MxInsight® White Paper

Operational Uses of Weather Information in GIS-based Decision Support Systems

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Operational Uses of Weather Information in GIS-based Decision Support Systems

1.0 Abstract

Meteorlogix has developed and refined technology that allows businesses to merge the locations of their assets (i.e. customer locations, critical infrastructure) with up to the minute localized weather information, to provide improved operational decision support. Geographic Information System (GIS) technology is used to geographically map weather information against business assets in an automated Decision Support System. Weather parameters, that are relevant to the business, are continuously monitored and compared to specific thresholds. Automated alerts are generated when critical weather thresholds are exceeded. These real-time location-based alerts can provide dramatically enhanced personal safety, improved logistics support, and superior advantage in operating business efficiencies relating to weather. Seven years of research and development has led to the development of this advanced capability to centrally provide weather decision support aides.

2.0 Introduction

The use of GIS as a tool to make analytical business decisions during the past 25 years is well documented. This "traditional" use of GIS was typically associated with decision cycles of longer time periods (on the order of weeks and months), the use of relatively static data (i.e. elevation contours), the near exclusive use of sophisticated desktop GIS analysis tools, and typically involved only a few, highly specialized users (i.e. GIS analysts). With the introduction of dynamically updating, localized weather information into a GIS, Meteorlogix has helped change the paradigm towards one of using GIS to perform operational decision support. The resulting weather-enabled decision support systems can support much shorter time scales (on the order of minutes), utilizing frequently updating data layers (weather information updates every minute), utilizing Internet communications technology for the sharing and distribution of the data, and allowing involvement of many users of varying experience performing simple viewing all the way to conducting complex analysis. The merge of weather information with GIS provides new and exciting capabilities now being realized by businesses to mitigate their weather-related risks.

Meteorlogix, the world's leading commercial weather service provider, has adopted a geospatially-enabled weather processing infrastructure whereby the data preparation and conversion, display and visualization, and active monitoring and alerting of weather events is substantially based upon GIS technology. The powerful spatial analysis capabilities inherent within GIS make possible an impressive array of capabilities that can help solve a variety of complex business/customer problems and creates new possibilities for business development.

3.0 Applications of weather data in GIS

Numerous commercial applications exist where the combination of specific weather information with GIS can facilitate improved business decisions.

- Personal Safety: The up to the minute location and movement of dangerous storm cells, compared to the precise location of businesses and customers, allow location-based event notification of impending weather threats resulting in advanced warning time

- Energy: The integration of real-time lightning and severe storm information with the energy infrastructure, allow precise correlations between weather and electrical substations and distribution power lines helping provide improved targeted dispatch of repair crews which ultimately result in more timely service restoration

- Emergency Management: The forecast position and track of a tropical storm or a hurricane, compared against population centers, allow an objective forward looking analysis of damage potential as well as a more precise determination of optimal evacuation routes

- Winter Highway Management: The combination of real-time radar, pavement conditions, and local surface winds allow public works officials to position snow crews over a city, county or state more effectively and determine proper manpower distribution for snow and ice removal

- Flood management: Historical and forecast precipitation, combined with hydrological models, can provide an objective analysis of flood potential and offer improved water management tools as the expected rainfall is compared against specific conditions within individual catch basins

- Surface transportation: Real-time storm cell tracking data showing storms with large hail and damaging winds, compared against roadway locations and characteristics, are combined to produce a “Road Speed Index” that objectively determines impedance to flow ultimately providing improved routing, logistics coordination, and operating efficiencies for the transport of materials

- Health issues: Radar-derived rainfall estimates, accumulated throughout the season, help mosquito control centers more precisely track areas of excessive water so that they can more efficiently manage chemical applications to minimize the spread of mosquito-borne diseases

- Wildfire management: The integration of real-time cloud-to-ground lightning strike data, with forecast wind and relative humidity, help provide early detection of fires and offer improved tactical fire fighting response

- Insurance: Near-term summaries of weather information depicting areas of storm damage can be analyzed against locations of insured customers to

validate claims and understand how best to provide improved customer service by proactively dispatching adjusters to the weather-effected areas

- Aviation: Weather information in 4-dimensions (3-D plus time) allow air traffic dispatchers to more precisely route aircraft around rapidly evolving weather ultimately providing improved ride quality, fuel savings, and safety

Similar applications can be also be extended into military related activities:

- Battlespace: Internal military weather information, converted into GIS formats, allows weather information to be precisely combined with the locations of other military assets (i.e. troops) and ultimately more seamlessly integrated into battle field command and control systems

- Intelligence gathering: Forecast cloud cover and atmospheric moisture profiles, compared against data acquisition targets, can provide more efficient and reliable scheduling of remote sensing from satellites

- Terrorist Threat Analysis: Highly localized real-time wind observations, integrated into plume dispersion models, provide timely and accurate projections of airborne concentrations of chemical gases that could endanger troops

- Inter-agency transfer: Internal military weather information, converted into a recognized "standard" GIS format (i.e. ESRI Shapefile) provides enhanced interoperability due to standardized data exchange with other non-weather data sets

4.0 The evolution of use of GIS and weather

Over the past 7 years, Meteorlogix has developed software that makes possible the operational merging of weather with GIS to solve complex business problems. The evolution of GIS and weather began with the development of software to operationally convert a wide variety of meteorological data sets into GIS compatible formats, then moved onto the development of advanced display and analysis of meteorological data using GIS technology, cumulating in the development of active GIS-based decision support systems capable of generating location-based alerts relative to business assets.

4.1 Conversion of meteorological data into GIS compatible formats

Weather information is ever changing and represents a very dynamic data set (i.e. some of the weather information updates as often as once per minute). The collection, management, quality control, and conversion of meteorological data into the appropriate GIS formats, in an *operational* environment, represent a set of formidable challenges.

Over the past 30 years, the ESRI data formats have become the de facto standard in the GIS industry. Due to ESRI's leadership role in the industry, Meteorlogix chose to adopt the ESRI data formats for the converted weather data. Meteorlogix provides a comprehensive suite of high-quality, commercial-grade weather information, converted into GIS formats, as a value-added service. The GIS weather data is available either via satellite transmission or via the Internet. Meteorlogix also provides licensed software technology capable of transforming proprietary (i.e. military) weather information, internal to an organization, into GIS formats for expanded specialized internal uses.

