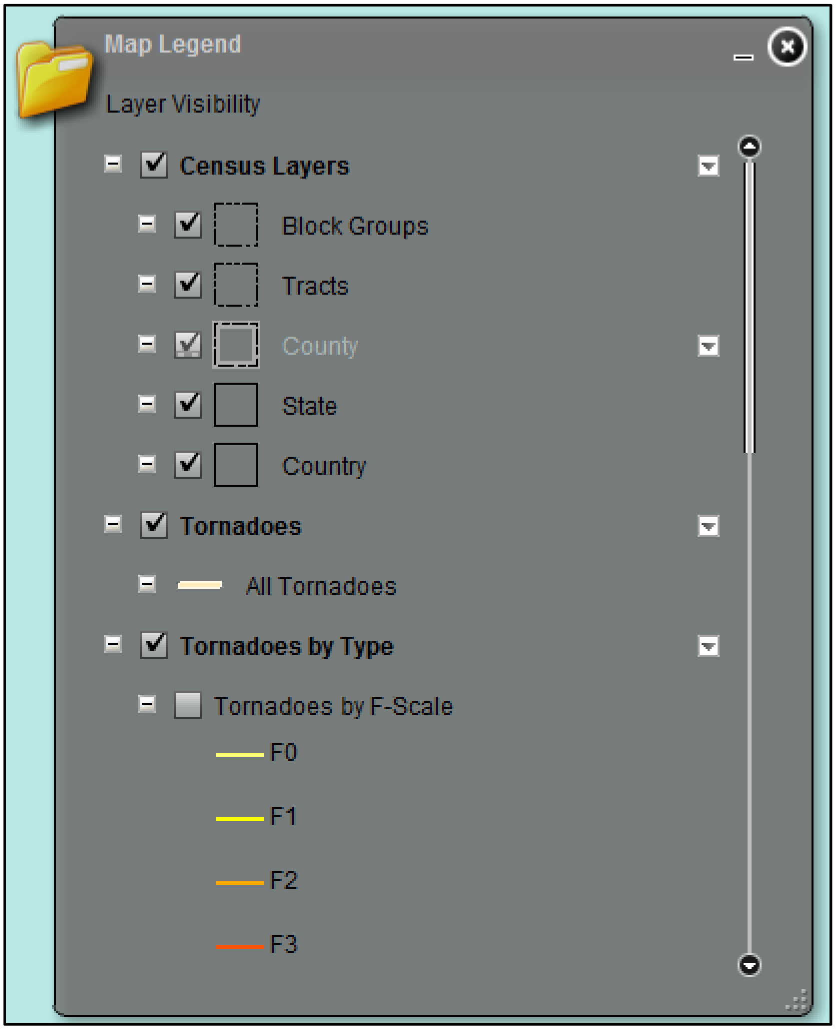
Figure 4.5 (c). The third part of the main configuration file adds the widgets or tools of the application. Each of these tools have their own configuration XML files as which need configured to work correctly with the layers defined in the map section of the *conFigurexml*.

The main configuration file for the Kentucky Tornado Database defines simple metadata of the website, all of the map layers and services used to create the map, and the widgets and tools used for analysis and risk identification. When editing the web application, the *conFigurexml* file is the first file to be read by the internet browser when loading the website. If this file becomes corrupted or edited incorrectly, the entire website will not work. It is very important to keep a copy of the *conFigurexml* file as backup if the original ever becomes corrupted.

4.2.2 Widgets/Tools

Analytical and dynamic tools are a critical aspect of all web mapping applications. By default, the Flex Viewer package comes with a wide selection of tools, or widgets. Configuring these tools requires similar steps as the main configuration file. Each widget contains an XML configuration file, and based on the tools functionality, each requires a different amount of editing.

The Kentucky Tornado Database website has a primary role as an SDSS to relay risk assessment information to stakeholders. In addition, allowing users to access the metadata or attribute data of the tornado tracks helps in any secondary research or analysis. The website was developed using both default and custom designed widgets in the Flex Viewer package. The first widget on the website is a custom Table of Contents/Map Legend widget (figure 4.6). This widget is where users can display the array or tornado track layers, and tornado day rasters. The user can also set the transparency of the layers and view the symbology.

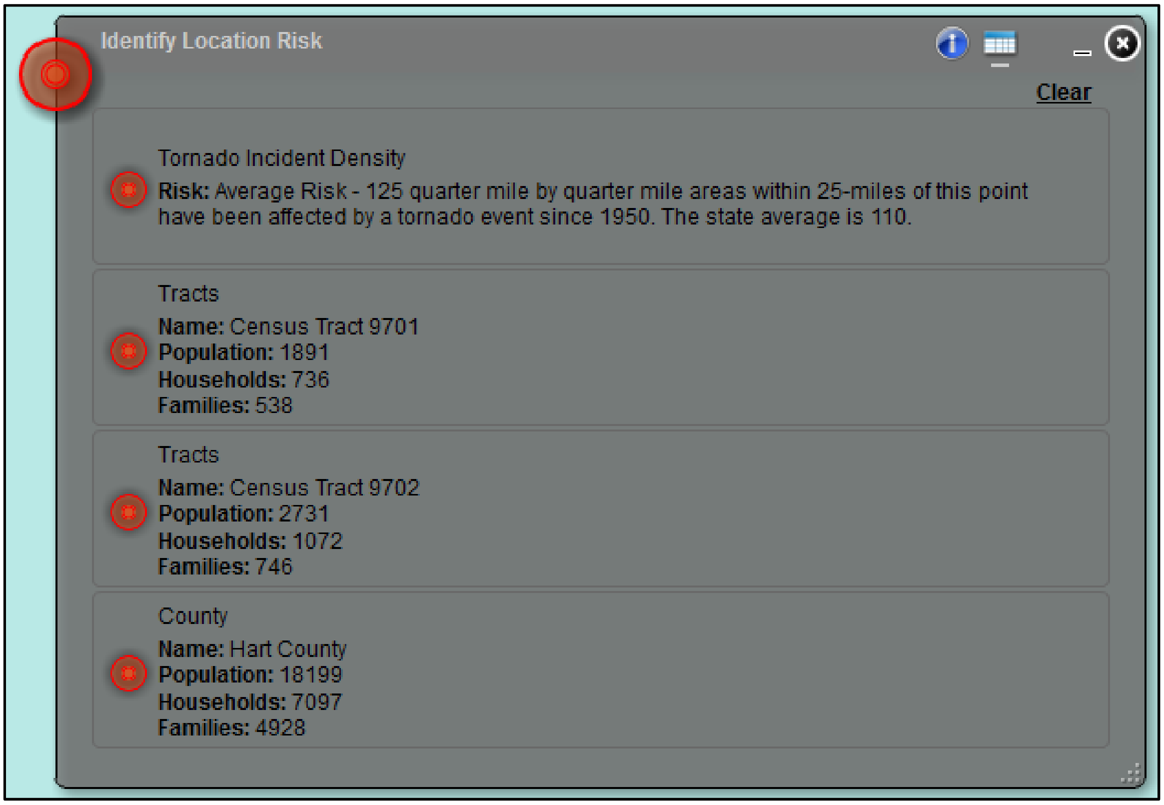


- ☑ Census Layers
  - ☑ Block Groups
  - ☑ Tracts
  - ☑ County
  - ☑ State
  - ☑ Country
- ☑ Tornadoes
  - All Tornadoes
- ☑ Tornadoes by Type
  - ☐ Tornadoes by F-Scale
    - F0
    - F1
    - F2
    - F3

Figure 4.6. The Table of Contents/Map Legend widget on the Kentucky Tornado Database website.

The second widget on the website is an Identify Location Risk tool (figure 4.7). This tool is used to identify the calculated risk level at any location in the study area. The value reflects the probability based on available historical data that a tornado day will occur within 25 miles of the selected point during the course of a given year. If the user selects to use the line, rectangle, or polygon tool to select an area, the risk value is taken from the centroid of the shape. The tool also returns the census tract and county (when selected in Kentucky), and their 2010 populations based on the 2010 Census.

Figure 4.7 (a). The Identify Location Risk tool on the Kentucky Tornado Database website.



Tornado Incident Density

Risk: Average Risk - 125 quarter mile by quarter mile areas within 25-miles of this point have been affected by a tornado event since 1950. The state average is 110.

Tracts

Name: Census Tract 9701
Population: 1891
Households: 736
Families: 538

Tracts

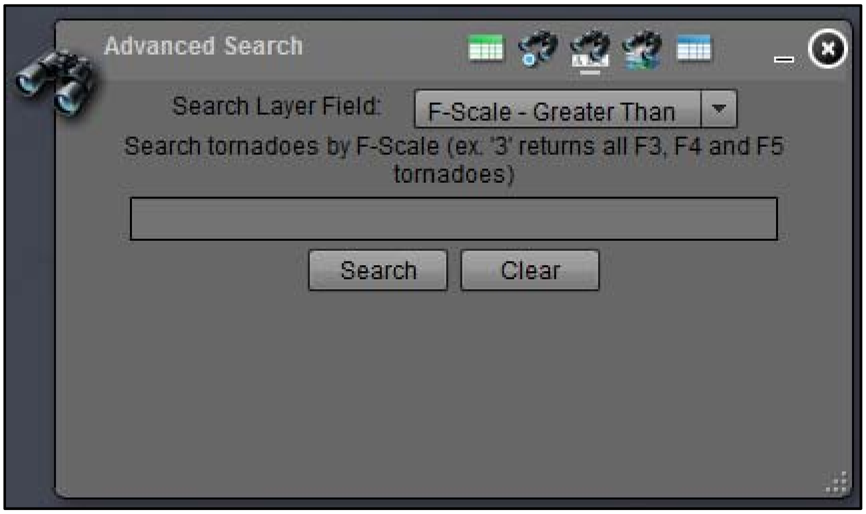
Name: Census Tract 9702
Population: 2731
Households: 1072
Families: 746

County

Name: Hart County
Population: 18199
Households: 7097
Families: 4928

Figure 4.7 (b). The Identify Location Risk tool also returns census data of the selected location, if within the state of Kentucky.

The third widget is the Advanced Search tool. This tool is made of predefined queries that allow the user to search tornado tracks by F-Scale (equal, greater than or equal to, or less than), date, month (exact, before, or after), year (exact, before, or after), length (exact, shorter, or longer), or width (exact, shorter, or longer) (figure 4.8). Once the query is made, a table of the matching records is shown, and the user has the option to view the tornado events individually, or export the list as a comma-separated value (CSV) table or text file.

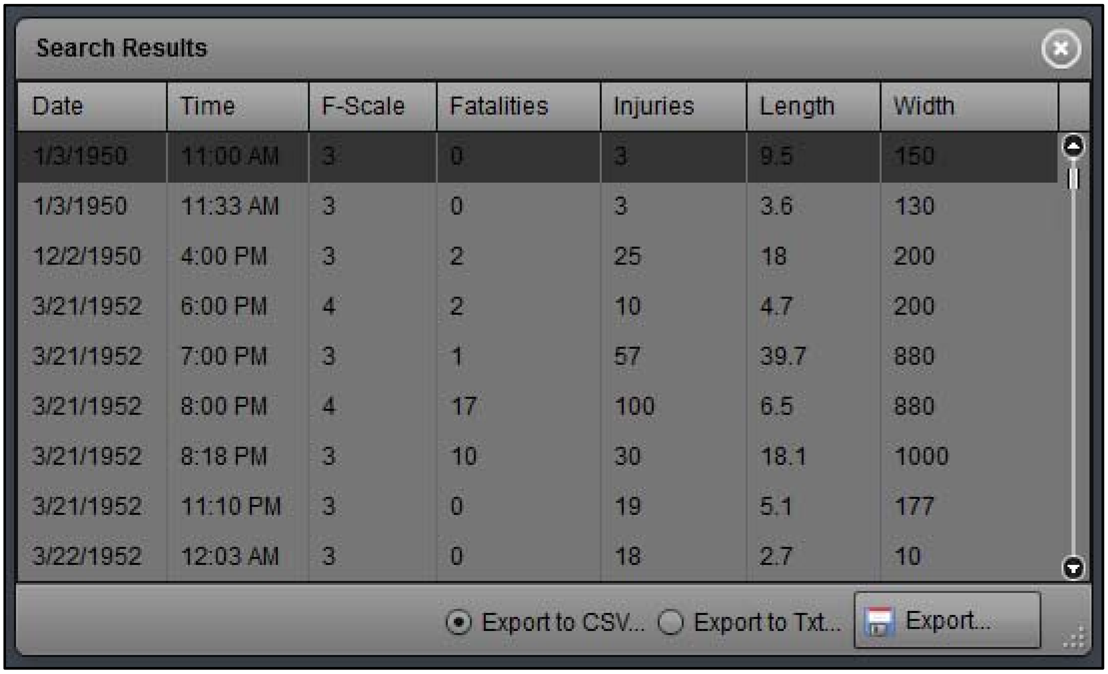


Advanced Search

Search Layer Field: F-Scale - Greater Than

Search tornadoes by F-Scale (ex. '3' returns all F3, F4 and F5 tornadoes)

Figure 4.8 (a). The Advanced Search widget on the Kentucky Tornado Database website.



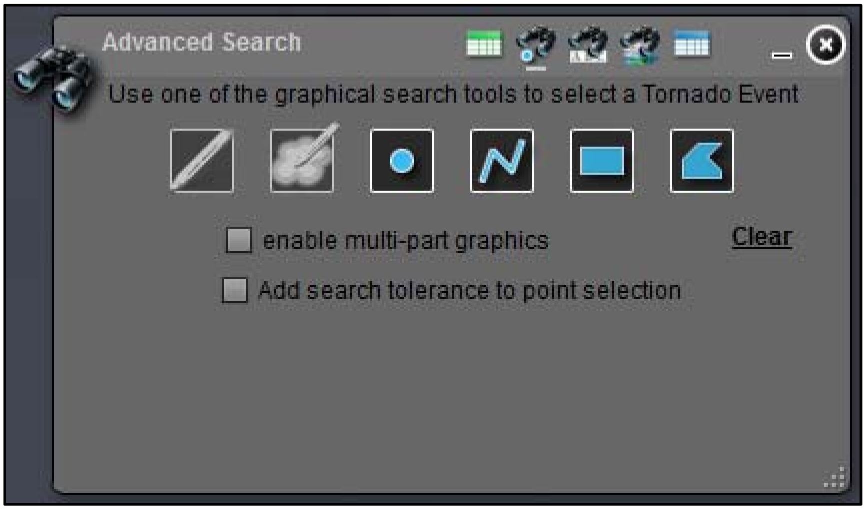
Search Results

Date	Time	F-Scale	Fatalities	Injuries	Length	Width
1/3/1950	11:00 AM	3	0	3	9.5	150
1/3/1950	11:33 AM	3	0	3	3.6	130
12/2/1950	4:00 PM	3	2	25	18	200
3/21/1952	6:00 PM	4	2	10	4.7	200
3/21/1952	7:00 PM	3	1	57	39.7	880
3/21/1952	8:00 PM	4	17	100	6.5	880
3/21/1952	8:18 PM	3	10	30	18.1	1000
3/21/1952	11:10 PM	3	0	19	5.1	177
3/22/1952	12:03 AM	3	0	18	2.7	10

● Export to CSV... ○ Export to Txt...

Figure 4.8 (b). The matching features from the query selected on the Advanced Search widget.

In addition to query searches, the Advanced Search tool allows the user select features using an area define tool. (figure 4.9). Further, the Advanced Search tool also gives the user the option to apply buffers to selected features. The buffer is then used to select additional features based on proximity to the initial feature (figure 4.10).



Advanced Search

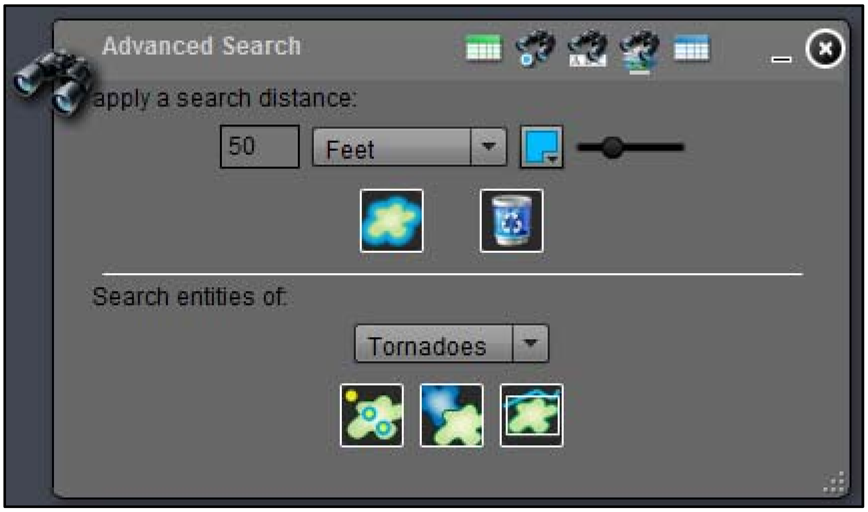
Use one of the graphical search tools to select a Tornado Event

☐ enable multi-part graphics

Clear

☐ Add search tolerance to point selection

Figure 4.9. Searching features by pinpointing or selecting an area.



