EMHURR
An ArcIMS based Hurricane Tracker

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1. 0 Abstract

In early spring of 2003, NOAA's (National Oceanic and Atmospheric Administration) National Weather Service (NWS) began development of an experimental ArcIMS™ site called EMHURR. This site was designed to provide Emergency Managers a means for accessing near real time weather data both prior to and after the land fall of a tropical storm or hurricane. This project benefited from excellent intra-agency cooperation. Several NWS programs and NOAA line offices contributed data and software to the project. This paper will focus on the EMHURR architecture, data, and interface. The paper will also discuss lessons learned and mention future plans for evolving EMHURR.

2.0 Background

A NWS team to investigate IMS use in hydrology was formed in September, 2001, and remained in place until April, 2002. The team was called the Water Resources Internet Mapping Team and was chartered to recommend a coherent and cost effective water resources Internet mapping strategy. The team briefed the Science and Technology (S&T) Committee of the NWS Corporate Board and recommended follow-up studies of internet mapping[1]. In August 2002 a follow-up team was commissioned by the S&T committee to further investigate the feasibility of using IMS technology with hydrologic and meteorological data. In April 2003 the final report to the committee concluded that it appeared feasible to display data in this manner, but there was much to be learned about the technology. Therefore the team proposed to develop a prototype website. The S&T committee accepted the report and agreed to fund the building of a prototype which is the subject of this paper. The website was given the designation EMHURR.

3.0 Scope

This prototype was developed to assist emergency management (EM) personnel with planning, and decision-making tasks required during the onset of a hurricane or tropical storm. The meteorological and hydrometeorological data sets included with this application were limited to the southeast Atlantic and Gulf Coasts of the United States. The primary objectives of this application were to provide EM's with a single geographically driven web portal for accessing, visualizing, and downloading weather data sets during a tropical cyclone event.

4.0 Architecture

The architecture of EMHURR used two Windows™ 2000 personal computers. One functioned as the processing (crunch) server and the other as the ArcIMS™ server. The processing server was used to decode, create, convert, update, and geo-process data sets. Data were pushed or pulled to the processing server from various NOAA line offices at predefined intervals. Intervals were established to ensure that datasets were updated in a near real time fashion. The data was then decoded, processed, written out to shapefiles, and pushed to the ArcIMS™ server. The one exception to this method was the process used to decode the hurricane track. The hurricane layer was the only layer that changed status, thus requiring edits to the map configuration (axl) file, and the subsequent refreshing of the map service. In order to refresh the map service, data processing functions were performed on both the ArcIMS Server and the crunch server. Data creation processes were run on the ArcIMS server, and updates to the axl file were performed on the crunch server. When a map service required an update due to a change in storm status (addition or deletion of layer), a new map configuration file was created on the crunch server. A "sentry" file, indicating the axl file had been modified, was then pushed to the ArcIMS server. The ArcIMS™ server continuously checked for the sentry file, and when detected, ran a batch file to refresh the EMHURR site.

5.0 Data

A unique challenge to the development of EMHURR was the acquisition and processing of the datasets served by the application. Since the majority of EMHURR datasets are dynamic (constantly changing), an automated system for retrieving, decoding, and processing source datasets into an ArcIMS compatible format (shapefile), in near real time was required. Below is a description of the datasets utilized by EMHURR, and a brief summary of data creation, conversion, and geo-processing functions applied to each dataset. For a more detailed description of automated processing functions please see "Decoding & Processing Tropical Cyclone & Related Weather Datasets" by Daniel Konde and Rory Moore.

5.1 Storm Track

The storm track consisted of a point layer representing storm forecast locations, a line layer representing the storm track, and a polygon layer representing the cone of uncertainty (max forecast error observed in previous 10 year). The point forecast layer displayed forecast points at 12 hour intervals to a forecast lead time of 120 hours or 5 days. The source of this layer was an HTML file downloaded from the National Hurricane Center (NHC). This HTML file was downloaded to the ArcIMS server, parsed and converted to a text file. Legacy ArcView/Avenue was then utilized to create storm track shapefiles for each layer. The newly created shapefiles were copied to the designated data directory. A text file containing information about the newly processed storms was pushed to the crunch server. In the event a storm changes status (such as the birth or death of a storm), a mechanism was established to update and refresh the map service. These processing steps were automated with a combination of Visual Basic, ArcObjects, Avenue, batch files and Soft Tree's 24 x 7 scheduler software.