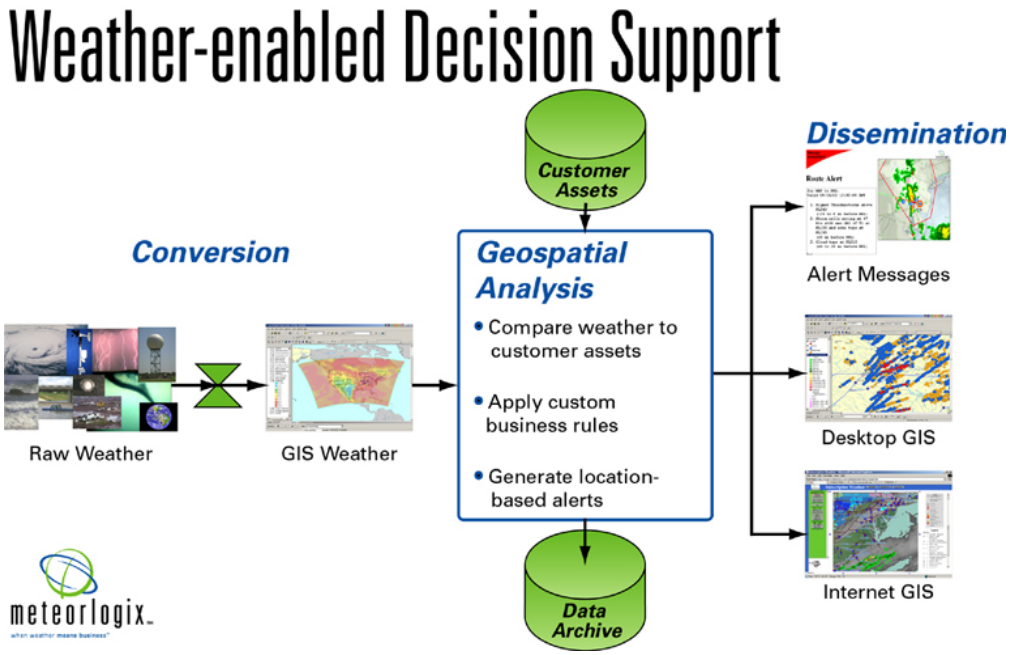

Figure 4.1.1
Weather data that is properly converted into GIS format, undergoes geospatial analysis against customer assets, and is then made available as alert messages or in weather displays both on the desktop and also via the Internet

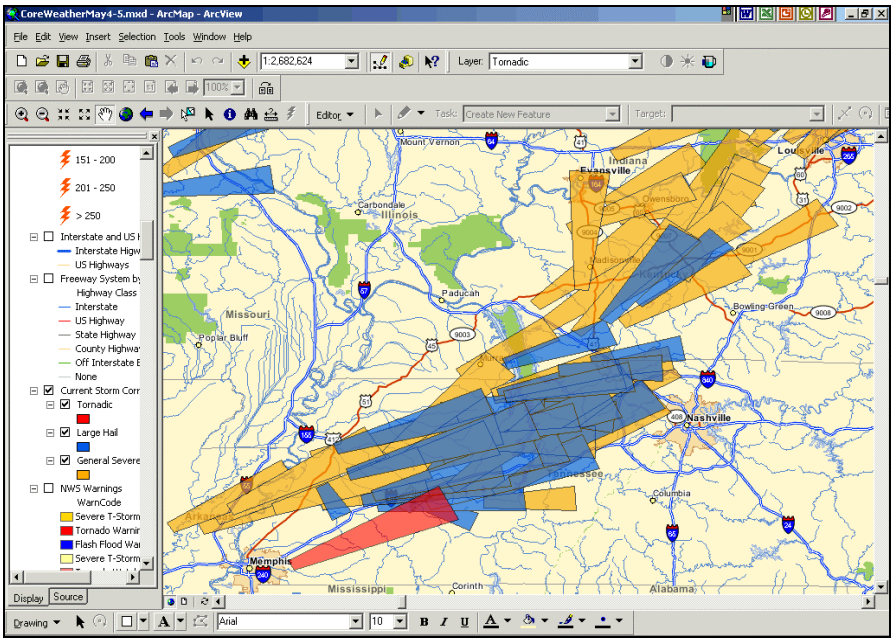

Figure 4.1.2
The geographical footprint of severe storm activity is one example of using GIS to produce a value-added weather display

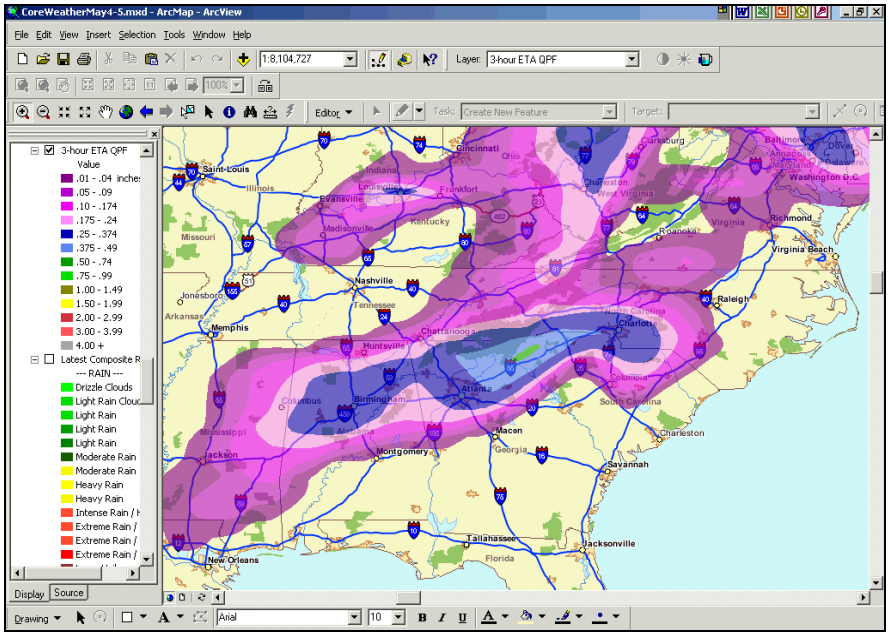

Figure 4.1.3
Forecast weather information, such as this quantitative precipitation forecast, converted into an ESRI polygon shapefile, is now available from Meteorlogix over the Internet via either an ftp service or a web service

4.2 Advanced display and analysis of meteorological data using GIS

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The combination of the availability of dynamic geo-referenced weather data along with GIS software development tools makes possible the creation of unique and powerful customized weather workstation applications. These more traditional “thick” client applications typically run on a Microsoft Windows-based PC platform and provide displays of weather information combined with a virtually unlimited number of geographical base map backgrounds. Using Meteorlogix converted GIS weather data in concert with a GIS software development toolkit such as the ESRI MapObjects enables software developers to create customized applications with a customized graphical user interface and specialized ease of use functionality that can reflect the specific client needs. Meteorlogix has developed several GIS weather display workstations including the Storm Pro and the Storm Commander.