Advanced Search

apply a search distance:

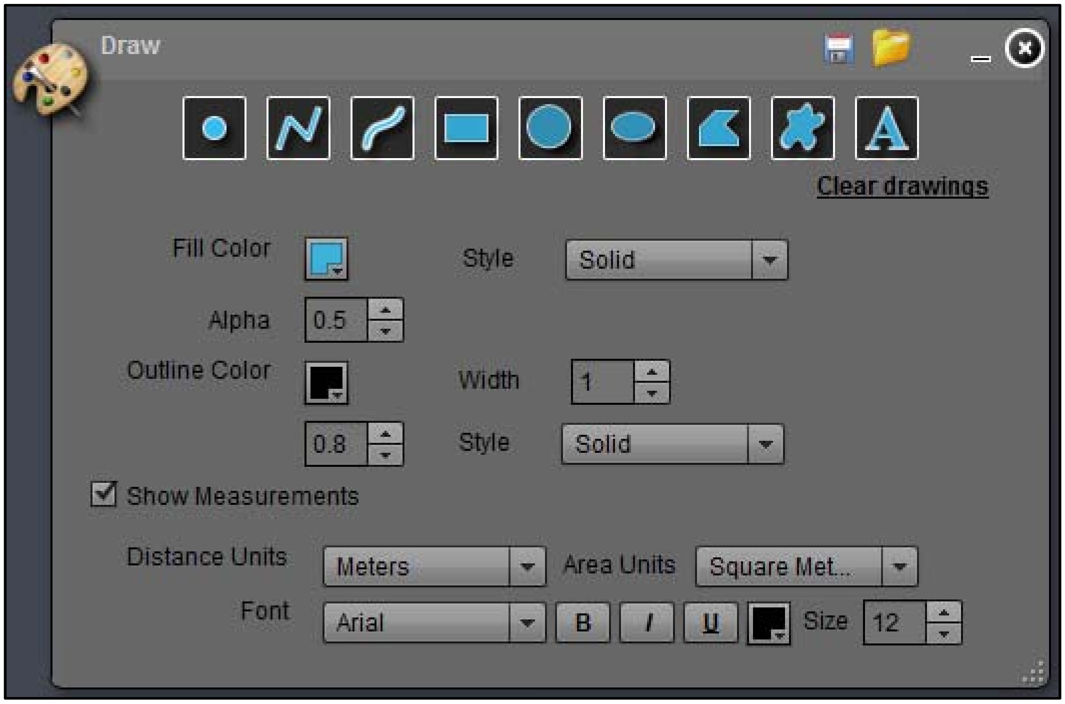
50 Feet

Search entities of:

Tornadoes

Figure 4.10. The selected features can have buffers applied to help with detailed and analytical researching.

The fourth widget is the Draw and Measure widget. This tool can be used for simple markups or planning situations. The tool also gives the users the option to save the graphics and labels they make as a text file, which can then be loaded at a later time and viewed as if they were just drawn (figure 4.11). The tool also takes spatial measurements of graphic objects that are drawn, including area and length of perimeter.



Fill Color
Style: Solid
Alpha: 0.5
Outline Color
Width: 1
0.8
Style: Solid
☑ Show Measurements
Distance Units: Meters
Area Units: Square Met...
Font: Arial
Size: 12

Figure 4.11. The Draw and Measure widget on the Kentucky Tornado Database website.

The fifth widget on the website is a Bookmarks tool. This widget has predefined areas on which the user can click, and the map view will then automatically zoom to that specific area (figure 4.12). The user can also add custom bookmarks that will append to the list automatically.

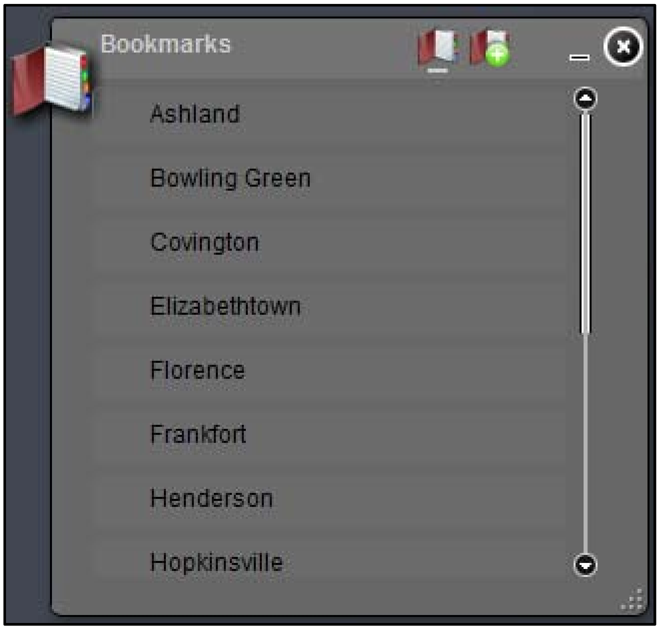


Figure 4.12. The Bookmarks widget on the Kentucky Tornado Database website.

Finally, two additional widgets were added to give the website more functionality. Both a Print tool and an Export Map tool were added for users to either print their current map view or save their current map view as a JPEG file.

4.3 Web Application Examples

The web application enables users with different interests to extract information from up-to-date tornado data as an aid to decision making. Upon loading the web application, the user is greeted with a splash screen (figure 4.13). The splash screen displays the terms and conditions for using the website, and also goes through the legalities which protect Western Kentucky University, the Kentucky Climate Center, and the web application users from using the data unlawfully.

Welcome to the Kentucky Tornado Database.

Welcome to our website! If you continue to browse and use this website, you are agreeing to comply with and be bound by the following terms and conditions of use, which together with our privacy policy govern the Kentucky Climate Center's relationship with you in relation to this website. If you disagree with any part of these terms and conditions, please do not use our website.

The term Kentucky Climate Center or 'us' or 'we' refers to the owner of the website whose department rests within Western Kentucky University. The term 'you' refers to the user or viewer of our website.

☐ Don't show again

Figure 4.13. The splash screen opens when the user loads the web application. The user can also read the sources of the data, navigate to the Kentucky Climate Center homepage, and prompt the web application to never show the splash screen again in the future.

When the user selects “Agree” on the splash screen the web application loads the default tornado layer, and the Table of Contents/Map Legend widget gathers the symbology for each layer from the ArcGIS Server REST page (figure 4.14).

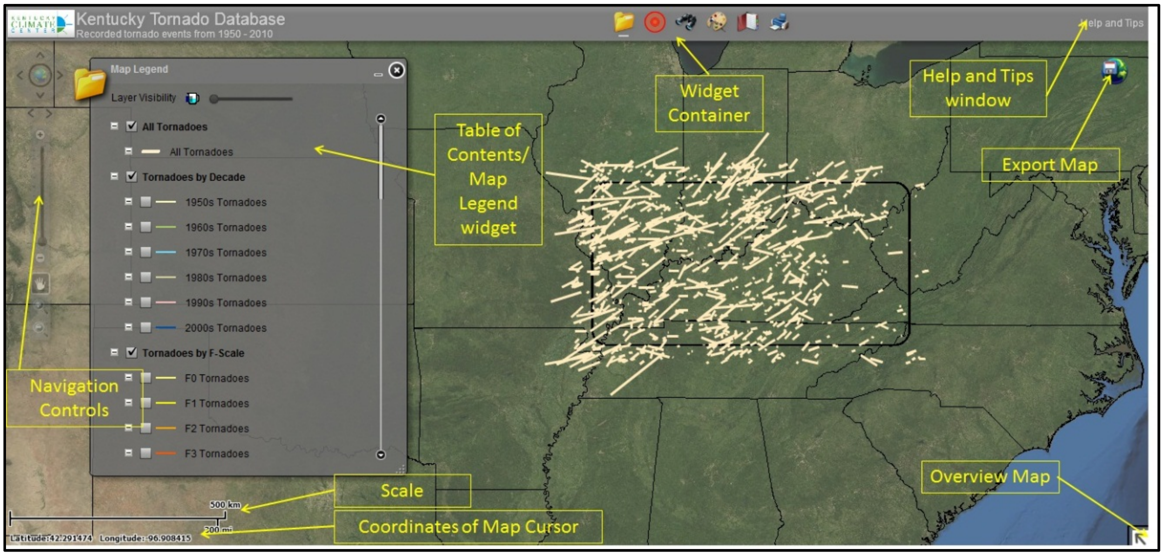
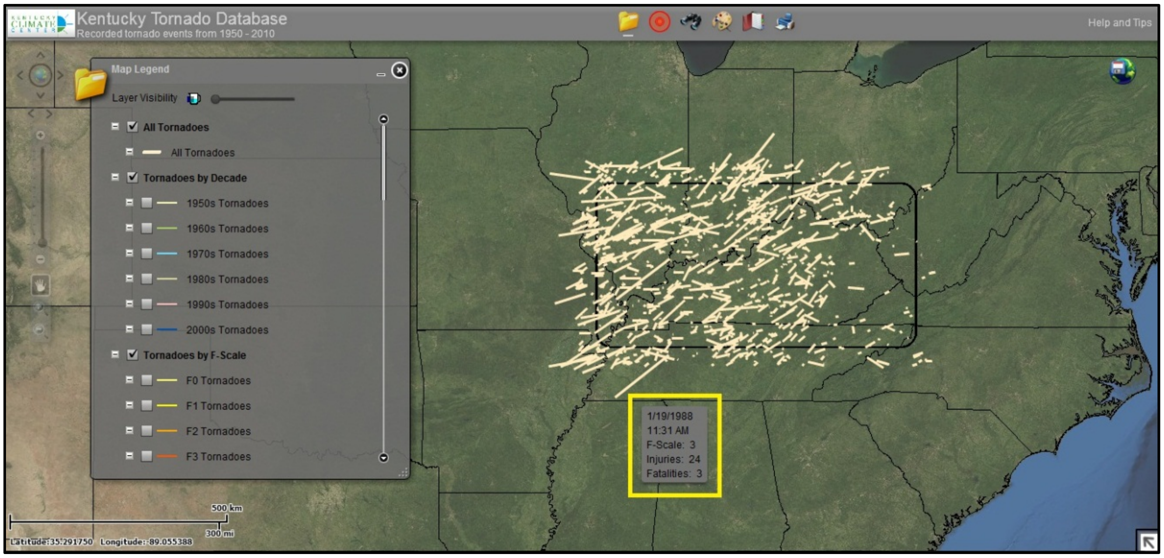


Figure 4.14. The initial view of the web application and the location of the different widgets and tools.

From the initial view, the user has the freedom to use any of the widgets from the widget container, or just use the web application as a viewer.

When viewing the web application, the user can view metadata for the tornado tracks by simply hovering the cursor over the track when the “All Tornadoes” layer is on (figure 4.15). The cursor rest causes a small pop-up window to appear, listing the tornado event date, f-scale intensity, number of fatalities, number of injuries and time of occurrence.



1/19/1988
11:31 AM
F-Scale: 3
Injuries: 24
Fatalities: 3

Figure 4.15. The pop-up window (yellow box) appears when the user rests the cursor on one of the tornado events and has the "All Tornadoes" layer on.

The user does have the option to use the Advanced Search widget to query the tornado layer and view only tornado tracks that meet certain criteria. However, to eliminate having to use the widget for some simple queries, individual layers were created and hosted. The simple queries disaggregate the tornado dataset by decade, f-scale, season, and diurnal and nocturnal events. The user can select to view these layers rather than the entire dataset. Each group of layers has a parent toggle control which allows the user to turn on and off and child toggle (figure 4.16).

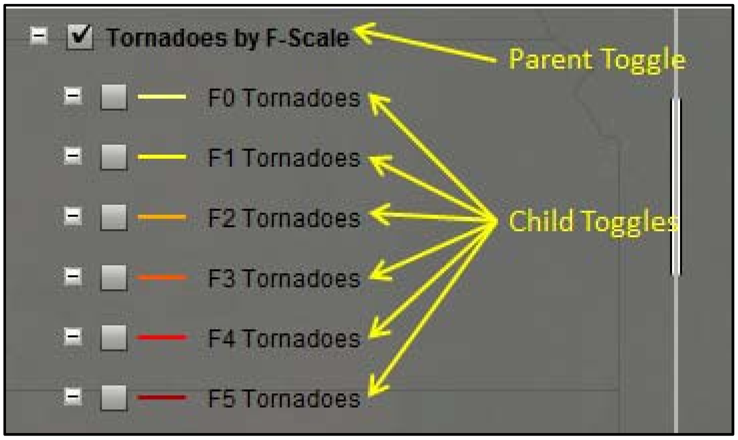
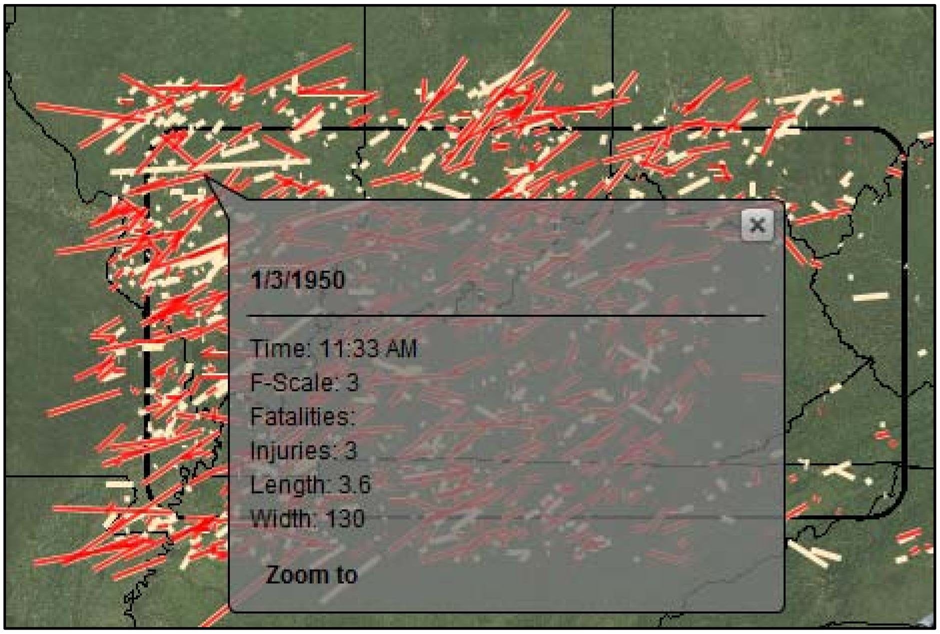


Figure 4.16. The parent toggle controls all of the child toggles. The child toggles must be turned on (checked) in order for the parent toggle to control its visibility.

When using the Advanced Search widget, one is required to either make an attribute query or a spatial selection. Once the tornado tracks are selected, each selected record appears red (figure 4.17). The user still has the capability to export the selected tornado tracks as a CSV, or just continue to view the selected records.



1/3/1950

Time: 11:33 AM
F-Scale: 3
Fatalities:
Injuries: 3
Length: 3.6
Width: 130

Figure 4.17. The selected records from the Advanced Search widget appear red, and the user can browse the records from the selection list. In addition, a pop-up window appears when the user clicks on a record in the selection list which displays attribute information about the tornado track.

The main purpose of the web application is to provide a risk assessment tool for decision makers and emergency management professionals. However, during the development stages of the web application, other uses of the web application became apparent. The website can be used as both an SDSS and also a research tool. For example, in addition to assessing tornado risk, a user can also use the site to collect data on historical tornado events in Kentucky. Using the Advanced Search widget, and/or the individual layers in the Table of Contents/Map Legend, the user can simply find the tornado or tornadoes of interest. Also, the web application makes it possible for users to conduct further research such as tornado destruction path analysis, risk levels by populations, and micro-scaled tornado occurrence migration.