5.2 Watches, Warnings, Statements

Watches and Warnings Advisories (WWA) are alerts issued by the NWS when there is a likelihood of a severe weather event. This layer was added to provide EM with near-real time weather advisories for counties affected by a tropical cyclone. The WWA layer consisted of county polygons rendered by advisory type. The source of this layer was an XML CAP file downloaded from the NWS Office of the Chief Information Officer (OCIO) [2]. This XML file was downloaded every six minutes to the crunch server, parsed and converted to a dbf file. The newly created dbf file was then compared record by record to the counties dbf file using the FIPS attribute. The attributes (event type, event time, URL) of records in the counties dbf file with an active advisory were then updated. The updated counties dbf file was then copied to the data directory on the ArcIMS server. During the copy process the existing counties dbf file was effectively replaced by the updated version. These processing steps were automated using Visual Basic, ArcObjects, batch files, and the 24 x 7 scheduler software. No updates to the geometry were required.

5.3 Satellite data

Near real-time infrared imagery from the GOES East Satellite was included in EMHURR to provide insight into the intensity and structure of the storm. This imagery was supplied by NOAA's National Environmental Satellite Services Division (NESDIS), via the GOES east satellite. The imagery was downloaded every 30 minutes in a geo-tiff format to the ArcIMS Server. No further processing was required for this data layer.

5.4 River Conditions

The river conditions layers were included in EMHURR to assist emergency managers with identifying areas likely to experience river flooding due to a storm event. There were two river condition layers included with EMHURR. The Crest Forecast layer displayed only river stations with stage values were forecast to exceed flood stage. These stations were rendered in ordinal categories, based on the severity of the flood. The Current Stage layer displayed all river stations regardless of stage value. Stations in this layer were rendered in interval categories based on stage values ranges.

The river station data were downloaded every 30 minutes in a text format from the West Gulf River Forecast Center (RFC), and the Lower Mississippi RFC. The text file was decoded, and loaded into an output array. The output array contained a variable called 'ID' that was populated with the Site ID value for each river station, and several other variables that stored additional entity values. Each 'ID' value in the output array was then matched with the corresponding Site ID value of the attribute table (dbf) used to update the river conditions shapefile. The river stage values of the matching records were then updated with the latest river stage values from the output array. The updated dbf file was then copied to the data directory. These processing steps were automated using Visual Basic and ArcObjects, batch files, and the 24 x 7 scheduler software. No updates to the geometry were required for this layer.

5.5 Flood Outlook

The Flood Outlook data layer delineates polygonal areas where flooding is likely to occur. The flood outlook data was obtained once per day from the Hydrometeorological Prediction Center in a text format. The text file was downloaded, parsed, and converted to a new text file. The flood forecast polygon shapefile was then created in ArcView from the newly formatted text file and rendered according to flood likelihood. These processing steps were automated using Visual Basic, ArcObjects, batch files, and the 24 x 7 scheduler software.

5.6 Flash Flood Guidance

Flash Flood Guidance layers consist of counties rendered by the amount of precipitation required to induce flash flood conditions within a given county and timeframe. There are five flash flood guidance data layers included with EMHURR. Each layer is comprised of county polygon layers rendered by the amount of rain fall required to induce flash flood conditions within a 1, 3, 6, 12, or 24 hour time period respectively. The source of this layer is a dbf file obtained on an hourly basis from the Lower Mississippi River RFC. The dbf file was downloaded and pushed to the ArcIMS Server effectively replacing the dbf in the existing flash flood guidance layer. No updates to the geometry were required.

5.7 *Precipitation*

Forecast precipitation and observed precipitation data layers are both accessible through EMHURR. The forecast layer displays precipitation forecasts for 12 and 24 hour time periods. The observed layer displays the amount of precipitation measured in the previous 24 hours, and 7 day time periods.

The Forecast Precipitation data was obtained from the HydroMeteorological Prediction Center in a GRIB1 (binary compressed weather service data format). The data were downloaded once per day to the crunch server, and converted to a floating point file (flt) using a conversion utility developed by the NWS. The flt file was then converted to a GRID, and a variety of raster processing functions applied. The GRID was then converted to a polygon shapefile and pushed to the data directory on the ArcIMS server. These processing steps were automated using Visual Basic and ArcObjects, batch files, and the 24 x 7 scheduler software.

The Observed Precipitation data was obtained from the Lower Mississippi RFC as a dbf file. The dbf file was downloaded to the crunch server twice per day, and pushed to the ArcIMS Server, effectively replacing the dbf in the existing Observed Precipitation point shapefile. No updates to the geometry were required.

5.8 Wind

The wind data layer is composed of polygons rendered by tropical depression, tropical storm, or hurricane wind speeds. The source of this data was the National Digital Forecast Database (NDFD)[3] maintained by the Meteorological Development Lab (MDL). This data was downloaded to the crunch server hourly in a GRIB2 format (compressed binary weather service data format), and converted to a floating point file (flt) using a conversion utility developed by the NWS. The flt file was then converted to a GRID, and a variety of raster processing functions applied. The GRID was then converted to a shapefile and pushed to the data directory on the ArcIMS server. These processing steps were automated using Visual Basic and ArcObjects, batch files, and the 24 x 7 scheduler software.