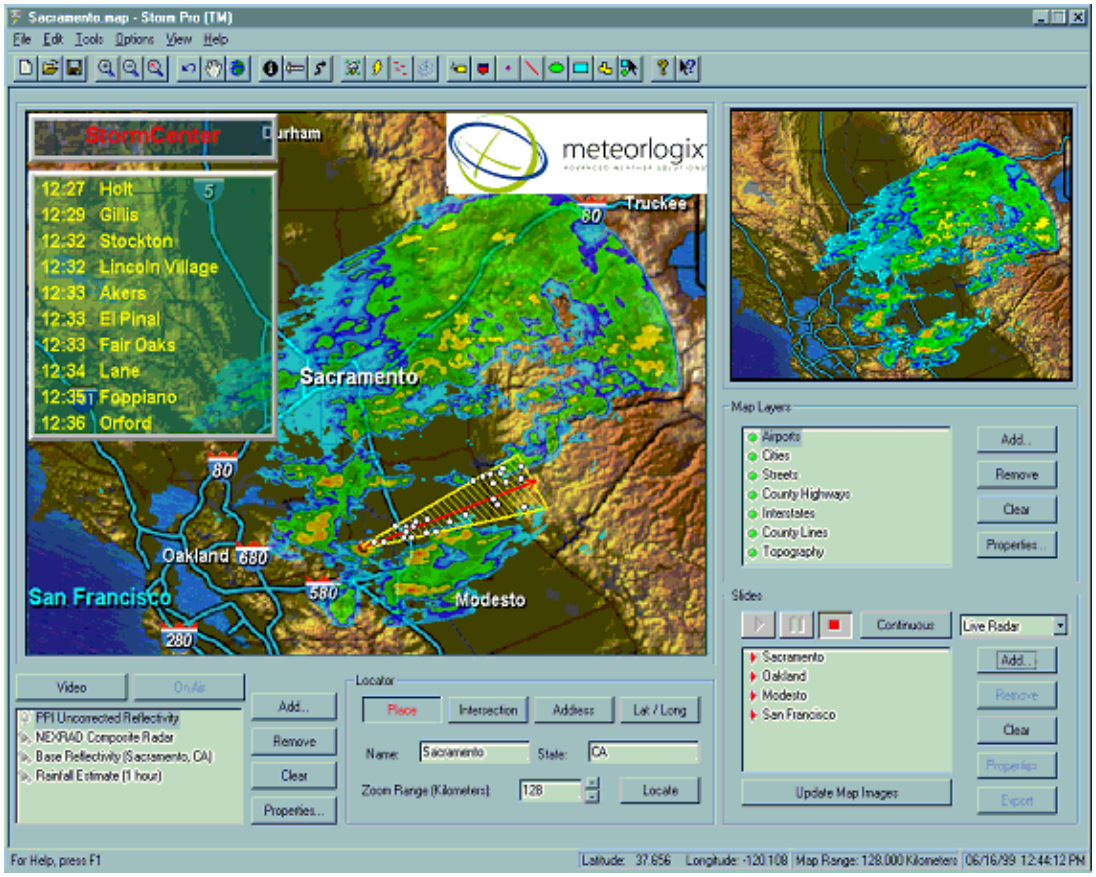

Figure 4.2.1
The Meteorlogix StormPro system was developed using the ESRI MapObjects GIS toolkit to display live weather radar on the air at broadcast television stations

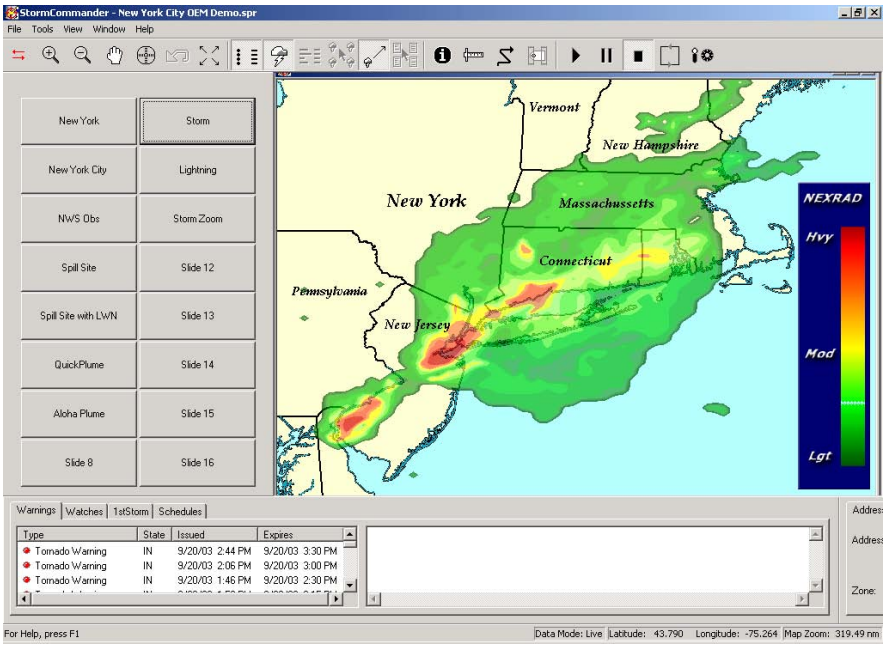

Figure 4.2.2
The Meteorlogix StormCommander severe weather management system was developed using the ESRI MapObjects GIS toolkit

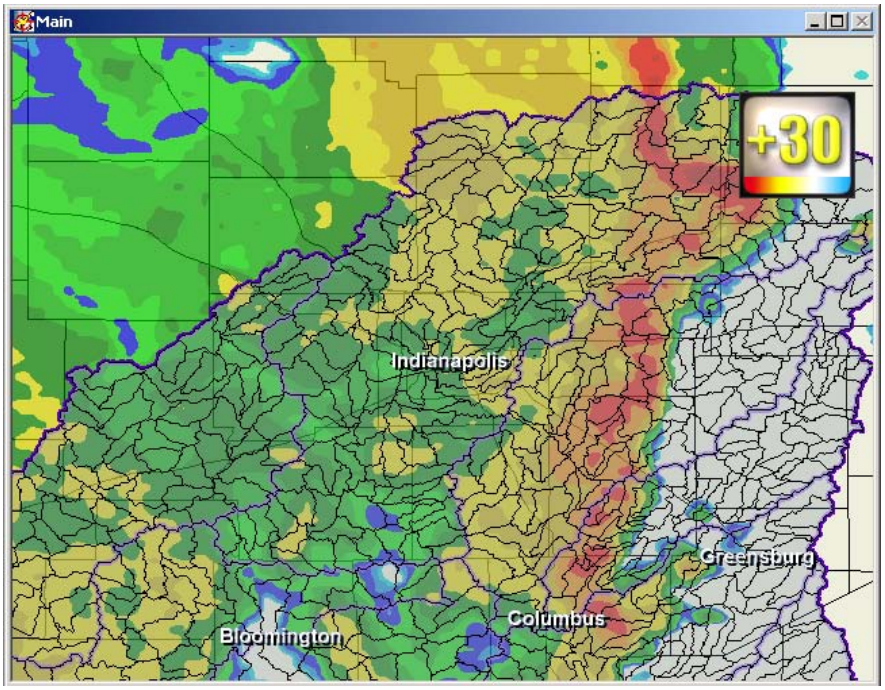

Figure 4.2.3
The Meteorlogix StormCommander provides access to a wide variety of specialty weather data including forecast precipitation, shown here against watershed boundaries
An alternative approach for a GIS weather display is to bring the weather data directly into off-the-shelf desktop GIS software (i.e. ESRI ArcView or ArcGIS) and leverage the

display and spatial analysis capabilities inherent therein. This approach offers virtually unlimited possibilities in the types of geographical base map backgrounds that could be used, as well as providing convenient access of the weather information to on-board spatial analysis utilities. The merge of GIS and weather, into a consolidated desktop GIS platform, can facilitate not only the integrated "display" of weather with other geographically referenced data layers, but also provide the unique opportunity to perform meaningful objective spatial analysis on these data sets to determine correlations and advanced deterministic statistics.