CHAPTER 5

DATABASE UPDATING PROCESS

The tornado dataset must be update annually. However, manually recreating the GIS data and website each year would not be most efficient updating process. To make the task manageable, models were created in ArcGIS ModelBuilder and macros were written to run in Microsoft Excel to automate various steps in the update process. Models are created in ArcGIS ModelBuilder (ArcGIS 2009) and represent workflows that connect sequences of geoprocessing tools, feeding the output of one tool into another as the input. Macros are a set of instructions that are programmed to execute a series of functions (Walkenbach 2010). In addition, a step-by-step tutorial was created to guide the user through the updating process.

5.1 – Updating Models and Macros

The updating process is comprised of six tasks (figure 5.1). The first task is to download the updated tornado dataset from the SPC website and then setup the configurations for the tabular and spatial data to work with the website. The configurations include adding necessary fields that will be populated throughout the updating process. The second task is to take an output table from the first task, and populate fields that cannot be populated in ArcGIS. The third task joins the output from the second task to GIS feature classes and populates the remaining fields. Also, the third task creates all of the individual feature classes used by the website, such as the tornado tracks by decade, season, and intensity. The fourth task involves iterating or looping through the entire tornado dataset to calculate the tornado day rasters. These rasters are what users see when they are viewing data on the website. The fifth task takes the resulting output rasters and uses the Weighted Sum tool in ArcGIS to create the input for the final task. This is the only task that is not automated. The sixth and final task takes the output from the fifth task and finishes the tornado day calculation and raster generation. This task also involves an iteration process.

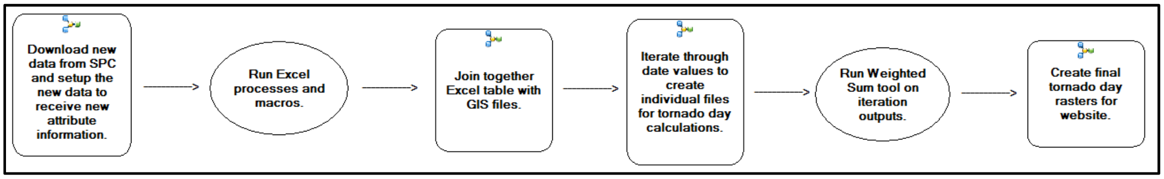
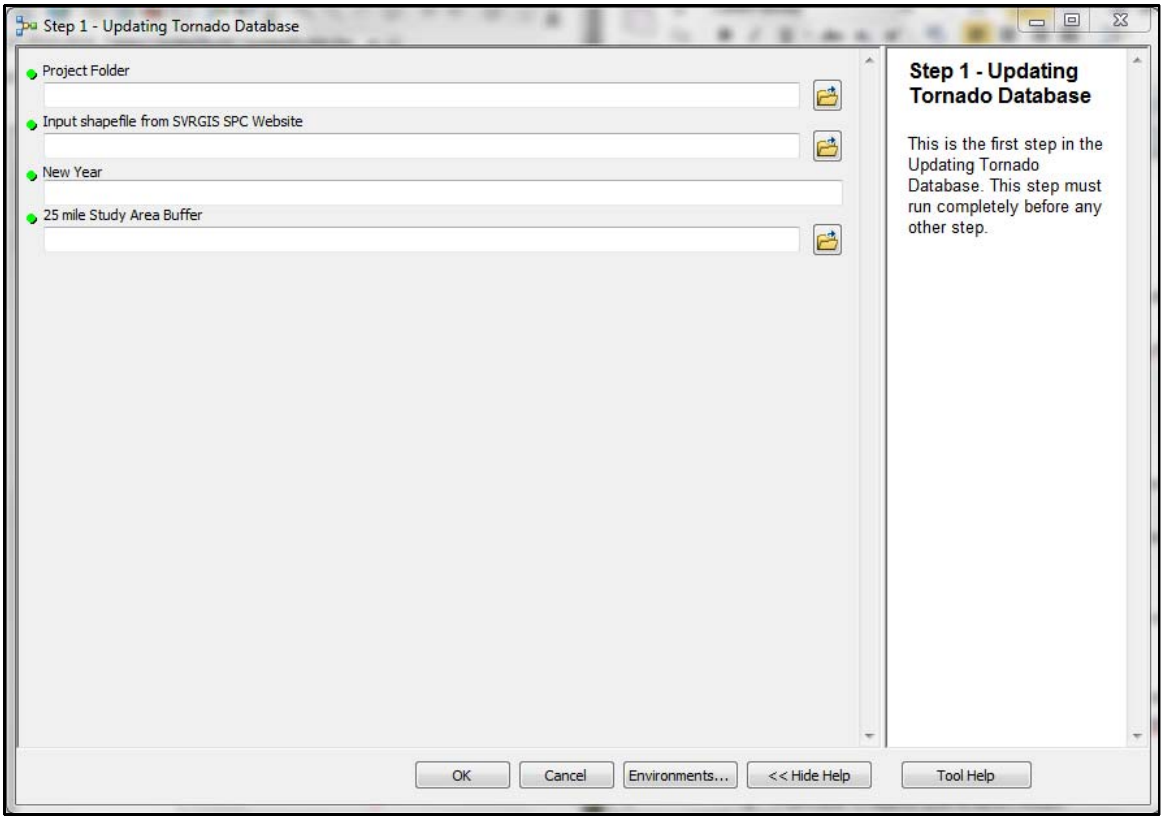


Figure 5.1. The updating process has a total of six steps.

The first task for the update process is to access the updated tornado tracks GIS shapefile from the SVRGIS SPC website, http://www.spc.noaa.gov/gis/svrgis/. This file is usually published in April of the following year. Once the file is downloaded, extracted and viewed in ArcCatalog, the automated updating process can start to run. These models are accessed directly in an ArcGIS toolbox. Each model requires the user to set various parameters before the model is executed. These values are explained in the Help dialogue that appears when the model is opened.

The first model in the toolbox is called Step 1 – Updating Tornado Database. There are four parameters that need to be set for the model to run correctly. The first parameter is the name of the Project Folder. For this, the user selects a current folder or creates a new folder to house all files that will be created and required during the update process. The second parameter is the name of the SVRGIS SPC tornado tracks GIS shapefile. The user simply navigates to this file and selects it to populate the parameter field. The third parameter is the New Year value. Here, the user types the year for which the update is to be added. The dataset is current through 2010. The final parameter is the value for the radius of the buffer. The default is a 25-mile study area buffer. This is a feature class in the current tornado database, and the user can navigate to and select it. Once each parameter is filled in the user can run the model (figure 5.2). The model runs numerous processes in the background that the end user does not see (figure 5.3).



Step 1 - Updating Tornado Database

This is the first step in the Updating Tornado Database. This step must run completely before any other step.

Figure 5.2. The first step in the updating process. Each parameter has an explanation for user-guided assistance.

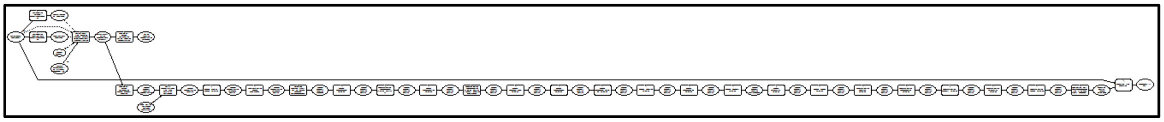


Figure 5.3(a). Background diagram of the multiple processes that run during the Step 1 model. A total of 28 processes run.

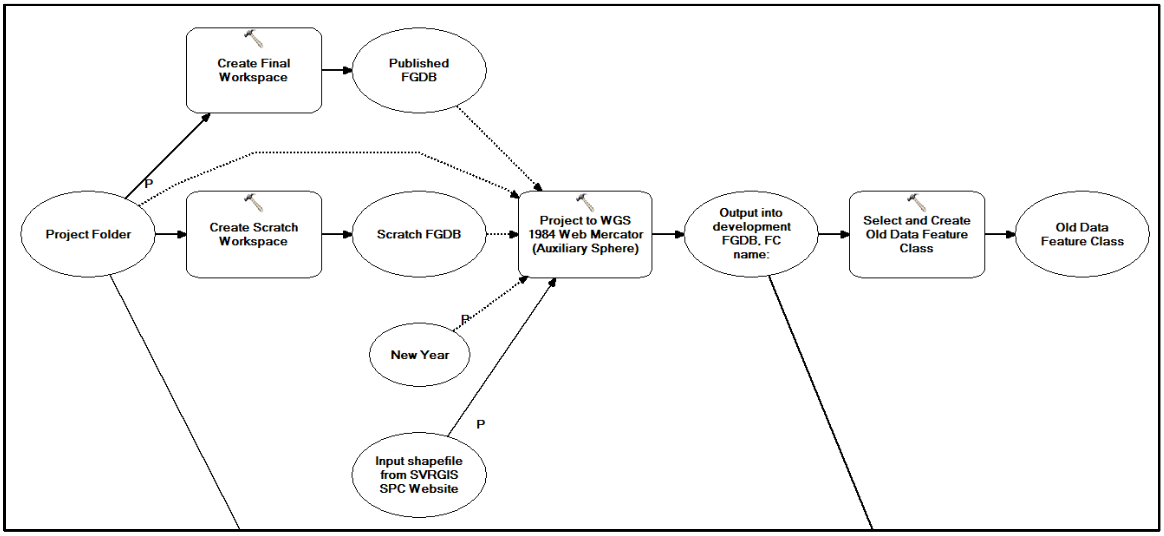


Figure 5.3(b). The first part of the model creates the final and scratch workspace for the updating process. Also, this section of the model creates a copy of the current data on the website.

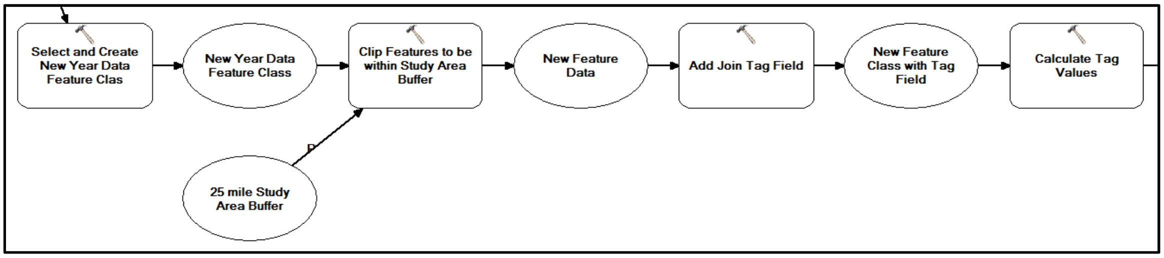


Figure 5.3(b). The second part of the model selects the new year data and prepares it to be joinable with the updated data that is calculated outside of ArcGIS.

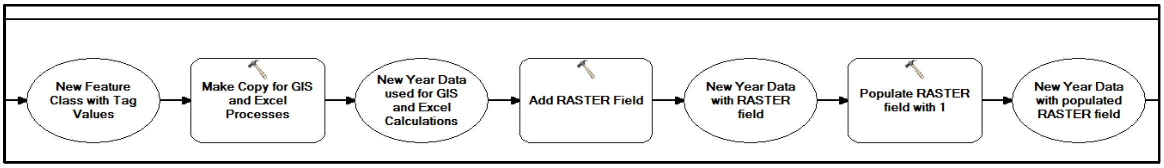


Figure 5.3(c). The third part of the model creates a copy of the data for the updating processes in Excel and begins to add fields that will be calculated.

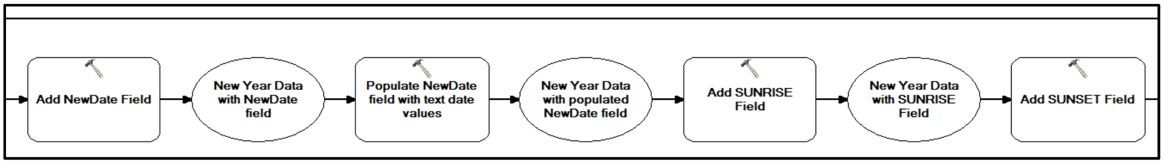


Figure 5.3(d). The fourth part of the model continues to add needed fields.

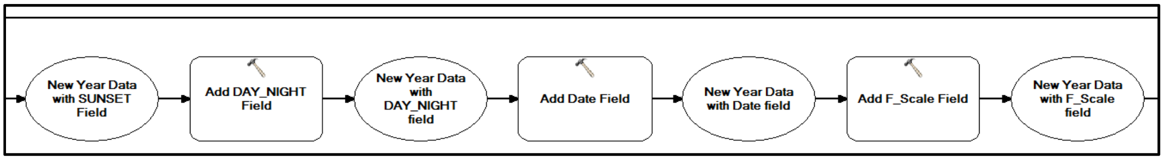


Figure 5.3(e). The fifth part of the model continues to add needed fields.

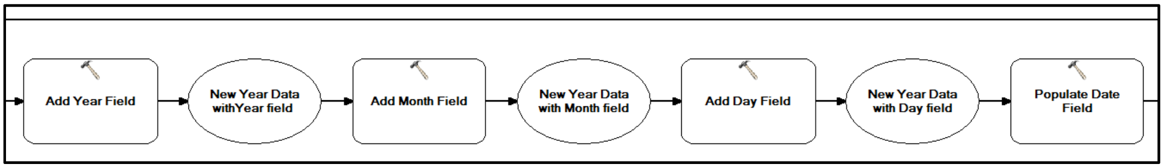


Figure 5.3(f). The sixth part of the model continues to add needed fields and begins to calculate some of those fields.

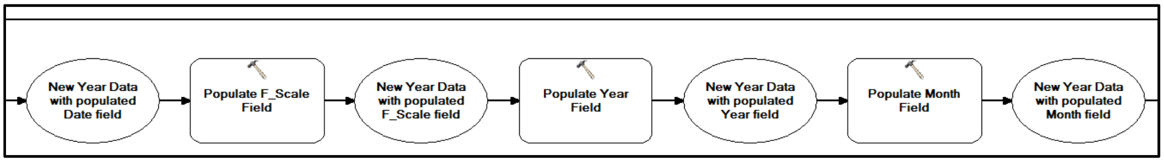


Figure 5.3(g). The seventh part of the model continues to calculate some of the added fields.

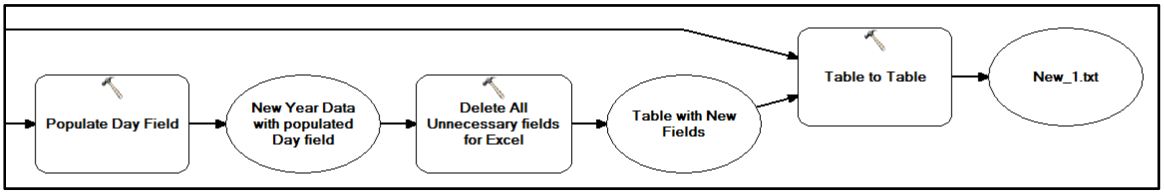
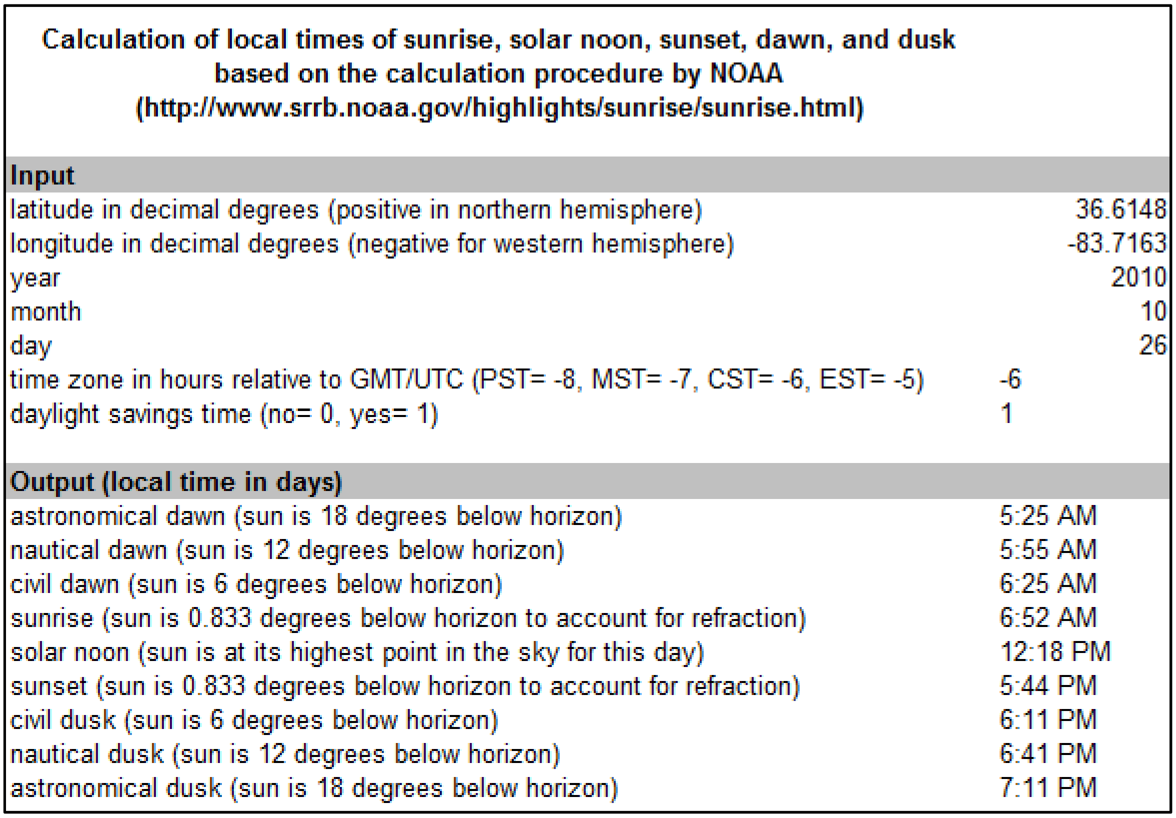


Figure 5.3(h). The eighth part of the model populates the remaining fields, deletes unneeded fields and exports a text file table in a comma-separated format (CSV).