6.0 User interface

EMHURR is based on an ArcIMS HTML template developed by staff at the NOAA National Ocean Service's Coastal Services Center (CSC). Their help with supplying the template, and follow-up support was instrumental to the success of the EMHURR prototype. The CSC template is a heavily customized version of the ArcIMS Designer produced HTML template. Major viewer customization was made to the table of contents, legend display, and the toolbar. In the following section these customizations will be described, and illustrated with screenshots.

6.1 Table of Contents and Legend

The table of contents was moved to the left side of the viewer and modified into a directory tree structure. Layers were grouped into categories that could be expanded to reveal data layers or extracted to hide data layers. Custom legends were created for each layer, and embedded within the tree directly below the layer. This structure provided a flexible method of viewing data layers by category, and allowed the site to contain many data layers without appearing cluttered. These customizations were made with HTML, and Javascript. The custom legend graphics were created with Macromedia Fireworks software, and saved in a gif or jpg format.

Below are screen shots of the table of contents captured during Hurricane Isabel. In figure 6.1a the Storms and Warnings category is expanded to reveal the Storm Path, Cone of Uncertainty, and Watches and Warnings layers. Layers were viewed by checking the layer selection box and clicking the Refresh Map button. The Watches and Warning layer was rendered according to warning type. The colors red, orange, and yellow were used to indicate the level of concern, with red being the most serious and yellow being the least serious. In Figure 6.1b the Wind Forecast legend category is expanded to reveal the 12 and 24 hour wind forecasts. The layer was rendered according to wind speed categories that correlate with tropical depression, tropical storm, and hurricane wind speeds. Notice that the legend color scheme applied to the Wind data layers is the same scheme that was applied to the WWA data layer, with red being the most serious. This color scheme was consistently applied to other EMHURR layers in order to create a uniform look and feel for the user.

Fig 6.1a – Storms and Warning Legend

Fig 6.1b – Wind Forecast Legend

6.2 Toolbar

The toolbar (figure 6.2a) was positioned at the top of the map frame in a horizontal orientation. Standard ArcIMS tools such as panning and zooming were retained in the toolbar. The Identify tool was customized and new tools for obtaining user feedback, and help were added to the toolbar. When clicked the feedback button opens an NWS web page containing a form for collecting user feedback. The help button when clicked opens an NWS web page containing information about the data layers, and the quick help button, when clicked, displays user instructions in the text frame positioned directly below the map display.

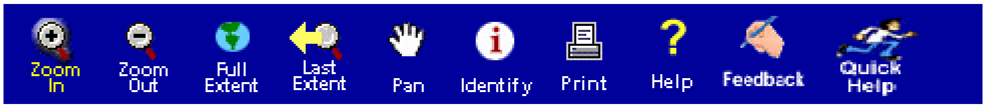

Figure 6.2a – Toolbar

Below is a screen capture (figure 6.2b) from EMHURR taken during the landfall of Hurricane Isabel. In the text frame directly below the map display is a table containing WWA information for Washington, County North Carolina. This table was returned when the user clicked on Washington, County with the identify tool. The identify tool was customized to return a pre-defined set of feature attributes in a newly formatted HTML table. The table below contains the county and state, type of event (flood watch), and the time of the event. Notice that the text values in the event field were converted to hyperlinks. These hyperlinks, when clicked, will take the user directly to a NWS Watches and Warnings web page, where more detailed information can be accessed.