Meteorlogix has developed MxAnalyst, a software extension designed to facilitate easy use of weather data within ArcGIS 9.x desktop GIS software and to overcome the challenges of displaying and manipulating weather information in this environment. Different weather data types, from different data sources, with different characteristics and different time update frequencies, are just some of the issues that have been addressed such that the weather data can be used by a non-meteorologist not adept with all of the nuances of the weather data sets. MxAnalyst also streamlines common display references to different weather data sets (i.e. symbolization of wind vectors) and performs many of the most common weather-related functions (i.e. plotting and analysis). MxAnalyst allows weather data to conveniently be imported into a desktop GIS environment, thereby protecting and extending that GIS software investment.

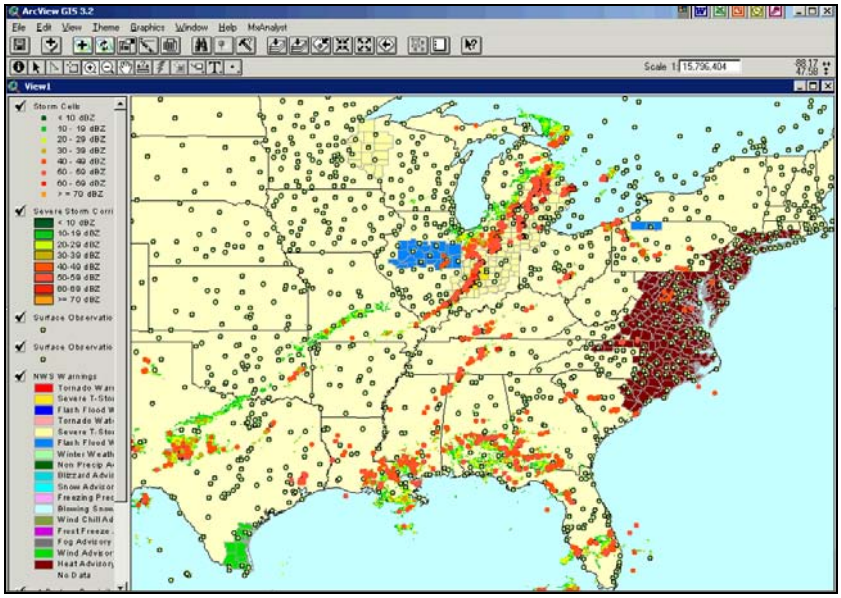

Figure 4.2.4
The Meteorlogix MxAnalyst extension for ArcGIS 9.x desktop GIS software helps facilitate the easy access, display, and manipulation of weather data within a commercial off-the-shelf GIS environment

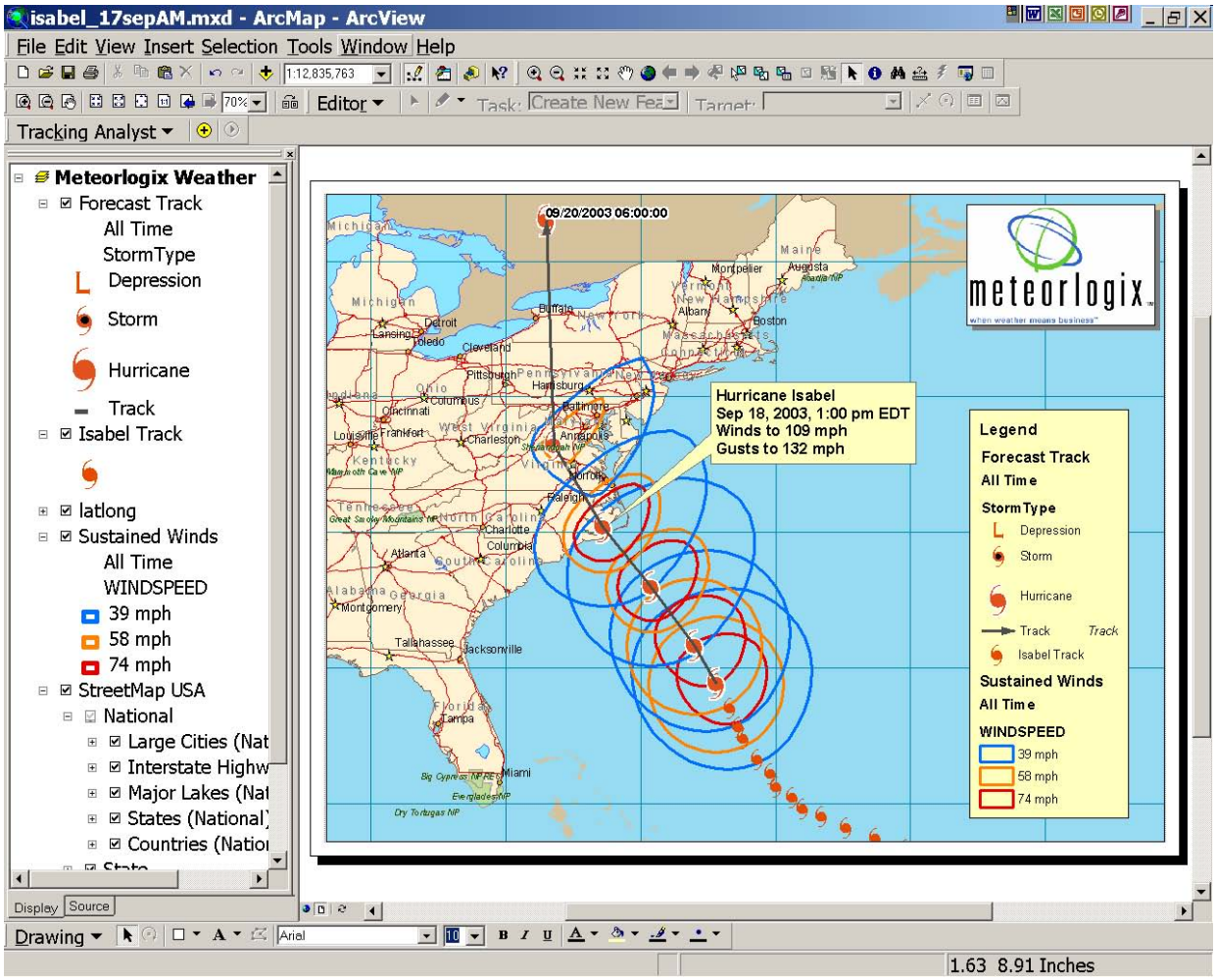

Figure 4.2.5
In addition to the advanced display of historical, current, or forecast weather information that can be facilitated by use of the MxAnalyst software extension to ArcGIS 9.x, the Meteorlogix GIS weather data is also compatible with ArcMap and associated features

A third approach to the visualization of GIS Weather is through geo-publishing -- utilizing the Internet to enable web users to conveniently access, display, and analyze weather information within a “thin-client” Internet Browser (i.e. Microsoft Internet Explorer or Netscape Navigator). This approach provides the advantage of maximum distribution flexibility throughout the enterprise, internally (i.e. Intranet) and/or externally (i.e. Internet). This approach does require an Internet server infrastructure to host the serving application (i.e. ESRI ArcIMS). To further enhance the operational reliability and efficiency of this hosted application, Meteorlogix has developed software applications that automatically manage the weather data, including an interface to the ESRI Spatial Data Engine (SDE) to optimize the loading and retrieval from a commercial relational database management system. These specialized weather Internet server capabilities can be licensed from Meteorlogix to support an organizations operational remote client deployment of ArcIMS services.