The next process to run is a set of preconfigured macros. The purpose of the macros is to automate the Excel updating process. The macros are written in Visual Basic for Applications and run in Microsoft Excel (Microsoft Office 2010). The first step is to load the twilight.xls spreadsheet in Excel. This spreadsheet was created by Greg Pelletier (2002), and was created to calculate solar position, sunrise and sunset times for a specific location on the planet for any day in history. The spreadsheet has multiple preconfigured functions which calculate these values with great accuracy (figure 5.4).

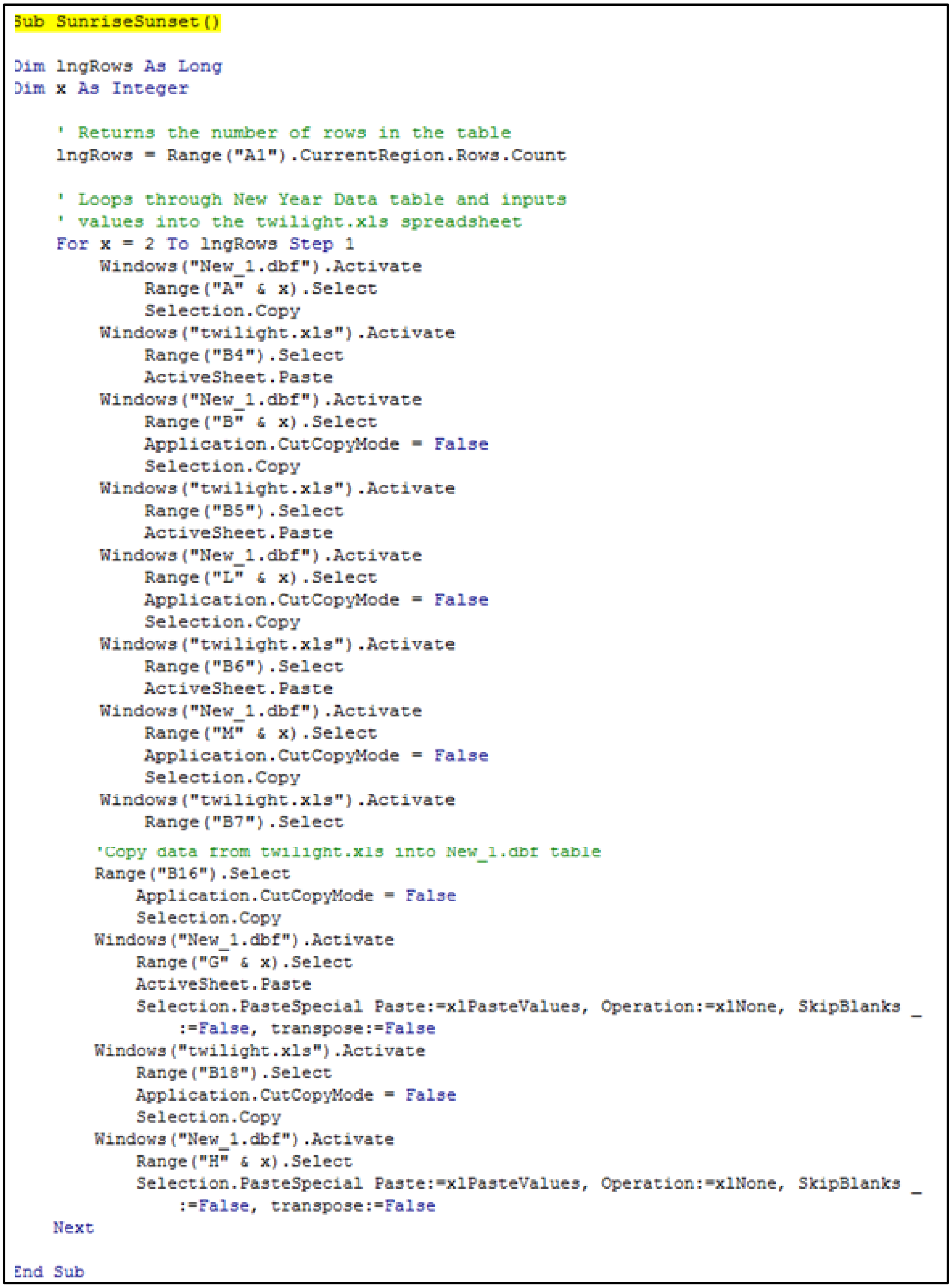


Calculation of local times of sunrise, solar noon, sunset, dawn, and dusk
based on the calculation procedure by NOAA
(http://www.srrb.noaa.gov/highlights/sunrise/sunrise.html)

Input	
latitude in decimal degrees (positive in northern hemisphere)	36.6148
longitude in decimal degrees (negative for western hemisphere)	-83.7163
year	2010
month	10
day	26
time zone in hours relative to GMT/UTC (PST= -8, MST= -7, CST= -6, EST= -5)	-6
daylight savings time (no= 0, yes= 1)	1
Output (local time in days)	
astronomical dawn (sun is 18 degrees below horizon)	5:25 AM
nautical dawn (sun is 12 degrees below horizon)	5:55 AM
civil dawn (sun is 6 degrees below horizon)	6:25 AM
sunrise (sun is 0.833 degrees below horizon to account for refraction)	6:52 AM
solar noon (sun is at its highest point in the sky for this day)	12:18 PM
sunset (sun is 0.833 degrees below horizon to account for refraction)	5:44 PM
civil dusk (sun is 6 degrees below horizon)	6:11 PM
nautical dusk (sun is 12 degrees below horizon)	6:41 PM
astronomical dusk (sun is 18 degrees below horizon)	7:11 PM

Figure 5.4. The twilight.xls spreadsheet lets the user input the variables on top and calculate the array of solar values.

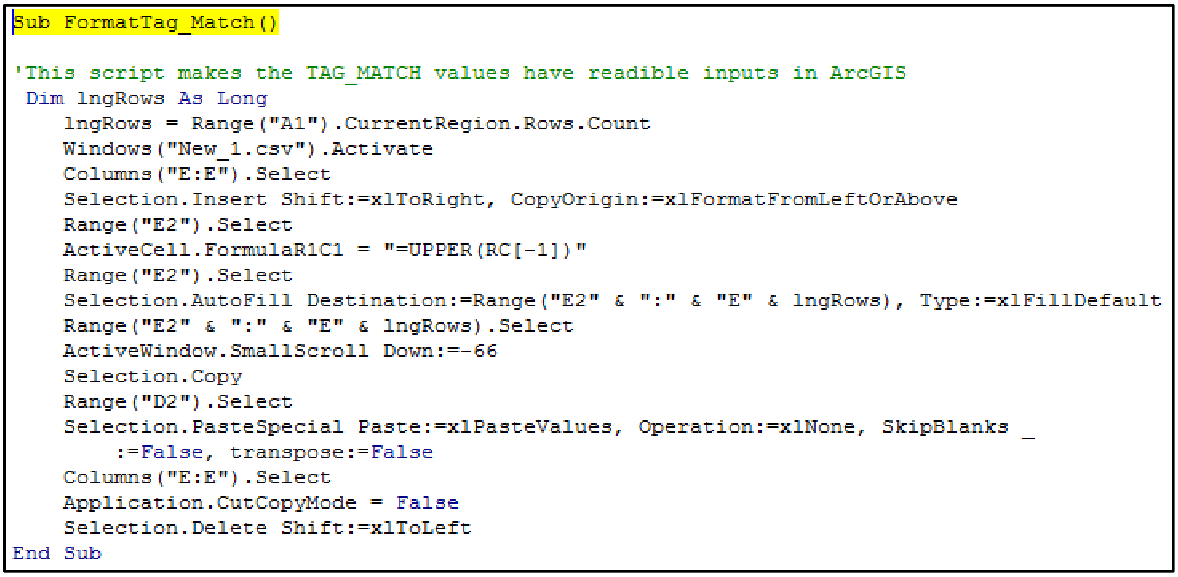
Although the twilight tool is very useful, manually inputting all of the data needed would be time consuming. To expedite this process, macros were written to read the data from another spreadsheet and calculate the values for each tornado track in the dataset (figure 5.5). The table of tornado tracks is created as a database table (.dbf) and is called New_1.dbf. When the first model completes, this file will be located in the project folder.



```
Sub SunriseSunset()

Dim lngRows As Long
Dim x As Integer

    ' Returns the number of rows in the table
    lngRows = Range("A1").CurrentRegion.Rows.Count

    ' Loops through New Year Data table and inputs
    ' values into the twilight.xls spreadsheet
    For x = 2 To lngRows Step 1
        Windows("New_1.dbf").Activate
            Range("A" & x).Select
            Selection.Copy
        Windows("twilight.xls").Activate
            Range("B4").Select
            ActiveSheet.Paste
        Windows("New_1.dbf").Activate
            Range("B" & x).Select
            Application.CutCopyMode = False
            Selection.Copy
        Windows("twilight.xls").Activate
            Range("B5").Select
            ActiveSheet.Paste
        Windows("New_1.dbf").Activate
            Range("L" & x).Select
            Application.CutCopyMode = False
            Selection.Copy
        Windows("twilight.xls").Activate
            Range("B6").Select
            ActiveSheet.Paste
        Windows("New_1.dbf").Activate
            Range("M" & x).Select
            Application.CutCopyMode = False
            Selection.Copy
        Windows("twilight.xls").Activate
            Range("B7").Select
        'Copy data from twilight.xls into New_1.dbf table
        Range("B16").Select
            Application.CutCopyMode = False
            Selection.Copy
        Windows("New_1.dbf").Activate
            Range("G" & x).Select
            ActiveSheet.Paste
            Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
                :=False, transpose:=False
        Windows("twilight.xls").Activate
            Range("B18").Select
            Application.CutCopyMode = False
            Selection.Copy
        Windows("New_1.dbf").Activate
            Range("H" & x).Select
            Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
                :=False, transpose:=False
    Next

End Sub
```

Figure 5.5. The SunriseSunset macro automates the process of filling in the twilight spreadsheet.

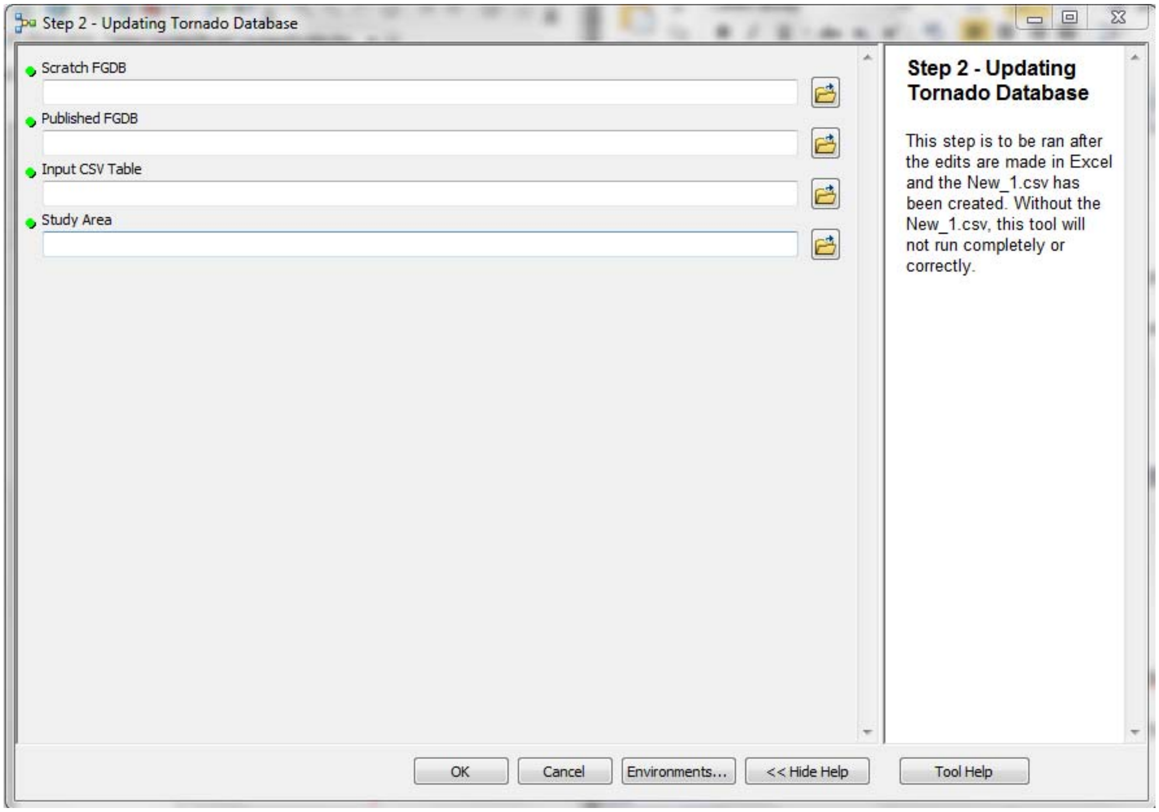
After the macro runs the user needs to run the FormatTagMatch.bas module which is a macro that formats the sunrise and sunset values to work in ArcGIS (figure 5.6). When this macro finishes, the user just needs to save the file as a comma-separated value (.csv) with the same name (New_1) in the project folder.



```
Sub FormatTag_Match()

'This script makes the TAG_MATCH values have readible inputs in ArcGIS
 Dim lngRows As Long
    lngRows = Range("A1").CurrentRegion.Rows.Count
    Windows("New_1.csv").Activate
    Columns("E:E").Select
    Selection.Insert Shift:=xlToRight, CopyOrigin:=xlFormatFromLeftOrAbove
    Range("E2").Select
    ActiveCell.FormulaR1C1 = "=UPPER(RC[-1])"
    Range("E2").Select
    Selection.AutoFill Destination:=Range("E2" & ":" & "E" & lngRows), Type:=xlFillDefault
    Range("E2" & ":" & "E" & lngRows).Select
    ActiveWindow.SmallScroll Down:=-66
    Selection.Copy
    Range("D2").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, transpose:=False
    Columns("E:E").Select
    Application.CutCopyMode = False
    Selection.Delete Shift:=xlToLeft
End Sub
```

Figure 5.6. The FormatTagMatch macro formats the time values to decimals which work better in ArcGIS.

When finished in Excel, the user needs to navigate back to ArcCatalog and run the second model, Step 2 – Updating Tornado Database. This model also has four parameters that need to be set (figure 5.7). The first is the Scratch File Geodatabase. This is created in Step 1, and is located in the project folder. The second parameter is the Published File Geodatabase. This is also created in the first model, Step 1. The third parameter is the Input CSV table, which is the saved comma-separated-value table from the Excel processes. If the user used the same naming convention it should be called New_1.csv in the project folder. The final parameter is the Study Area. This can be located in the original 2010_Tornado_Database File Geodatabase. Once the parameters are set, the model can run. Like the first model, the second model also runs multiple processes in the background (figure 5.8).



Step 2 - Updating Tornado Database

This step is to be ran after the edits are made in Excel and the New_1.csv has been created. Without the New_1.csv, this tool will not run completely or correctly.

Figure 5.7. The second model, Step 2.