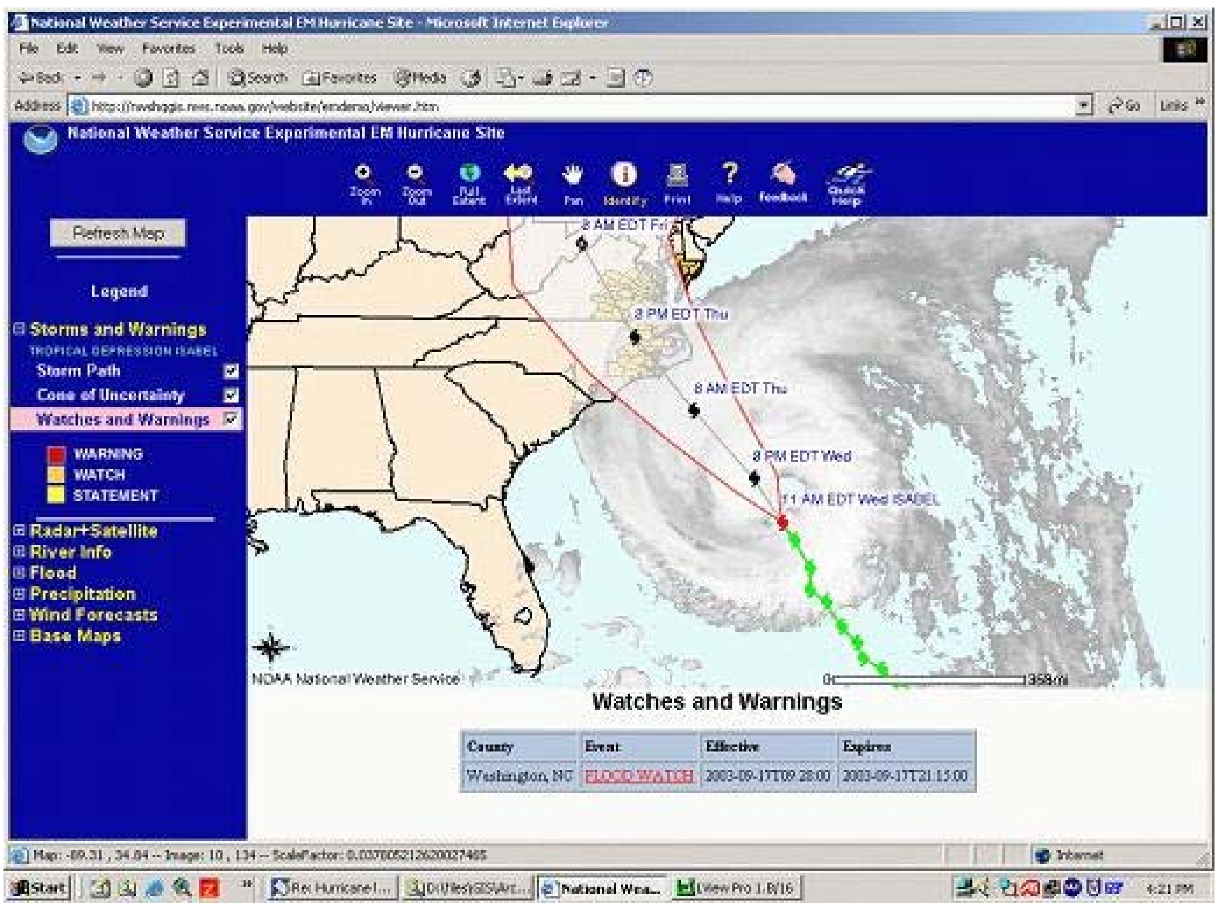

Figure 6.2b – Identify results for Watches and Warning data layer.

The Identify tool was customized in a similar fashion for the river conditions, flood outlook, and flash flood guidance data layers.

7.0 Lessons Learned

The real test for EMHURR came in mid-September during the approach and land fall of Hurricane Isabel. It was during this time that limitations of the processing software and the website were exposed. Of primary concern were limitations in the application's ability to adequately handle the increased volume of user requests. As server demands increased, response time decreased significantly.

The primary point of failure was believed to be the network connection between the crunch server and the ArcIMS server. The servers communicated with each other by sending files back and forth via mapped drives. A couple of issues impeded this communication process. First the network connectivity between mapped drives was lost, and second the processing and updating scripts lost synchronization due to the complexity of multi server processing of storm data. A third problem was a lack of on-site system support. Since Isabel made its way directly through Washington D.C., the federal government was shut down, and there was no onsite support to manually address these issues. Attempts to administer the site remotely failed due to widespread power outages in the area.

8.0 Future Plans

EMHURR is currently in phase II development in preparation for the 2004 hurricane season. The major objectives for phase II are the implementation of a database driven architecture, and the migration of data creation scripts to a Visual Basic/ArcObjects environment. The interface will also be modestly enhanced with the addition of some custom zoom capability, and a data extraction/download tool.

The phase II database centric architecture will hopefully solve some of the speed and communication issues encountered during Isabel. In addition, the scheduling software will be installed as a windows service, thus allowing it to be run automatically upon reboot and preventing multiple versions to be run simultaneously. The migration of the Avenue code to Visual Basic and ArcObjects will allow the crunch machine to do all the data processing, thus reducing the communication required between the servers. The use of ArcSDE should simplify the data update process, and increase the speed, capacity and overall performance of the site.

9.0 Conclusion

This project has proven that ArcIMS can be used as a vehicle for integrating, displaying and disseminating weather data. Data in a wide variety of formats, from multiple NWS programs, and NOAA line offices were leveraged to create EMHURR. The development of this application was dependent on the resources and support of staff from multiple NOAA line offices and NWS programs.

10.0 Acknowledgements

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11.0 References

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