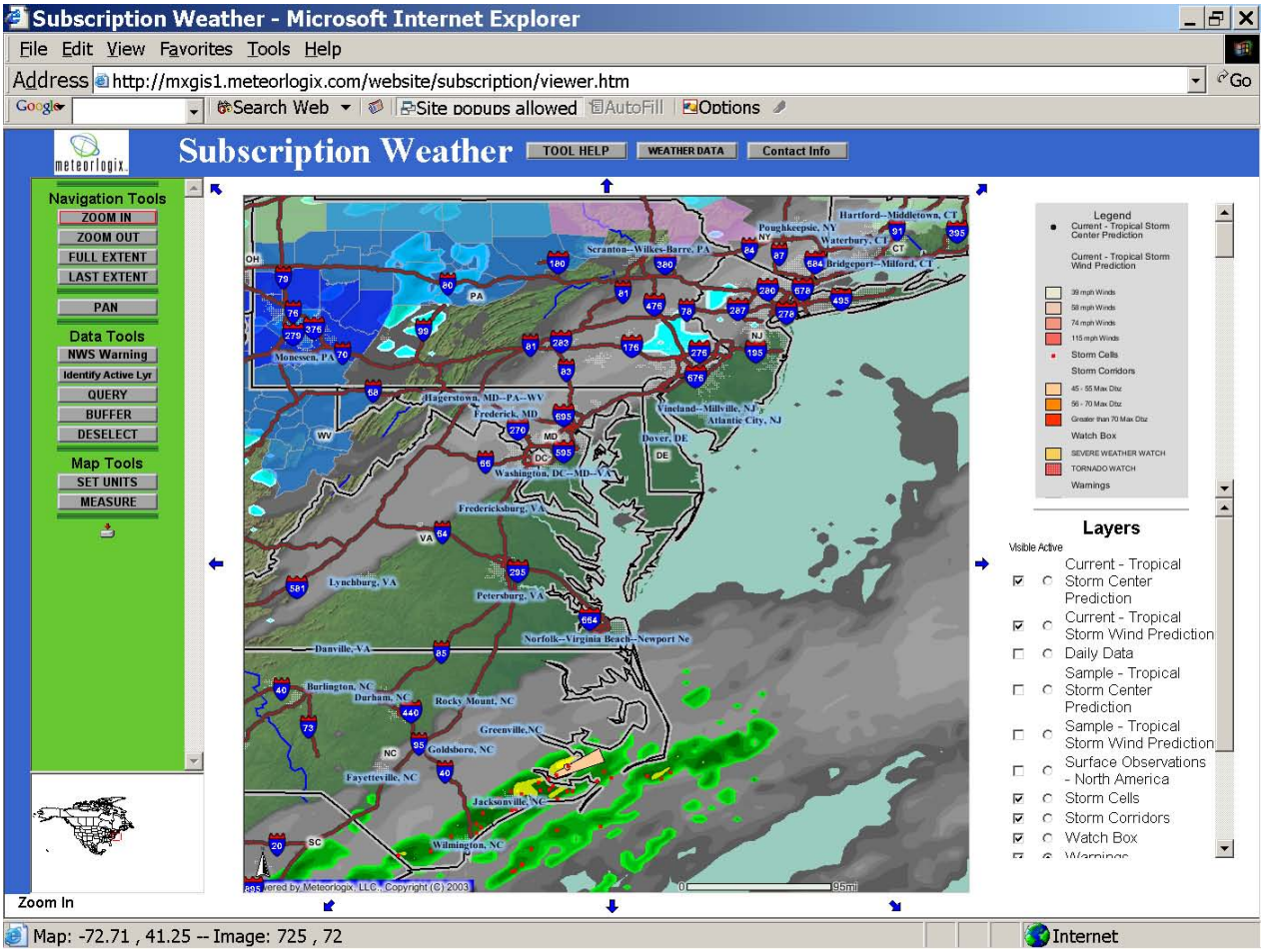

Figure 4.2.6
Meteorlogix utilizes ESRI ArcIMS technology to transmit current weather information over the Internet for real-time visualization and query within a Internet Browser viewer

4.3 Introduction of active location-based weather alerts

The most powerful capability yet realized from the combination of weather information and GIS is the ability to facilitate the continuous monitoring of multiple weather parameters against geographical assets, and automatically trigger active location-specific alerts when critical thresholds are exceeded. This "weather-enabled" decision support system can help businesses monitor specific weather threats and manage their weather related risks in ways heretofore unimaginable.

The active location-based weather alert technology developed by Meteorlogix can be applied both in time and space:

- Spatial alerts:
  - Alerts for specific points (fixed or mobile)
  - Alerts along line segments
  - Alerts for specific geographical areas
- Temporal alerts:
  - Alerts applying to future forecasted weather conditions

The spatial and temporal alerts are not mutually exclusive and may be combined to provide maximum benefit.

4.3.1 Active weather alerts for specific point locations

The continuous monitoring of multiple weather parameters relative to business assets can be achieved within a GIS-based weather alert system. An example would be the continuous monitoring of aviation specific weather parameters at an airport (i.e. horizontal visibility, surface wind speed, cloud ceiling height). The system would compare actual conditions against aviation-specific weather tolerance thresholds that, if exceeded, would generate a unique real-time alert message notification. The weather parameter alerts could be administered singularly (i.e. the wind speed exceeds the set threshold of 35 miles per hour). Another possibility would entail having disparate weather parameters assigned specific thresholds whereupon any combination of these weather parameters degrading past minimum thresholds, would also trigger an alert notification message (i.e. the wind speed exceeds the set threshold of 35 miles per hour AND the set threshold of horizontal visibility degrades below one nautical mile). It is this type of flexible and configurable weather alert technology that can assist airline dispatchers to more quickly respond to rapidly changing weather conditions that can substantially impact their operational decisions.

In addition to current weather conditions, future or forecasted weather conditions, up to 54-hours in advance, can also be incorporated into the decision support system (i.e. snow removal crew receives advance notification of newly forecasted snow storm that is anticipated to effect a particular point location such as a shopping mall parking lot), a line segment (i.e. roadway), and/or an area (i.e. county). All alert notification messages can be distributed via e-mail, pager, or telephone.