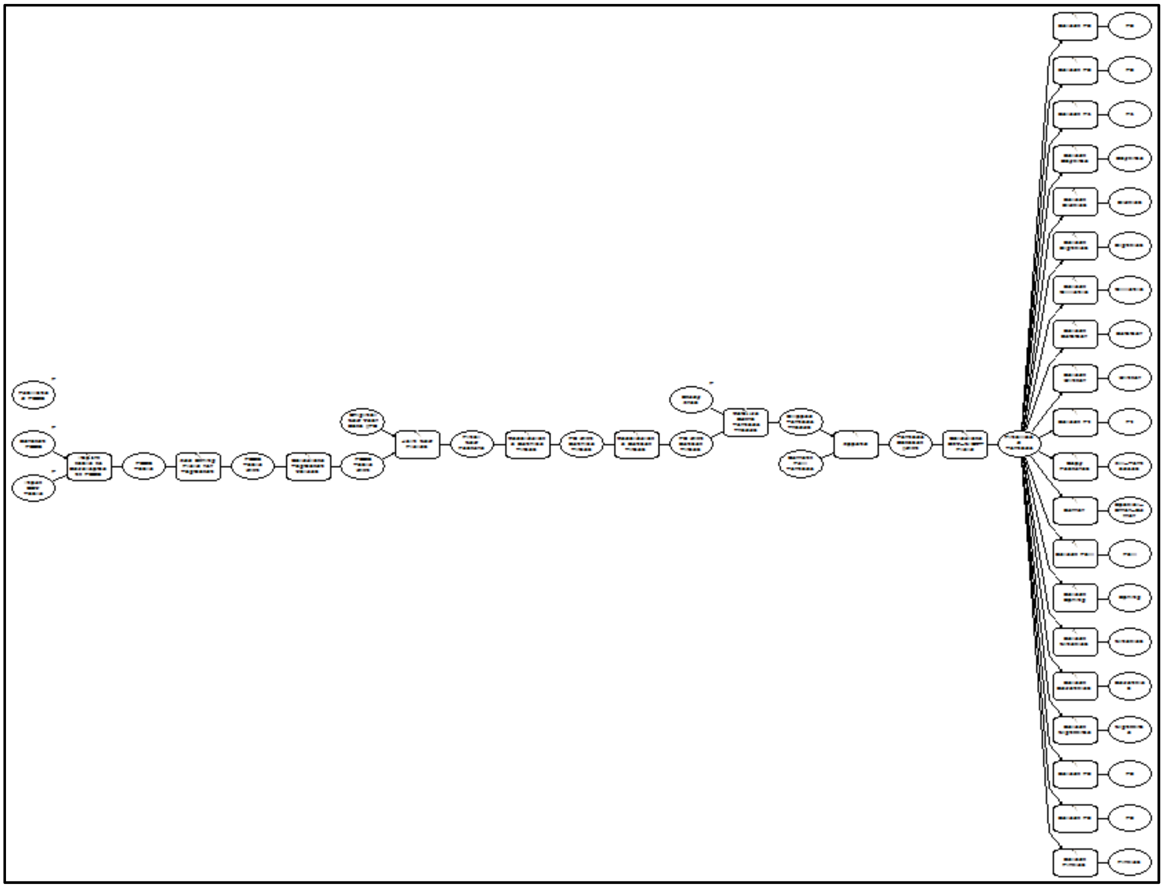


Figure 5.8(a). The background processes for the Step 2 model. There are a total of 30 processes that run.

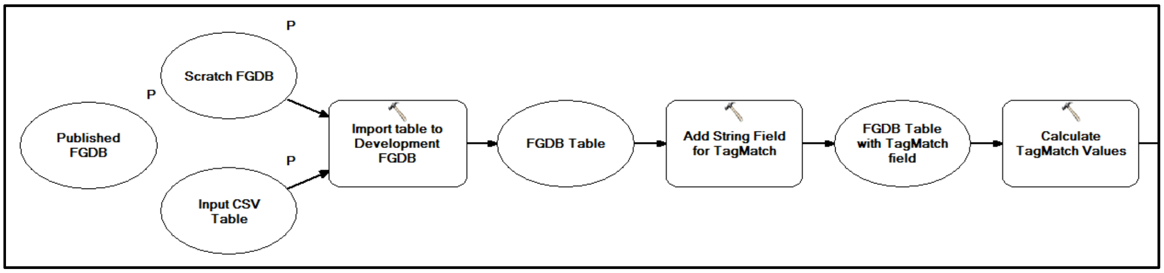


Figure 5.8(b). The first part of the model imports the output table from Excel and prepares it to be joined to the GIS file.

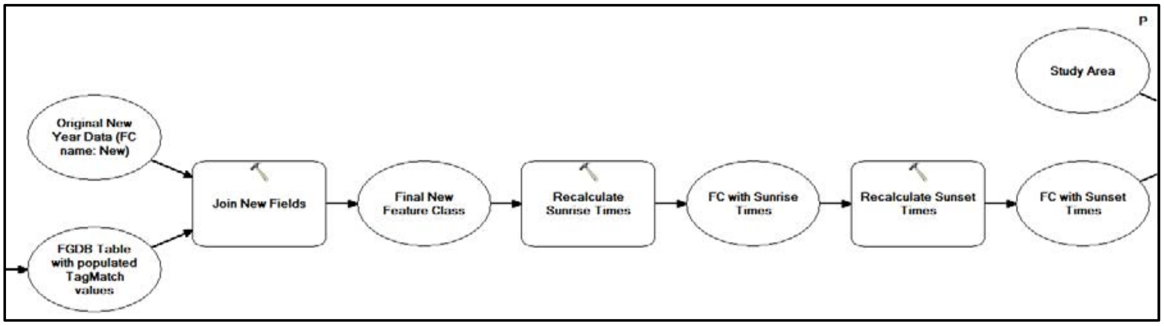


Figure 5.8(c). The second part of the model joins the output table from Excel to the GIS feature class, and then recalculates some of the values from Excel.

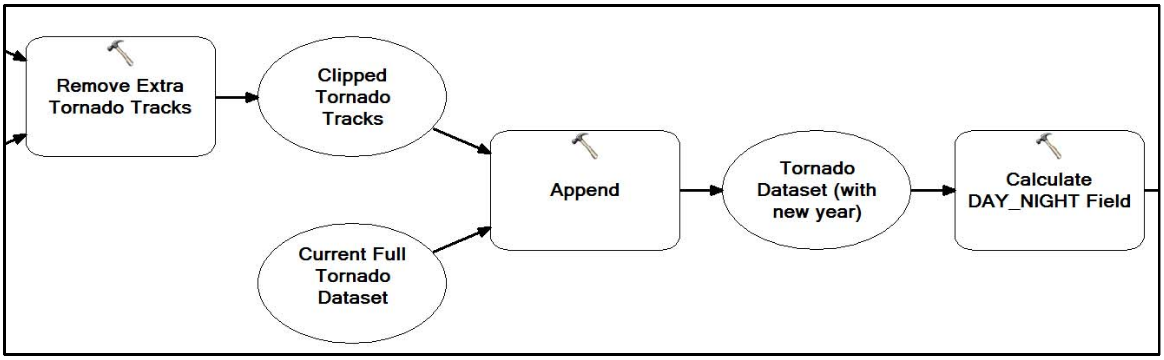


Figure 5.8(d). The third part of the model clips the tornado tracks to inside the study area, appends the records to the new year data, and calculates the last field added in the update process from the first model.

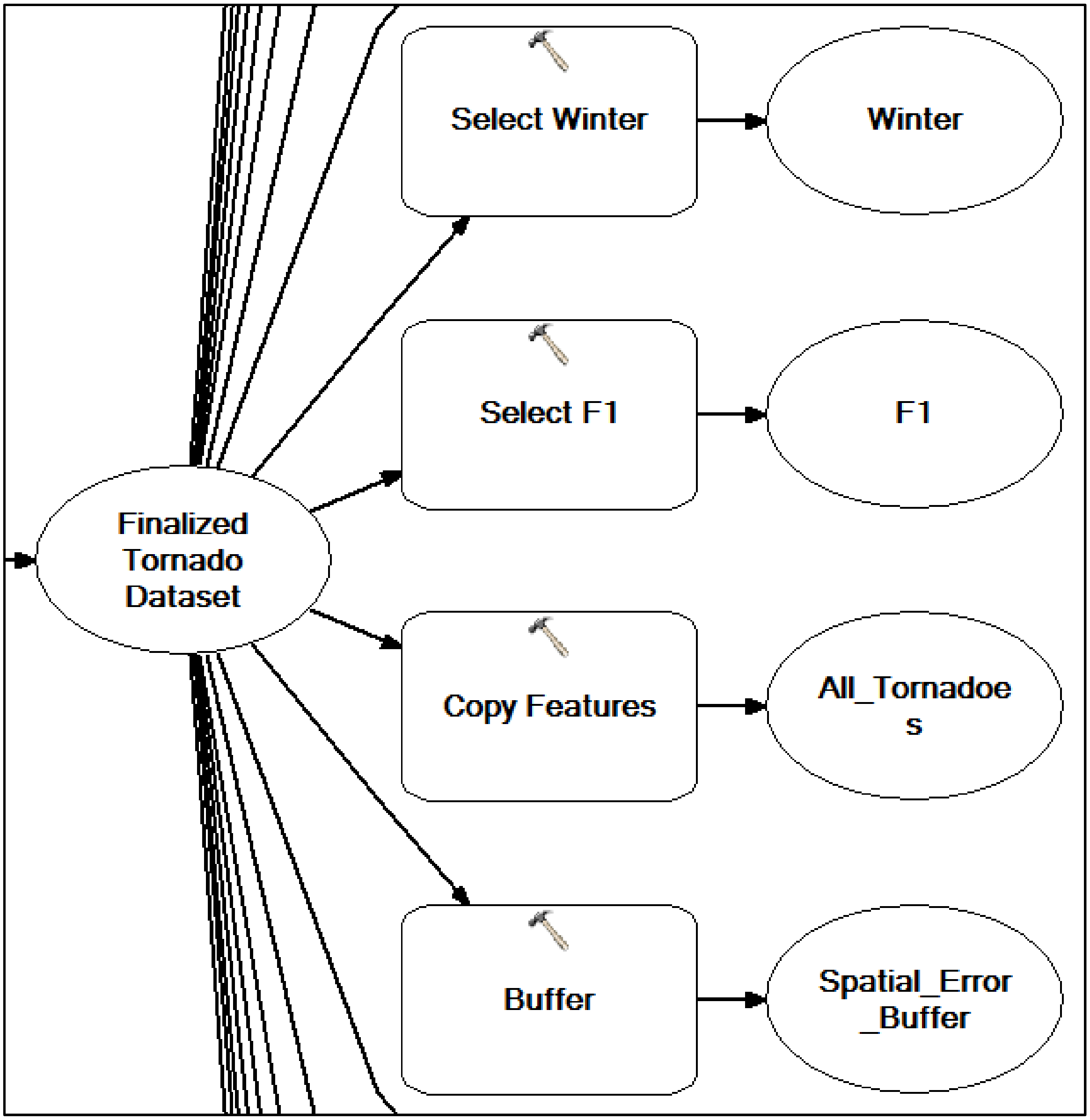


Figure 5.8(e). The fourth part of the model begins to create the individual GIS feature classes.

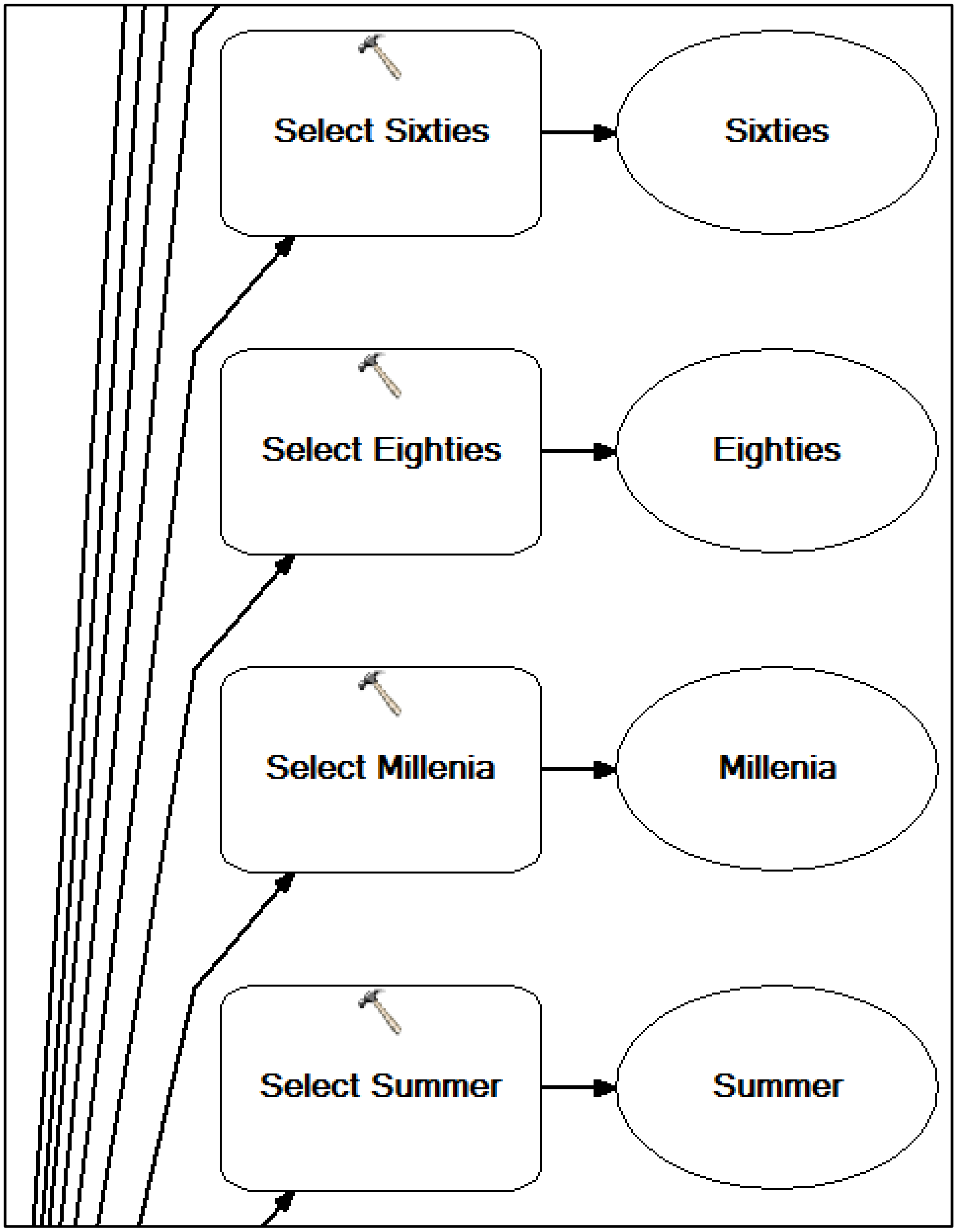


Figure 5.8(f). The fifth part of the model continues to create the GIS feature classes.

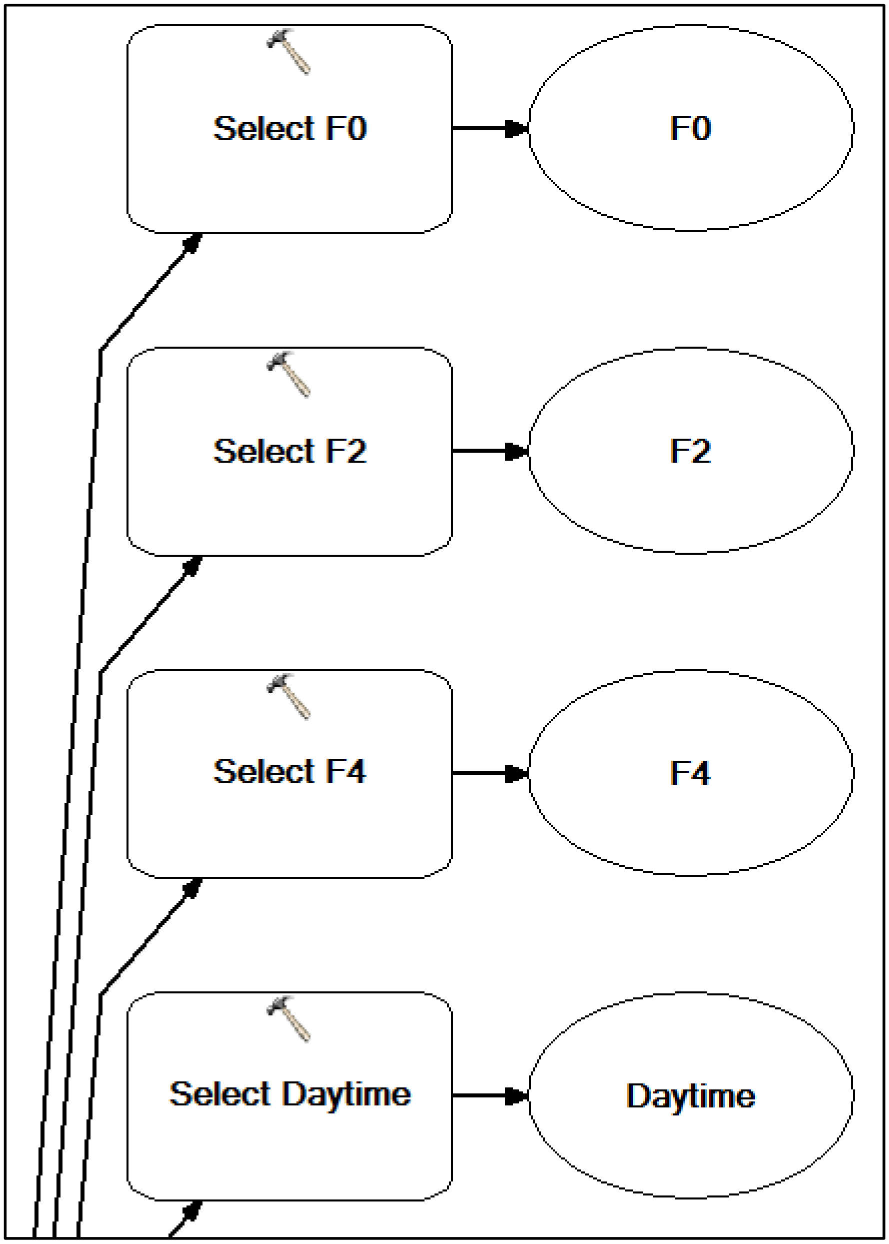


Figure 5.8(g). The sixth part of the model continues to create the GIS feature classes.