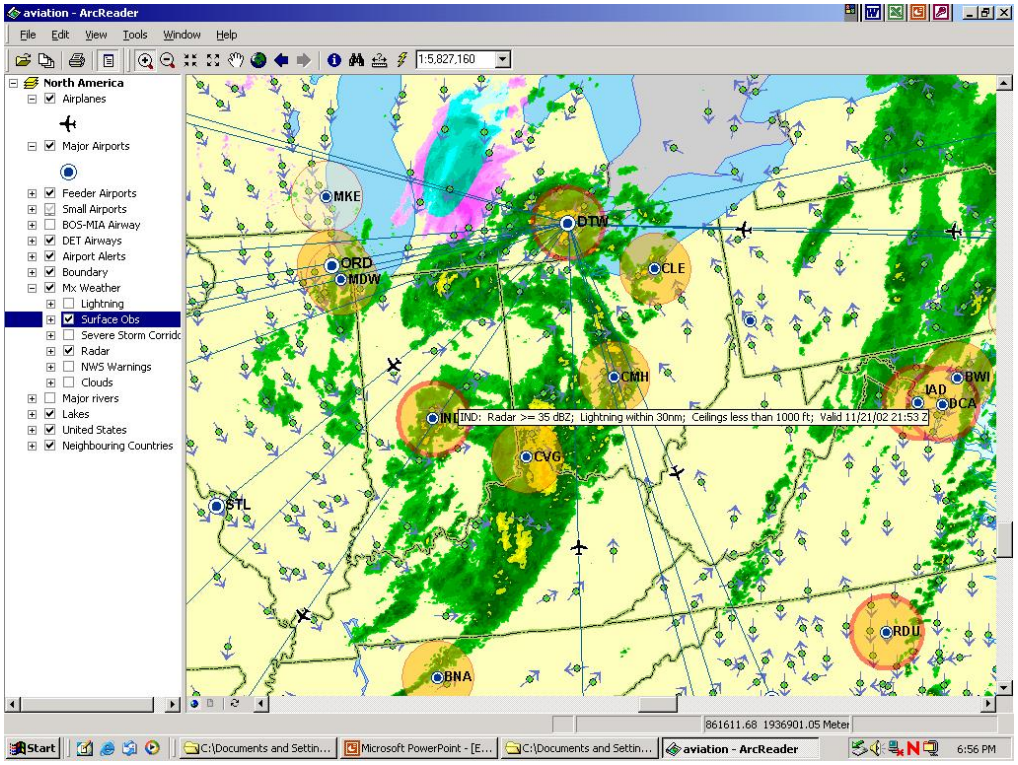

Figure 4.3.1
Multiple aviation weather parameters can be monitored around a series of airports, constantly monitoring changing weather conditions and dynamically generating short-text alert messages that can be distributed via e-mail, pager, or telephone

4.3.2 Active weather alerts along line segments

The proximity of specific weather relative to line segments, such as highways or railways, can be monitored within a GIS-based Decision Support System providing benefit to the transportation management systems. One example is the railroad industry, interested in increasing overall efficiencies and reducing costs from weather induced derailments (i.e. high winds blowing material off rail cars and/or blowing rail cars off the track). Meteorlogix has implemented an advanced automated weather alert system for the railroad industry whereby specific weather events, as defined by the railroad, are continuously monitored. When a particular weather parameter exceeds a pre-defined threshold, and threatens to affect a particular section of railroad track, a dynamic alert message, complete with graphics, is automatically sent to the individual dispatcher responsible for the affected section of track who will order the train to stop. This system allows continuous monitoring tens of thousands of miles of track for user specified weather conditions. The combination of GIS technology and weather information makes possible these advanced automated alert systems which have the potential to save substantial money due to smoother operations and fewer weather related disruptions of service.

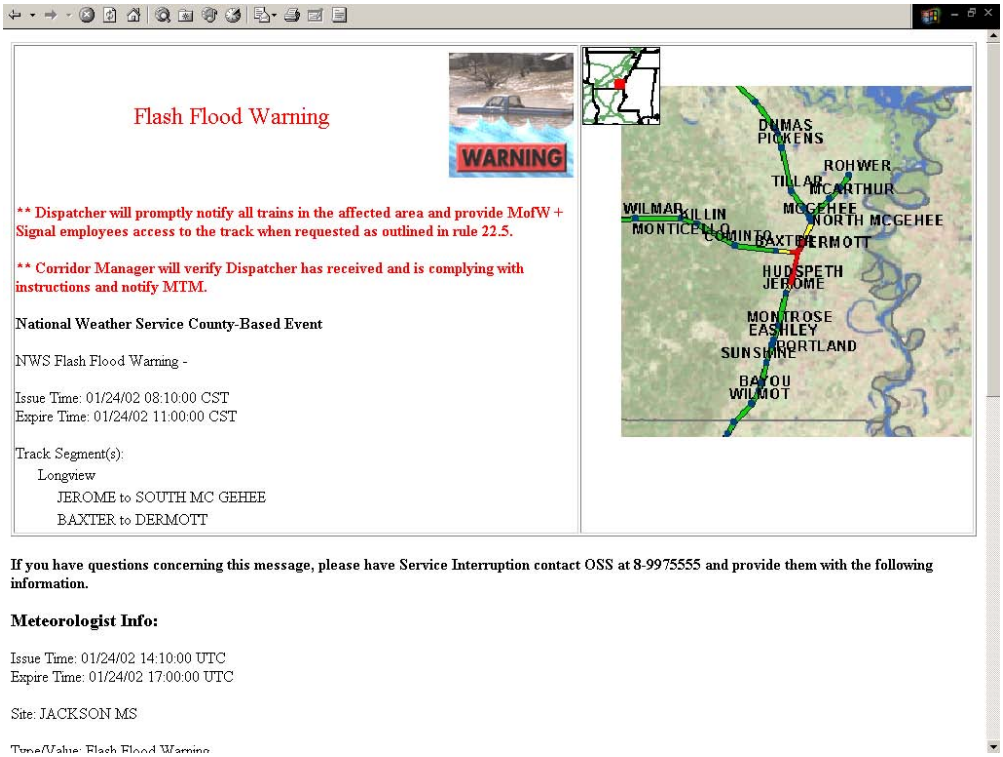

Figure 4.3.2.1
The Union Pacific Railroad weather decision support system automatically monitors weather approaching railroad track segments and sends a highly descriptive, dynamically built message that is routed to the dispatcher responsible for the segment of track about to be effected by weather

The powerful spatial analysis capabilities within a GIS, combined with the appropriate weather information, provide the opportunity to objective “model” the net effect that adverse weather may have. An example of this is the objective determination of a “Road Speed Index” (RSI) that estimates the impedance to traffic flow (i.e. percentage of degradation from normal speeds) due to weather conditions. For example, during ideal driving conditions with dry pavement, the average speed of travel along a section of highway might be 45 miles per hour. However, with light rain and moderated restricted horizontal visibility, the nominal speed of travel would be reduced, say to 30 miles per hour. Heavy rains, resulting in pooling of water on the highway, would provide further slowing of traffic. The objective calculation of the RSI can be applied in an instantaneous mode (i.e. using current weather) and/or in a projected mode (i.e. using forecast weather). The forecast winds and precipitation associated with an advancing tropical storm or hurricane can be used to model the expected RSI so that optimal evacuation routes can be selected, and orders for evacuation are given far enough in advance in order to support the anticipated traffic flow. This is a synergy of weather and GIS that can provide substantial benefit to emergency managers who rely upon the transportation system.

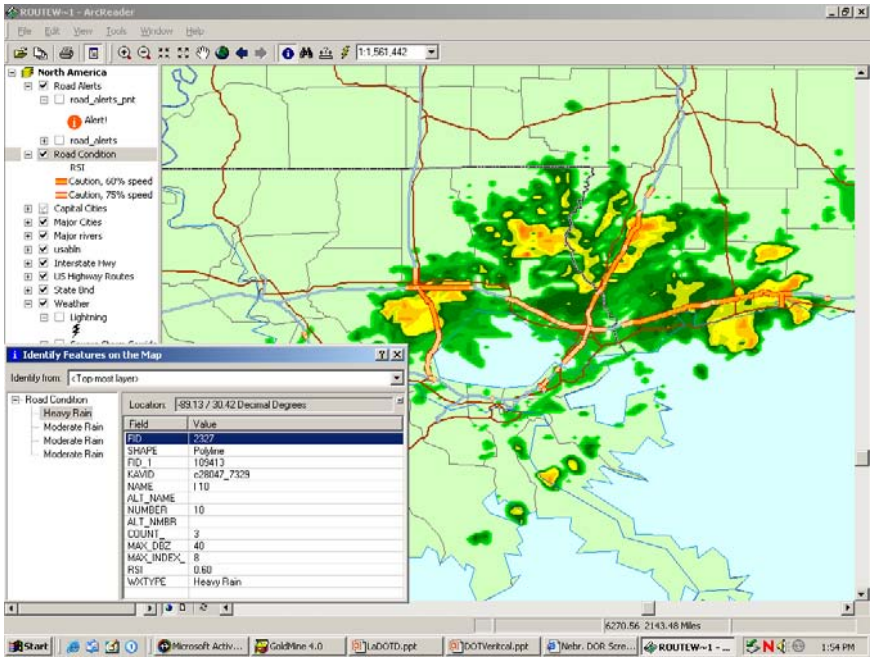

Figure 4.3.2.2
Forecast weather associated with an approaching tropical storm or hurricane can be used to calculate a forecast RSI ultimately to provide decision support for selection of evacuation routes and timing

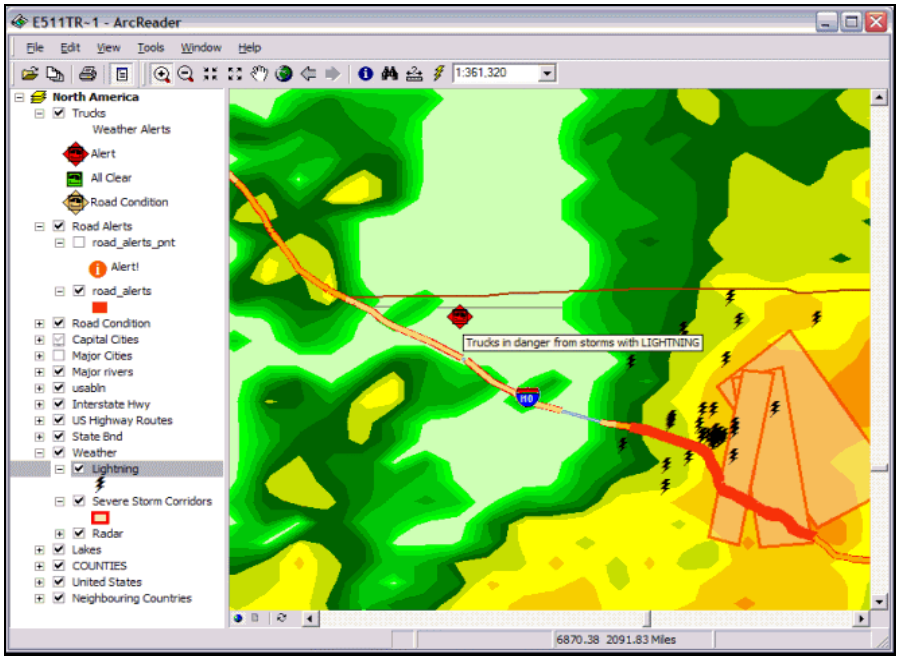

Figure 4.3.2.3
The proximity of weather activity relative to individual highway segments can be automatically monitored and alerts triggered as necessary

4.3.3 Active weather alerts for geographical areas

In addition to specific point locations and along line segments, the Meteorlogix GIS-based decision support systems also have the ability to objectively evaluate weather threats that may exist over larger geographic areas. One example of this capability is the integration of highly localized real-time weather observations as the direct input into sophisticated plume dispersion models. The time averaged local wind direction and speed, combined with other meteorological parameters, provide more timely and precise representations of where the highest concentrations of threatening levels of air pollutants or chemicals are expected to be present, enabling emergency managers to make better decisions (i.e. set up road blocks at most appropriate intersections, where to evacuate, etc.) in the cases of an accidental release (i.e. chemical fire) or a terrorist attack (i.e. possible biochemical release into the atmosphere). Use of this technology allows emergency response personnel to provide a faster, more intelligent and thoughtful response to a crisis situation that can be effected by the weather.