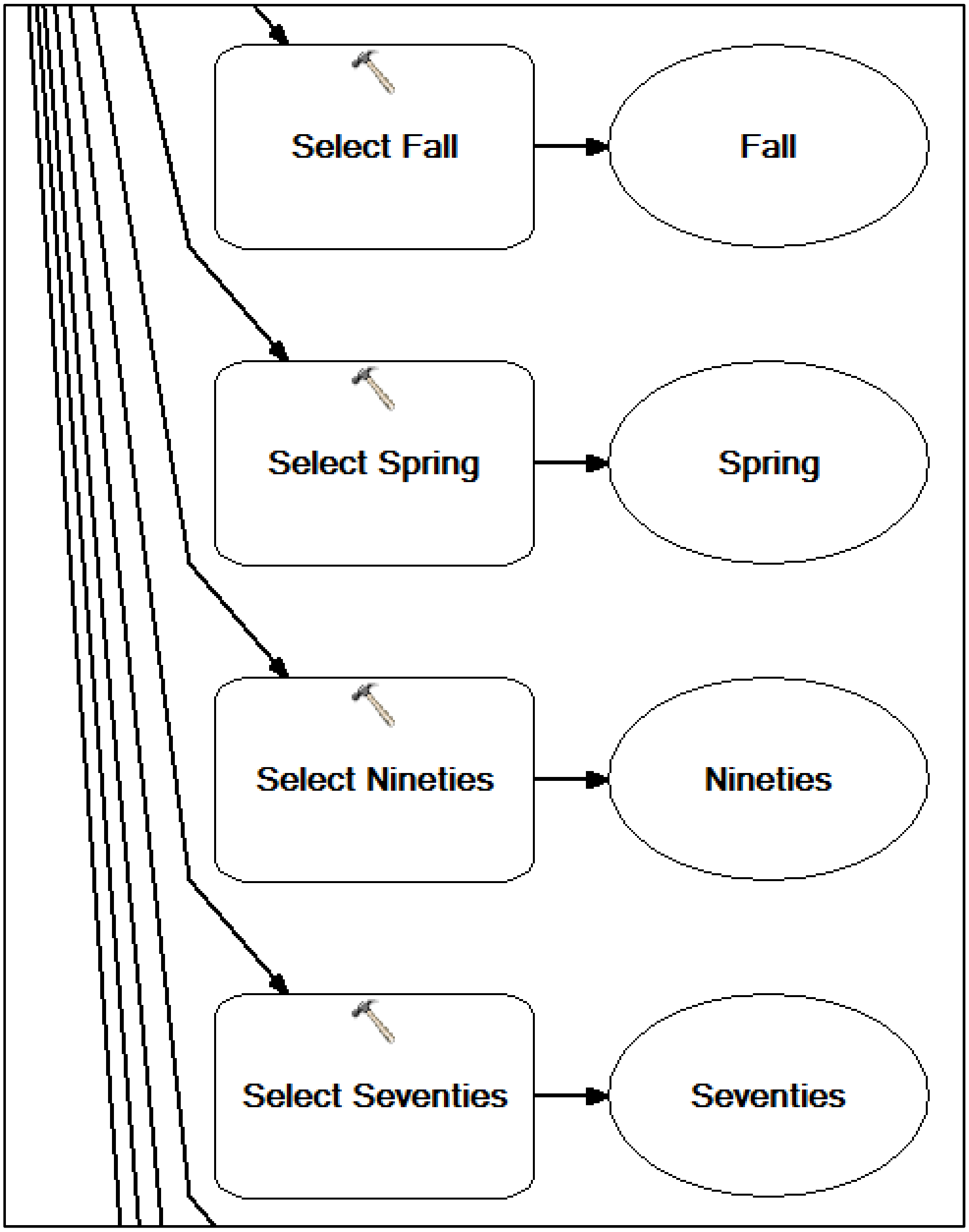


Figure 5.8(h). The seventh part of the model continues to create the GIS feature classes.

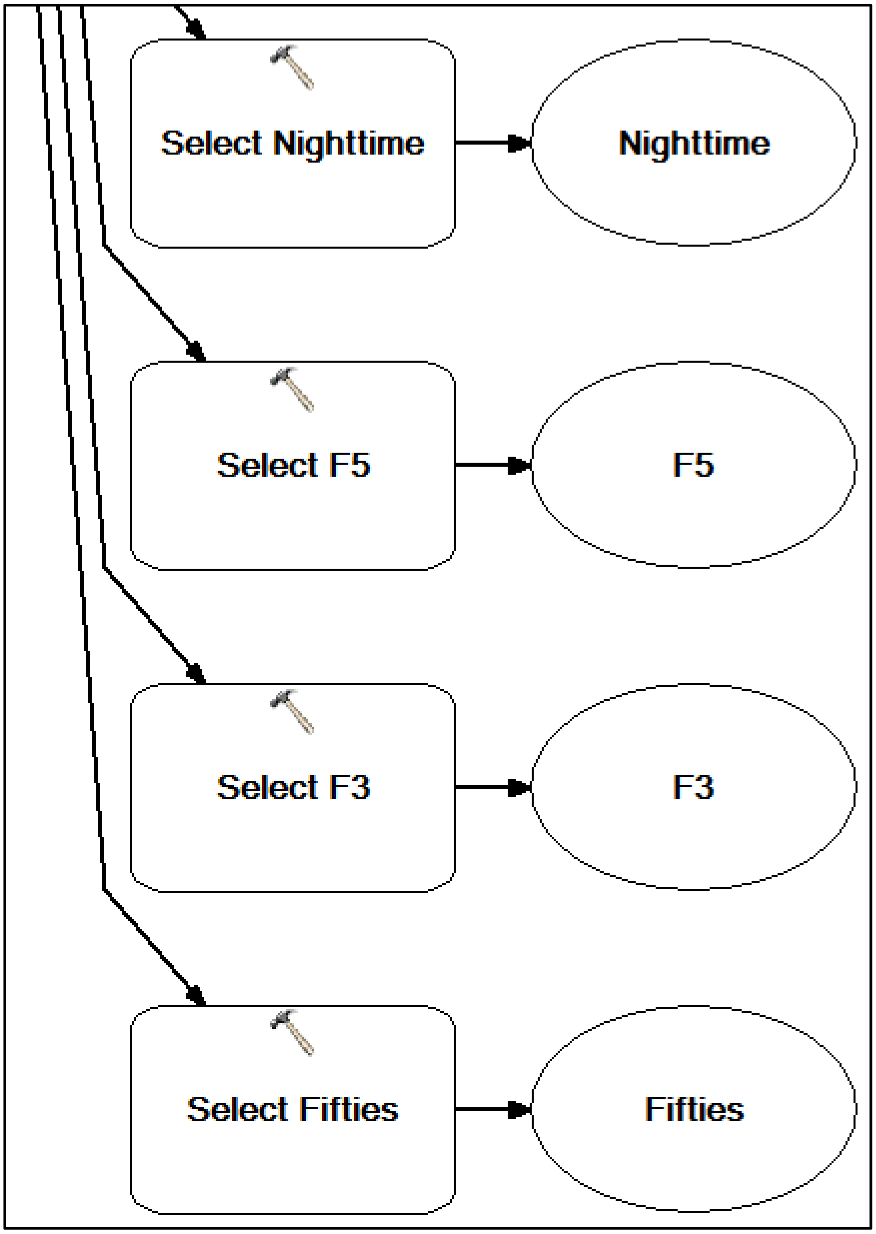
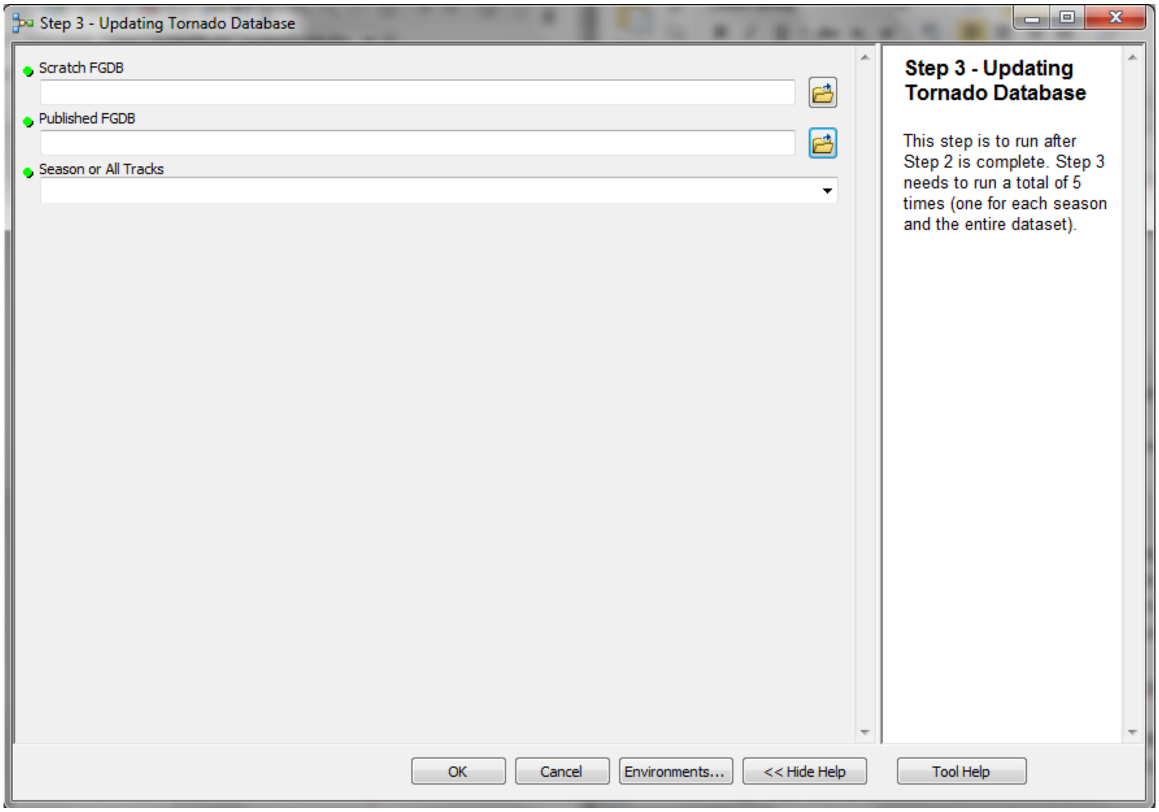


Figure 5.8(i). The eighth part of the model continues to create the GIS feature classes.

At the completion of the second model, the user needs to run the next model, Step 3 – Updating Tornado Database. The remaining models, Step 3 and Step 4 are different in that they will be run a total of five times each. Rather than creating individual models for each season and the entire dataset, it was best to create a universal model that would be used for each. Step 3 has only three parameters, the Scratch File Geodatabase, the

Published File Geodatabase, and a drop down value for the user to select which season or if the model needs to run for the entire dataset (figure 5.9). Step 3 is also the first model to run an iteration process. This iteration process loops through the entire dataset, making this step one of the most time consuming. In development tests, using a TOSHIBA laptop with an Intel® Core™ i7 processor CPU, Q720 @ 1.60 GHz and 4.00 GB RAM, the model took roughly two hours to run completely. Although the model does not have many processes, each takes a great deal of time to run (figure 5.10).



Step 3 - Updating Tornado Database

This step is to run after Step 2 is complete. Step 3 needs to run a total of 5 times (one for each season and the entire dataset).

Figure 5.9. The third model, Step 3, only has three parameters but takes much longer to run than some of the other steps due to iteration.

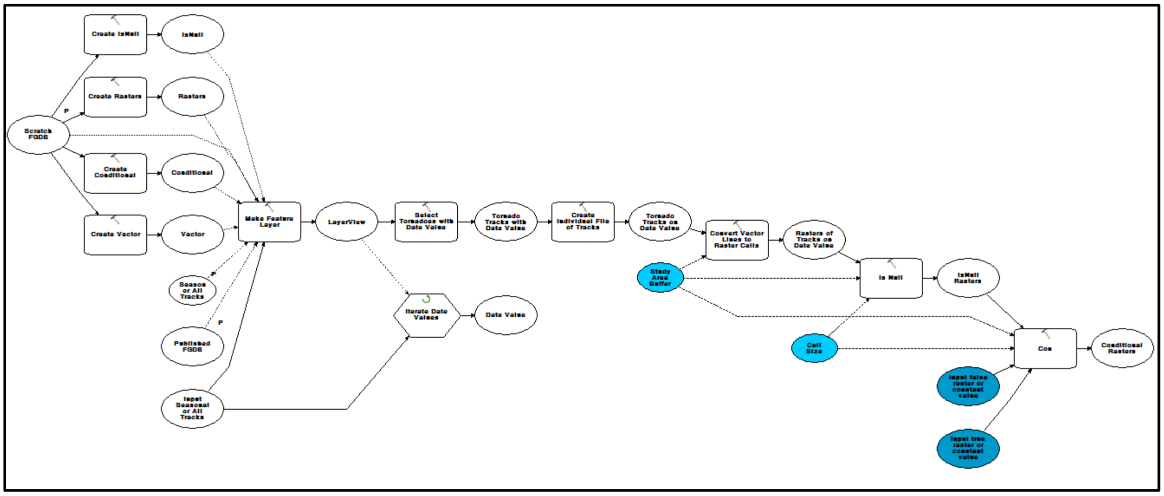


Figure 5.10(a). The background processes for the third model, Step 3. The hexagon shape is the iteration process.

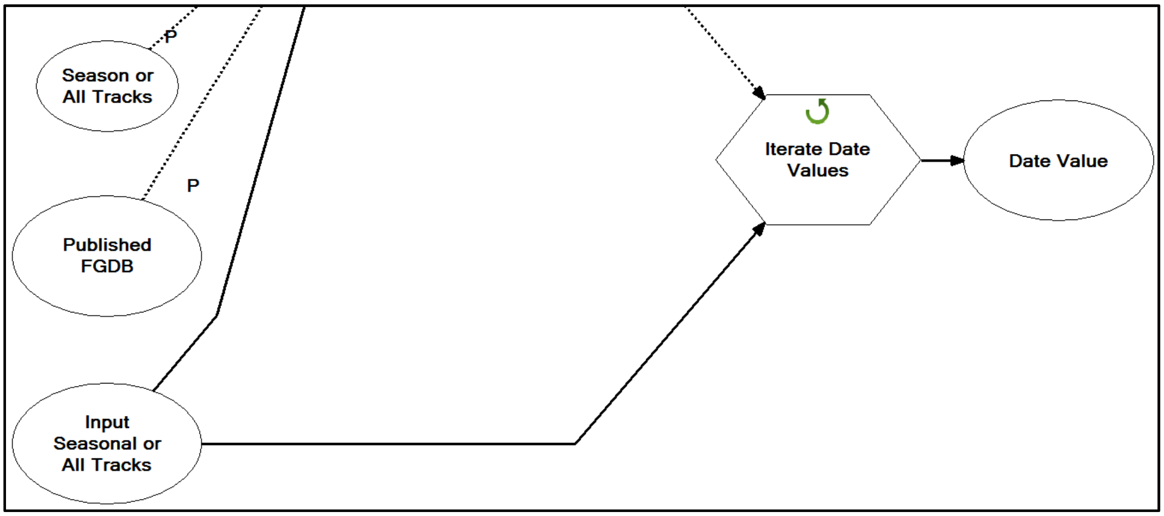


Figure 5.10(b). The first part of the model is where the iterator (hexagon) function selects the individual date values in the entire dataset.

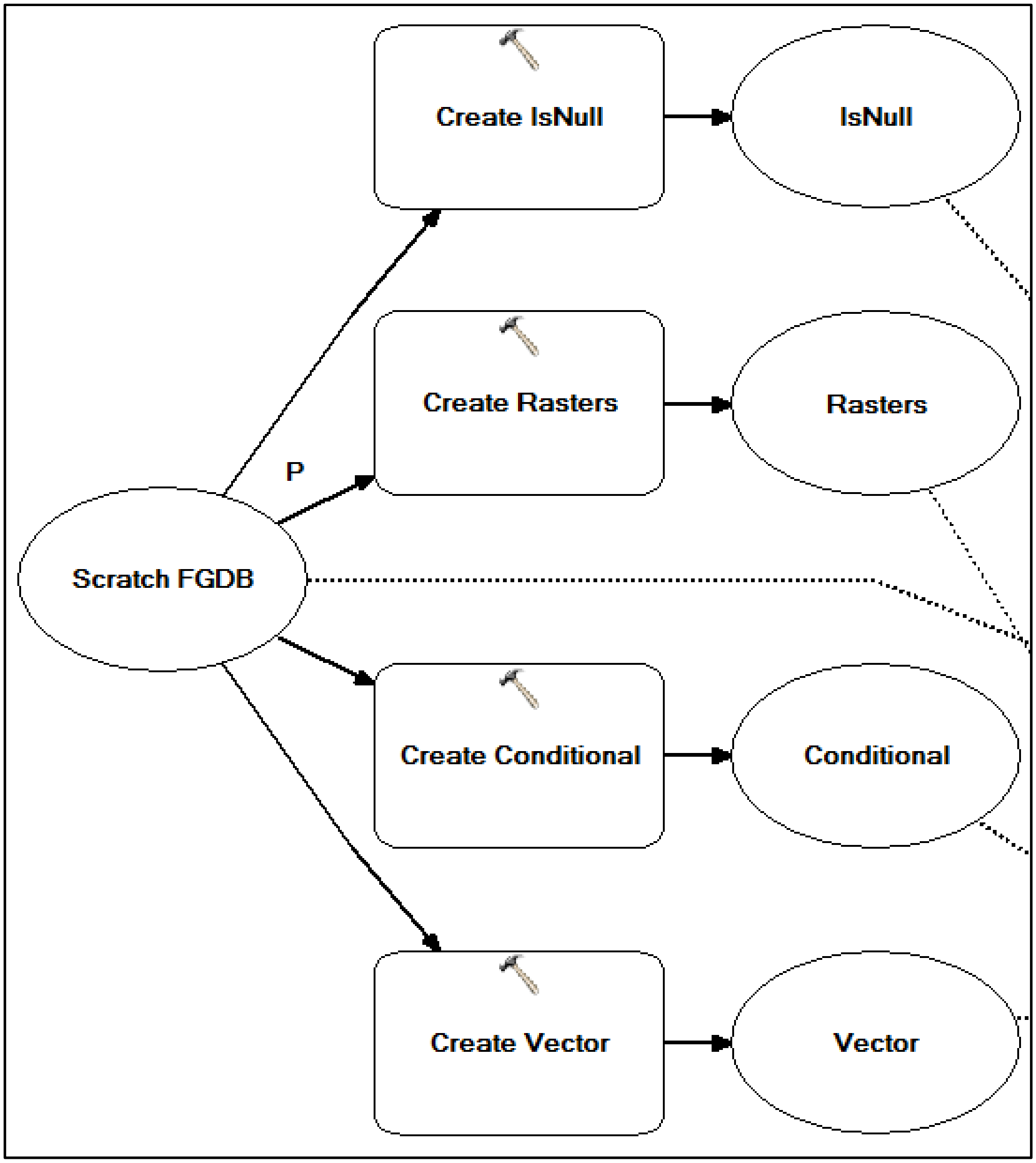


Figure 5.10(c). The second part of the model creates the four necessary GIS file locations for creating the tornado day rasters.

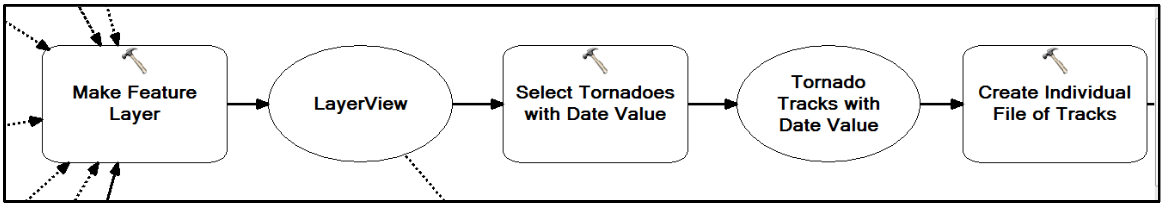


Figure 5.10(d). The third part of the model starts the tornado day selection process and creates individual GIS feature classes for the tornado day calculations.

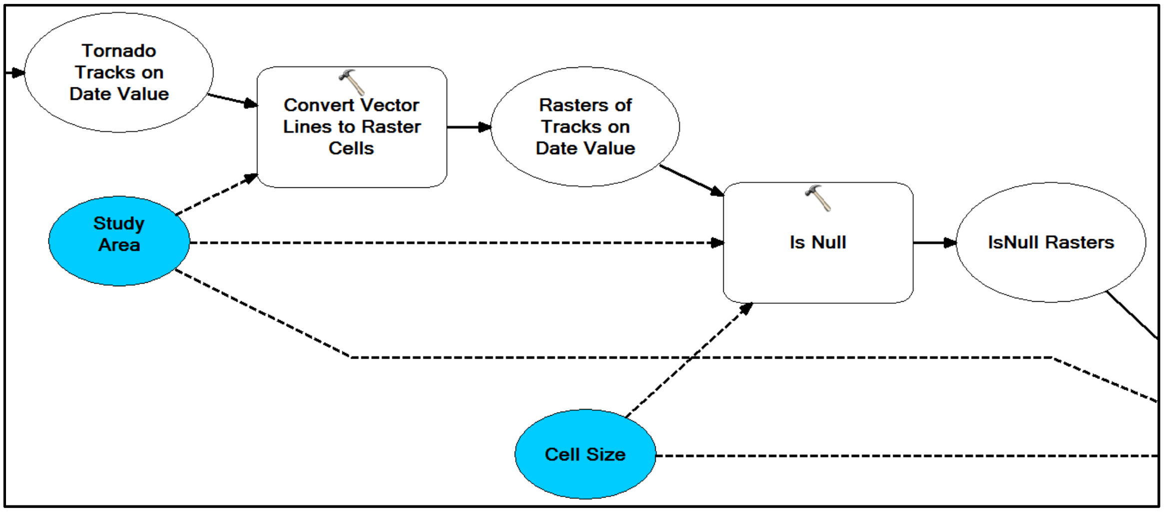


Figure 5.10(e). The fourth part of the model creates the first rasters used to calculate the tornado day values.

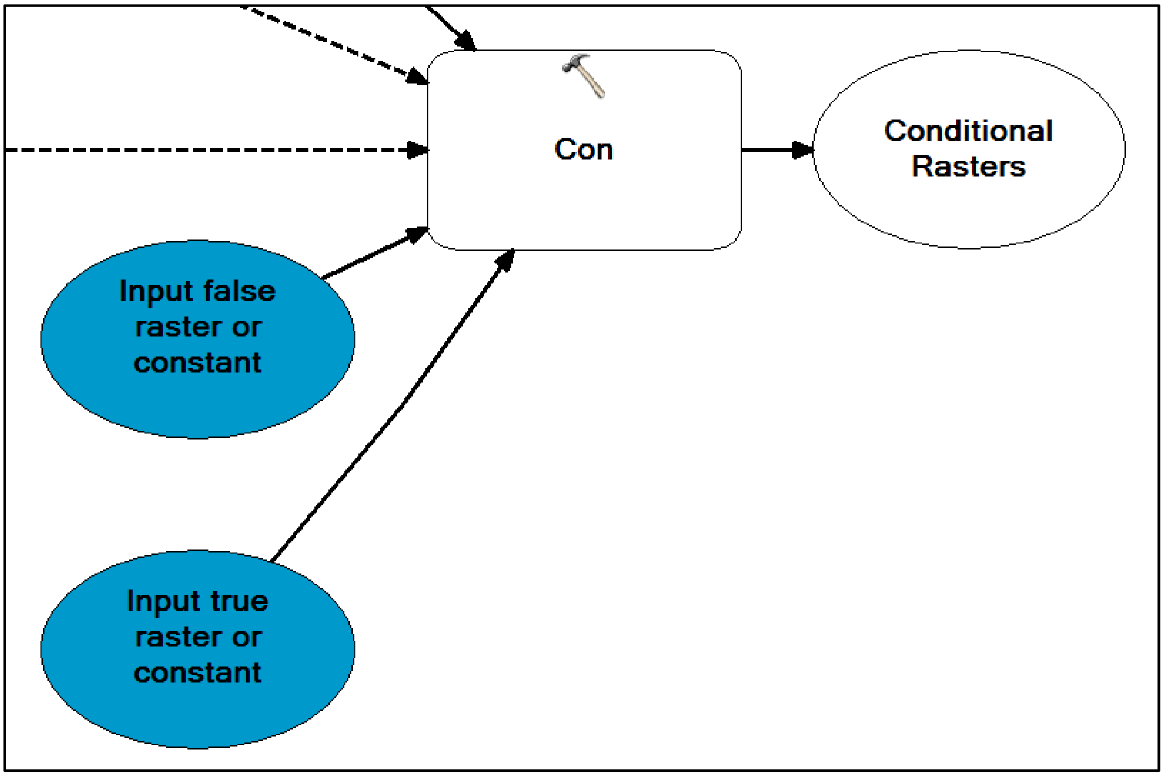
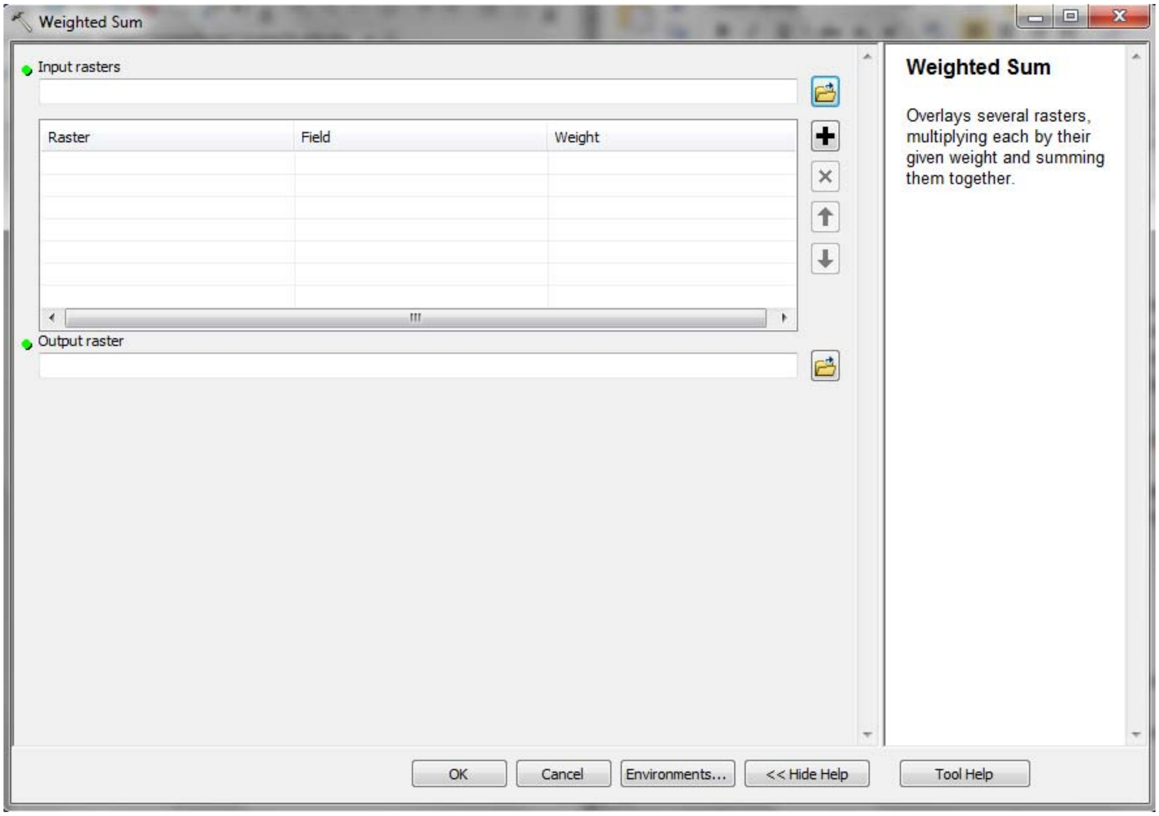


Figure 5.10(f). The fifth part of the model converts the first raster files into new rasters which have binary values; 0 for areas where no tornadoes impacted, and 1 for areas that were impacted.

Once completed, the model creates multiple raster files in a folder named Conditional. The raster names are given the same syntax but have a unique number to keep them apart. The next step of the updating process requires an ArcGIS raster analysis tool. In ArcCatalog, the user needs to navigate to the Weighted Sum tool (Master Toolbox→Spatial Analyst Tools→Overlay→Weighted Sum) (figure 5.11). This tool will sum all of the conditional rasters to create the input for the final model. The user is required to navigate to the Conditional folder, select all of the files in the folder, and specify the output raster location and name. The tool can then run and create the raster to be used in the last model.

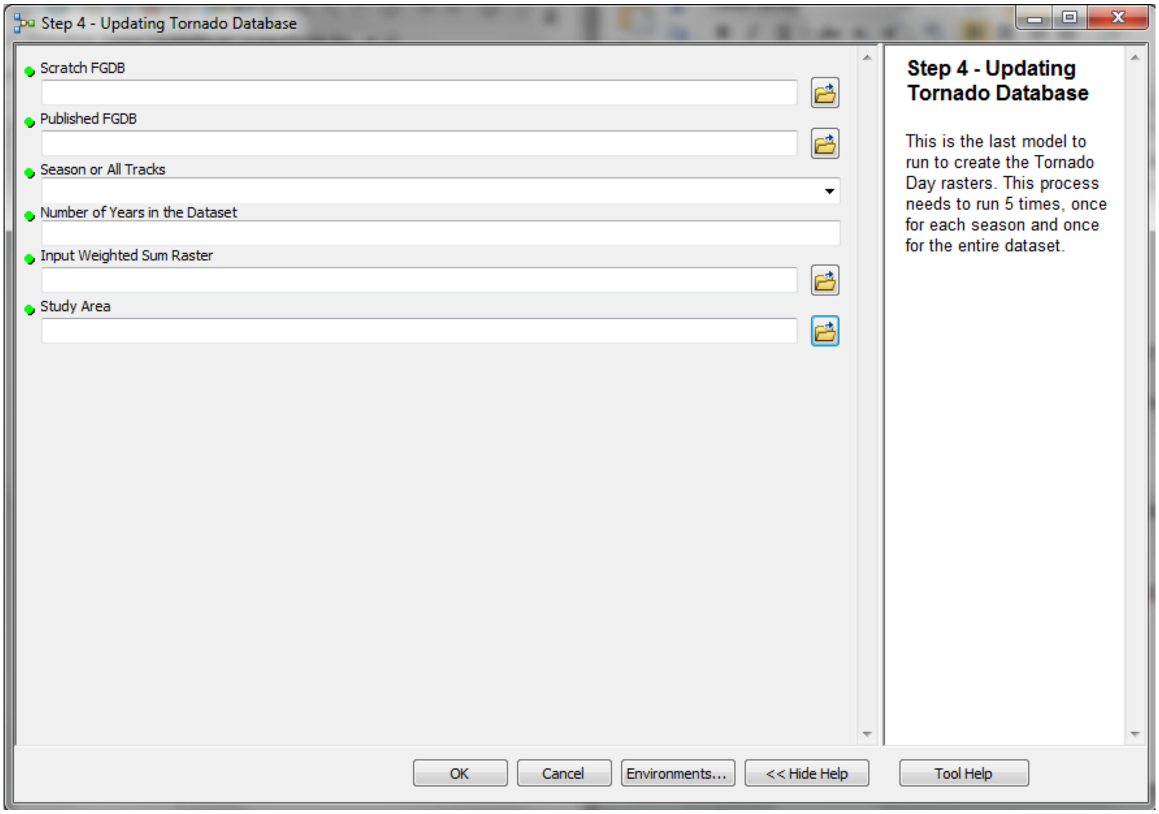


Weighted Sum

Overlays several rasters, multiplying each by their given weight and summing them together.