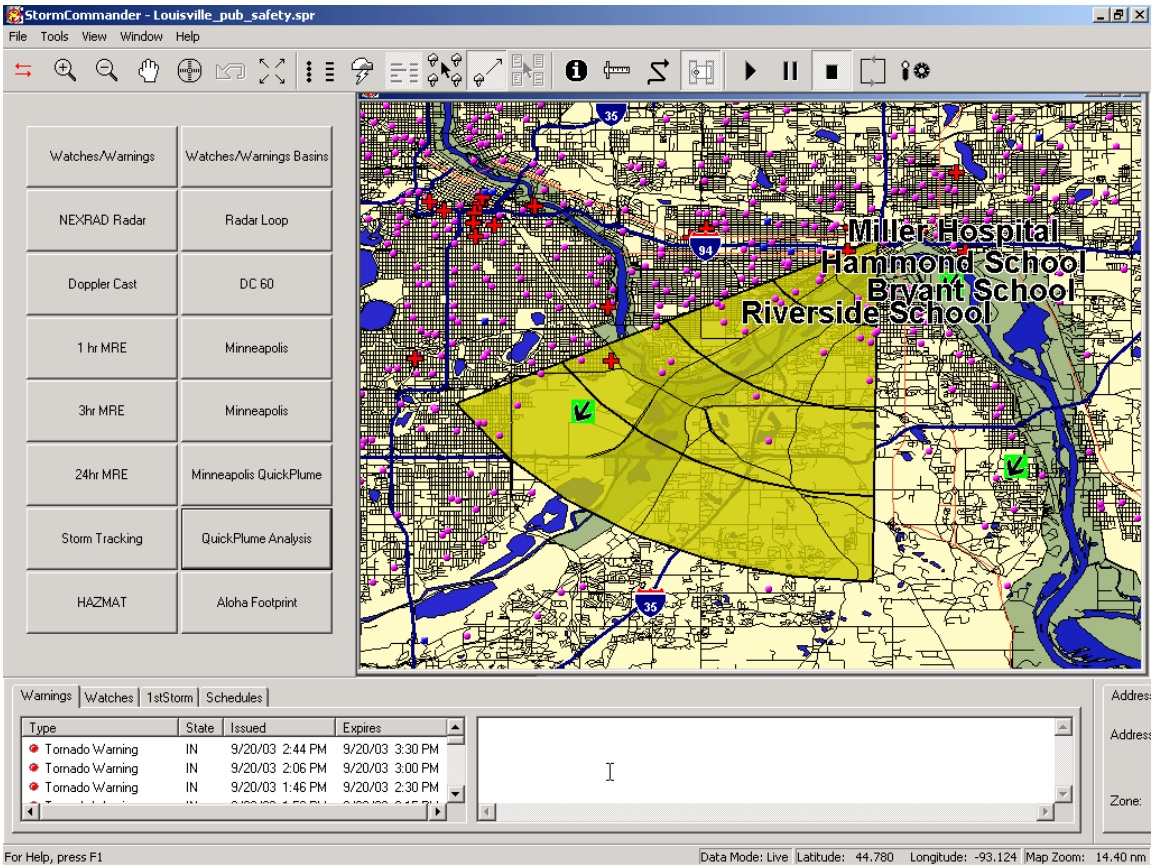

Figure 4.3.3.1
The integration of real-time wind observations into a GIS-based decision support system allows accurate derivation of the geographical areas effected by airborne chemicals

Historical weather data, combined with temporal and spatial analysis within a GIS, can be used to generate an accurate depiction of the geographical footprint of areas affected by past weather. Time series summaries, or roll-ups, of past weather information, in GIS formats, are available from Meteorlogix and are used to show geographical areas where significant weather has occurred. Different types of weather activity, moving in different directions and at different speeds, can be analyzed and cross-referenced against business assets. For example, insurance companies can use geo-referenced historical weather data, compared against customer locations, to determine the locations where weather related damage claims are likely.

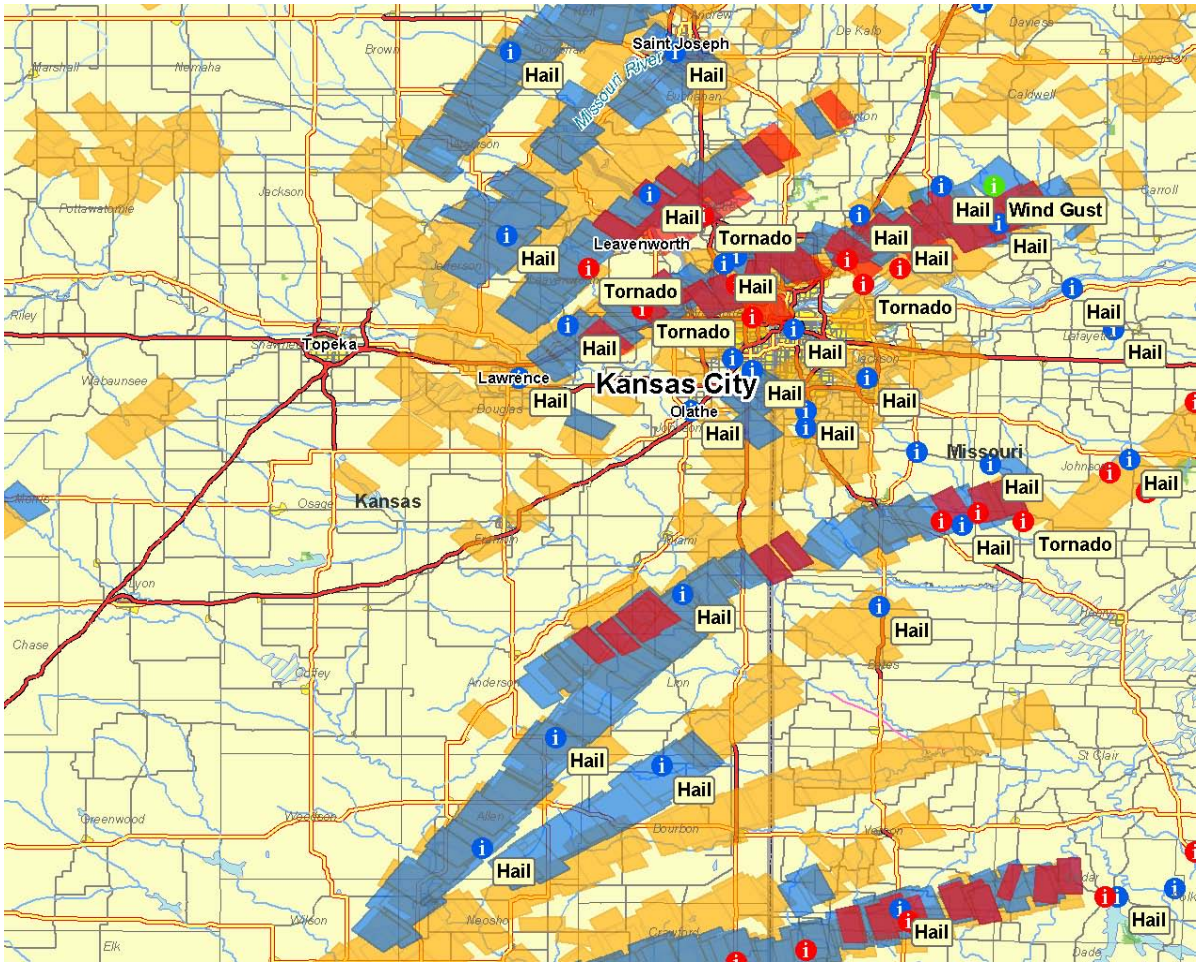

Figure 4.3.3.2
Time-series roll-ups of past weather activity can show the geographical footprint of areas recently affected by specific weather phenomena

5.0 Conclusion

Meteorlogix has pioneered the merge of weather information with GIS that has led to the development of weather-enabled decision support systems. This technology allows businesses to seamlessly merge the locations of their assets (i.e. critical infrastructure) with up to the minute localized weather information, to provide improved operational decision support. GIS is used in these systems as an "enabling technology" that allows the effective merge of weather with business assets, perform sophisticated spatial and temporal analysis, and help determine the customized net effect of the impending or past weather event. Automated alerts are generated when critical weather thresholds are exceeded.

The deployment of operational "weather-enabled" decision support systems continue to provide dramatically enhanced personal safety, improved logistics support, and superior advantage in operating business efficiencies relating to weather. Seven years of research and development by Meteorlogix has led to the development of this advanced capability to centrally provide weather decision support aides. This synergy of technologies holds great promise for businesses being able to use weather information to their advantage in the future.

Please see www.meteorlogix.com/products/mxinsight/GIS for more information on Meteorlogix GIS weather products and services.

6.0 Author information

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