Figure 5.11. The Weighted Sum tool the user needs to run manually for each Conditional folder of rasters from the third model, Step 3.

The final model, Step 4 – Updating Tornado Database, also runs an iteration process which takes approximately two hours to finish. As with the previous model, this one needs to run a total of five times. There are six parameters that need to be set prior to running the model. The first parameter is the Scratch File Geodatabase. The second parameter is the Published File Geodatabase. The third parameter is the drop down list the user chooses either a season or “All” for the entire dataset. The fourth parameter is the number of years in the dataset. As of 2010, there were 61 years in the dataset (61 years between 1950 and 2010). The fifth parameter is the output weighted sum raster from the third model. Finally, the last parameter is the Study Area feature class (figure 5.12). The last model has the least amount of processes but takes the longest to run because of the iteration process (figure 5.13).



Step 4 - Updating Tornado Database

This is the last model to run to create the Tornado Day rasters. This process needs to run 5 times, once for each season and once for the entire dataset.

Figure 5.12. The last model, Step 4, for updating the tornado database.

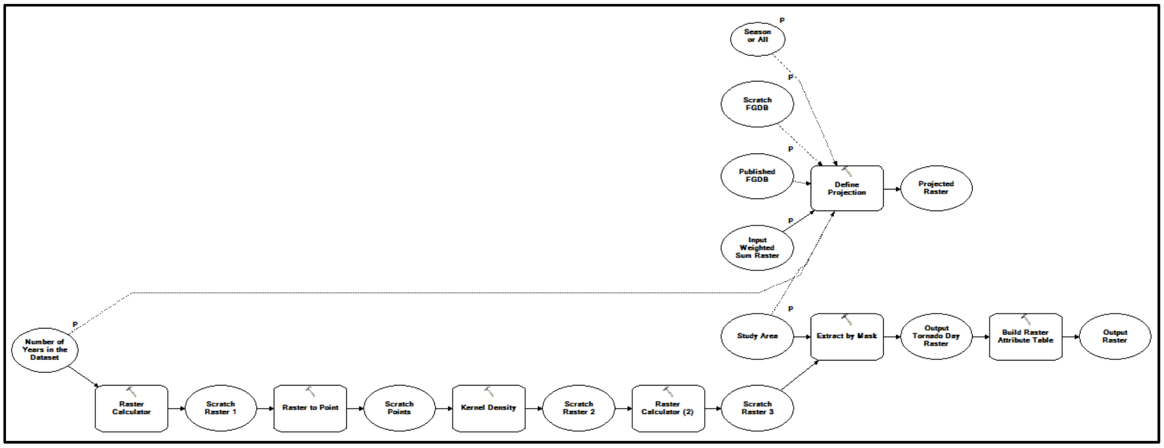


Figure 5.13(a). The background processes for the final model, Step 4.

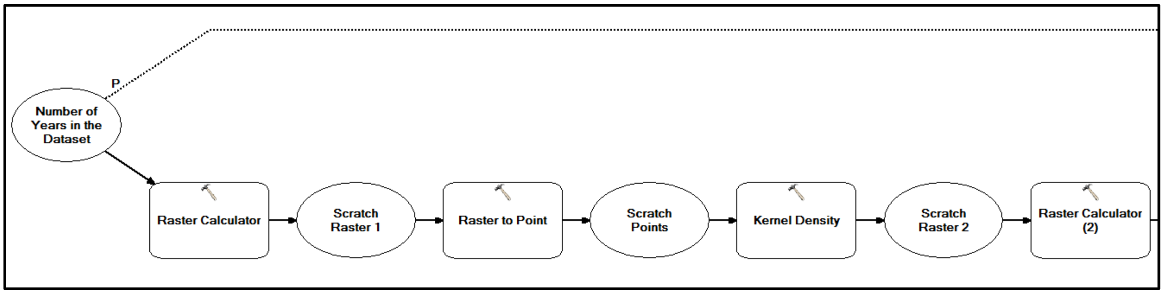


Figure 5.13(b). The first step in the model takes the output of the Weighted Sum tool, converts the rasters to points, and calculates the Kernel Density of the points.

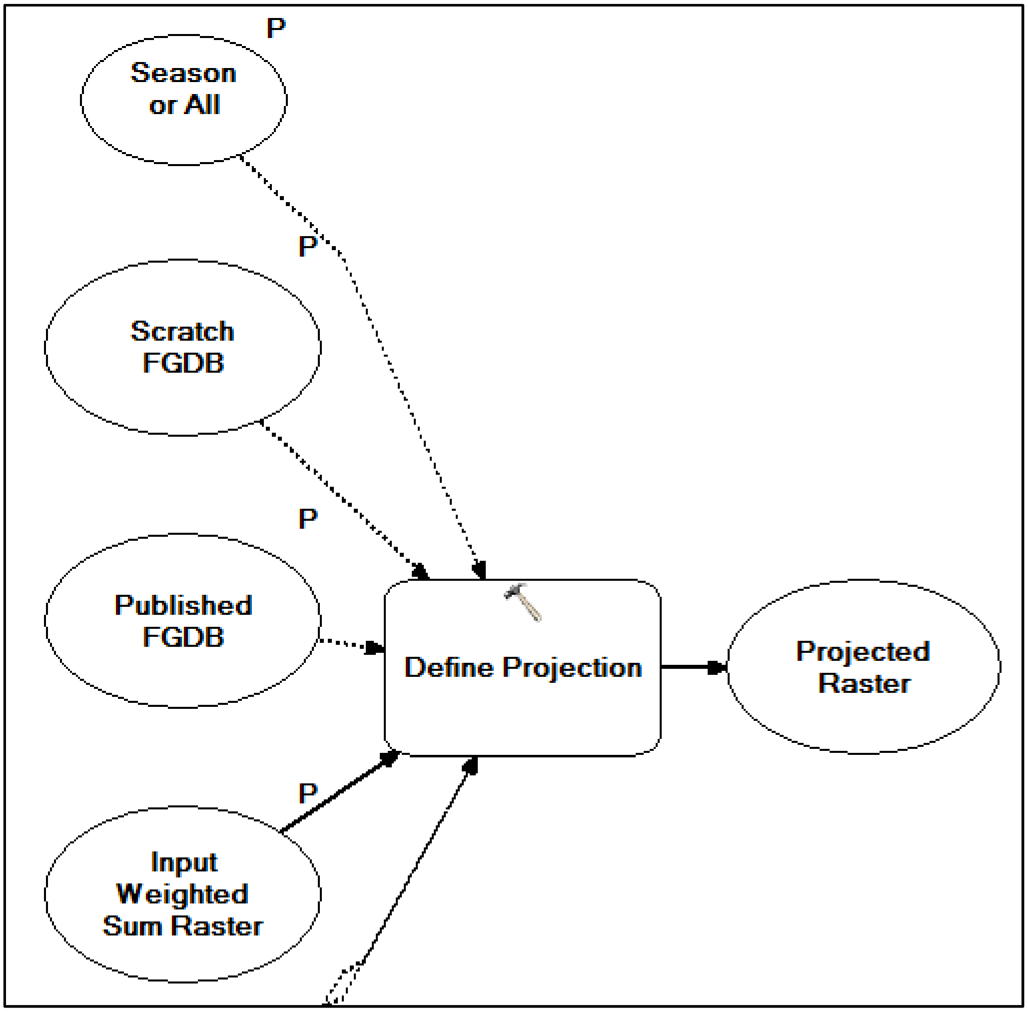


Figure 5.13(c). The second step in the model gives the rasters a spatial reference.

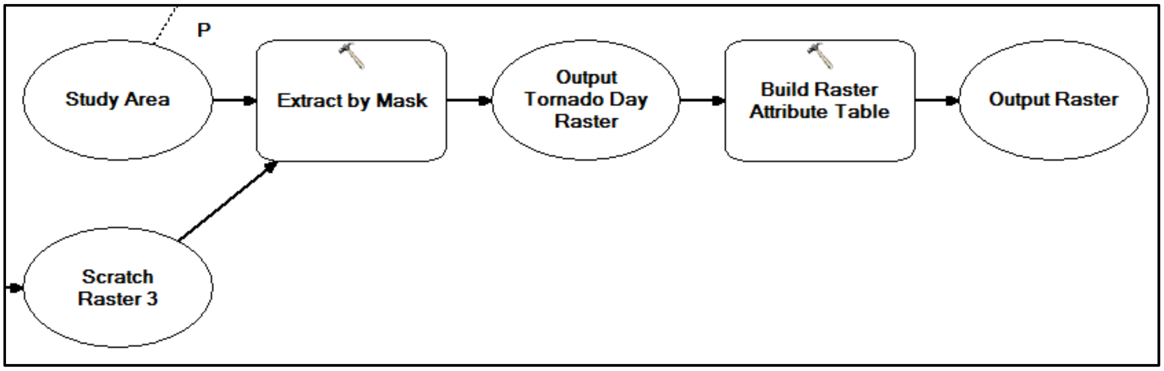


Figure 5.13(d). The third step in the model clips the rasters to the study area and creates an attribute table of the raster values.

Collectively, the updating process should take six to eight hours with many of the processes being automated. When complete, all of the data will be located in the Published File Geodatabase and be ready to be published for the website.

CHAPTER 6

CONCLUSIONS

6.1 – Conclusion

In summary, the SDSS created to assess the risk of tornadoes in and around the state of Kentucky is a valuable tool for a range of stakeholders including emergency management agencies, public safety officials, and the general public. By creating a sophisticated Internet-based GIS application, users can extract valuable information that would otherwise not be available. The website is housed on a Western Kentucky University server, and can be accessed at the following web address: http://gisapps.wku.edu/kentuckytornadoes. To view the website, Adobe Flash Player 10 must be installed.

The website is hosted by Western Kentucky University and is managed by both the Kentucky Climate Center and the Department of Geography and Geology. All three of these entities provide services for students and the public, both local and abroad. The Kentucky Tornado Database website adds to those services and expands the outreach from the university. In addition to providing services, the website is a true example of how GIS has evolved over the past decade. Internet GIS has allowed for people without a background in the science to be hands on with GIS capabilities and functionality.

The primary goal of this project was to create a tool which took a readily available dataset, and derived critical information which can then be obtained via the internet. Although the importance of such information cannot be quantified, it would be difficult to say it does not exist.

6.2 – Future Work

The study shows that the state average Tornado Incident Density value is 121, meaning 7.5625 square miles within 25 miles of the given point of interest have been affected by a tornado incident since 1950 (121 divided by 16, or the total number raster cells in a square mile). The maximum impacted cell has a Tornado Incident Density value of 213 (or 13.3125 square miles impacted within 25 miles). The GIS analysis section of this project included a great deal of raster and spatial analysis. However, future work can be done to better understand the output files used in this study. When looking at Tornado Incident Index output raster, it is possible to note some spatial patterns within the output. The northern border of Kentucky is mostly set on the Ohio River, and above than average Tornado Incident Index values tend to exist along that border (figure 6.1). Future studies can look further into these patterns and try to understand why they exist. Perhaps the higher density areas also correlate to the changing topography across the region near the Ohio River. Additional raster analysis work could be done to find any correlation between the densities and elevation.

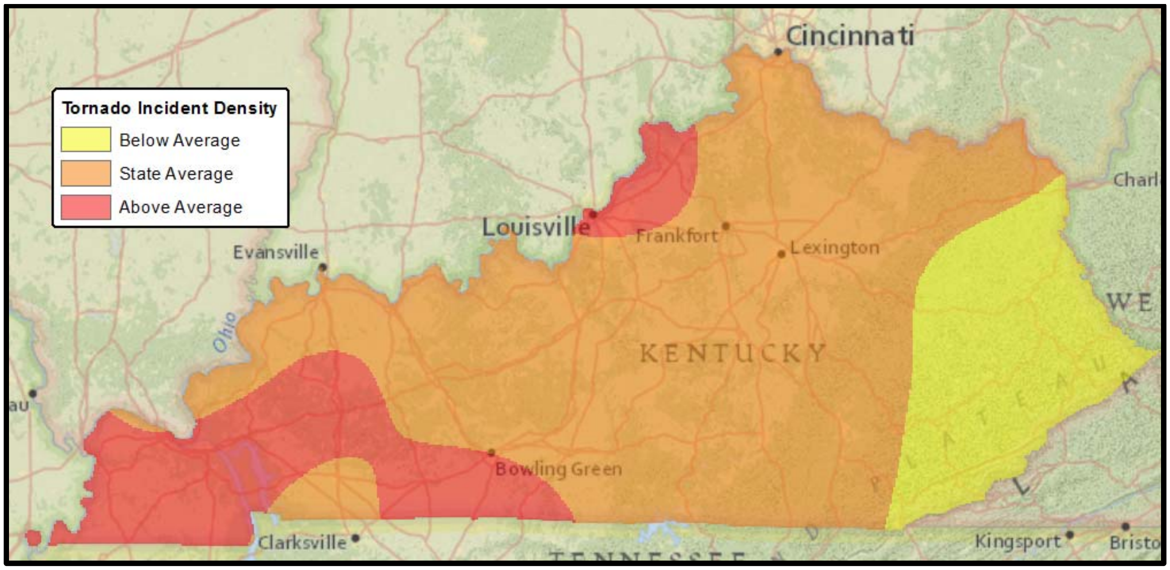


Figure 6.1. Above average Tornado Incident Density values tend to exist over the Ohio River border and extreme western regions of the state.

Although the website is very handy and useful, technology changes and improves upon itself constantly. With improving technology come the possibilities to improve on the website's functionality and performance. In addition, the incorporation of individual tornado event data such as photos, radar images, and newspaper articles would give the website more personal outreach for general public use. Also, incorporating such data would allow for more qualitative research to take place in addition to the quantitative abilities.

A potential update to the website would be to add other types of severe weather. The SPC SVRGIS website also has GIS-ready files for significant hail swaths, wind, high wind events, and wind swaths. Adding this data would make the website a great resource to gather data and information and a variety of severe weather phenomenon. In addition, stakeholders can use the website as a complete source for severe weather data in the Commonwealth.

The current state of the website offers a great deal of information, and functionality for both viewing and analyzing end users. The hosted data gives decision makers and stakeholders the needed information to make constructive choices on tornado risk for the state of Kentucky. Similar methodologies can be adapted for other states, which could be implemented to assist in their own historical tornado analysis.

Looking back at the methodology used in this study, some approaches could have been conducted more fluidly. For example, when creating individual GIS feature classes and raster files for each day a tornado took place, a manual process of selecting the tornado track file(s) and converting all to a raster file was conducted. Once complete, iteration scripts were discovered to mitigate the time spent repeating this process. The iteration scripts led to the discovery of using ModelBuilder for many of the GIS processes. It is recommended to anyone looking into conducting future work which is similar to the approaches used in this study that any form of automation is looked into prior to beginning GIS analysis work.

In addition to better preparation, when this study began the latest ArcGIS Desktop and Server software version was 9.3. However, early into the study ArcGIS Desktop and Server 10.0 were released. Looking into the additional functionality and more intuitive design, the updated software was the catalyst for changing the original idea of creating a web application using default ArcGIS Server tools, to creating a web application using Adobe's Flash Builder and Flex suite of tools. Due to the transition from one ArcGIS platform to another, some of the methodology for calculating and processing the GIS layers also changed. Although the functionality and style of the Flex Viewer web application surpasses that of the default ArcGIS Server web applications, making the transition required numerous redundant processes to take place. If the analysis portion of the study would have waited for the release of the updated ArcGIS platform before beginning GIS processes, then a great deal of time could have been saved by removing the redundant processes.

The website and analysis conducted in the study is a pure example of how analysis of a tabular dataset can be transformed into a powerful tool capable of providing beneficial information. The Internet-based SDSS performs well as both an educational resource and also as a risk assessment tool for decision makers. In the end, the benefits of such website should continue to educate and assist all users in a time where critical information such as the Tornado Incident Density of an area can help save lives.

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