2. The Application of Geo-Technologies after Hurricane Katrina

data needed for mapping pre and post disaster.

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Abstract

Geographic Information (GI) Science accelerated and enhanced decision-making in the emergency response after Hurricane Katrina. Since most of the information needed in disaster management has a spatial dimension, geo-technology is a vital source for streamlining response activities. The rapid-response situation after a disaster, however, exposes new challenges in the use of geo-technologies. In order to move forward and enhance the GI applications in disaster response, this paper pinpoints the bottlenecks and highlights the successes of the use of geo-technology after Hurricane Katrina. Challenges and accomplishments in the response to the storm are analyzed and lessons learned are documented in the five areas of management, technology infrastructure, data, workflows, and map products. One of the explanations for the experienced bottlenecks is traced to difficulties with regard to timely data access and dissemination; one of the successful practices was the intensive integration of web-based tools.

2.1 Introduction

While mainstreaming geo-information in disaster response is becoming increasingly recognized as a key factor for successful emergency management, systematic knowledge about the benefits and bottlenecks of geo-technologies in the response phase is still in fledging stages. In the complex, dynamic, and time-sensitive disaster response situation of Hurricane Katrina, geo-information enhanced decision-making and effectively supported the response but it did not reach its full potential. The overwhelming complexity of the disaster exposed challenges and highlighted good practices. Hurricane Katrina affected an area of nearly the size of the United Kingdom (230,000 square km), it killed more than 1,700 people, and the total cost of damage is estimated at more than $200 billion dollars. The destruction, which has affected primarily the coastal regions of Louisiana, Mississippi, and Alabama, was caused by high-speed winds, storm surge flooding in coastal areas, and in New Orleans also by levee failures.

Information management is a crucial component of emergency response. The ability of emergency officials to access information in an accurate and timely manner maximizes the success of the efforts. Since most of the information used in disaster management has a geographic dimension (Bruzewicz 2003), geo-technologies have a large capacity to contribute to emergency management. The capabilities of geo-technologies to capture, store, analyze, and visualize spatial data in emergency management have been documented in the literature (Cutter 2003; Zlatanova 2006; Carrara and Guzzetti 1996). Paradoxically, in praxis the convergence of the two fields of geo-information and emergency management is only rudimentary developed and little work has been undertaken to enhance the integration.

What were the bottlenecks of using geo-information in the response phase of Hurricane Katrina? Which mapping services were requested frequently? Which workflow procedures streamlined the mapping support? What were the best practices?

In the following these questions are addressed focusing on five areas:

- managerial lessons with regard to information flows and staffing issues;
- the perfidies of technology infrastructures in an emergency situation;
- important datasets and best practices of data documentation and access;
- workflows that streamlined the mapping response;
- the “stars” of the mapping products, which were requested or needed the most.

2.2 Lessons Learned

The knowledge about best practices was gained from the experience of GI responders. Input was gathered mainly during the Louisiana Remote Sensing and GIS Workshop (LARSGIS) in Baton Rouge, Louisiana, in April 2006 in which practitioners from the coastal southeastern United States presented and discussed their experiences of using geo-technologies after Hurricane Katrina. The author’s own experience in the Emergency Operations Center (EOC) of Baton Rouge after the storm also influenced this paper.

2.2.1 Managerial Lessons

Improving Information Flows
Large amounts of data were acquired and processed after Hurricane Katrina. In the immediate aftermath of the disaster, governmental agencies and private geo-technology companies, realizing the extent of the damage and the gravity of the situation, supported the relief efforts by contributing data. Numerous sets of aerial photographs were taken and distributed to assess flooding and damage, private companies donated satellite images, data, and hardware, and new data layers concerning emergency shelters or power outages were created. Public agencies released and shared existing but previously undisclosed data layers. The usual obstructive administrative barriers caused by competition and conflicts between divisions were abrogated, and instead ad-hoc alliances were built to support the common goal of saving lives and containing the devastation. Data streamed in quickly, resulting in the availability of a multitude of new data layers. The dissemination of the data to the appropriate parties at the desired locations in a timely manner, and in a useful format may have been the biggest challenge for the GI response community. Agencies were not always aware which information was available or where to find certain data. Due to miscommunication, excessive workloads, and general distress, information was distributed only to a limited extent and did not always reach the first responder crews or county governments in remote areas that were in crucial need of this information.

Information flows and structures between the different actors must be identified before the disaster. One possible strategy is to appoint a central data authority that collects and disseminates information, a solution that is effective but difficult to realize due to political and economic reasons. Spatial data infrastructures and web-based solutions have proven to enhance information flows and data accessibility. These tools should to be established before the disaster strikes.

Establishing Geo-Technologies as an Integral Resource
Mapping support often evolved as an ad-hoc component after the storm being triggered by a high demand for maps and geo-information. Impromptu volunteers were engaged or geo-information companies were hired on the spot. Emergency preparedness units need to recognize geotechnology as crucial part of disaster management and incorporate it accordingly into their planning. It is the task of the GI community to increase the awareness of emergency managers towards the value of spatial technology. During the emergency knowledge gaps became apparent on both sides: governmental emergency staff was unclear about the potential of

geo-technologies and the use of maps and the GI community was not informed about governmental disaster plans and strategies. Both parties have to gain an increased understanding of each other's duties and capabilities. Communication and training platforms are means to enhance awareness.

Building Partnerships

Formal and informal partnerships between GI professionals that were established before the disaster proved to be essential in the disaster response. Relationships facilitate coordination and thus the flow of information. One way to strengthen collaboration is the establishment of a workgroup of GI-skilled personnel in governmental agencies, universities, and private industries. Regular meetings foster networks and enable the exchange of news about available data and technologies.

Identifying Staff

GI responders were confronted with many requests for maps and an understaffing in the EOCs. It proved valuable to call on the support of GI colleagues. Volunteers played an important role in the response to Katrina, and it is recommended to integrate them into emergency planning. Staff to support operations during an emergency needs to be identified beforehand. If a disaster occurs, a call-up of pre-defined GI-skilled personnel should be initiated to assemble teams. The response teams should include staff from different governmental departments and from academia, assembling specialists from the different fields in geo-technology, such as remote sensing, programming, databases, and GIS. It is helpful to allocate staff to certain responsibilities pertaining to data collection, logistics, technical support, mapping, distribution, and operational management. Specific staffing challenges are caused by the 24 hours per day, seven days per week operations which require a high staff rotation. For the rotation not to affect efficiency, detailed documentation of requests, actions, files, and file locations are necessary.

2.2.2 Technology Infrastructure Lessons

Ensuring Hardware Resources

The EOCs were not or only rudimentary equipped for geo-technologies prior to Hurricane Katrina. Computers, plotters, printers, and other supplies had to be identified and installed after the storm. Difficulties occurred with regard to finding space in the EOCs not only for large hardware devices and storage systems for hard-copy maps, but also for laptops and workstations. Mapping teams should establish sources and localities of all necessary hardware beforehand and explain their special demands so that physical space in the EOCs can be allocated. In the response to Hurricane Katrina, innovative solutions were found, such as the one from a mapping team in Mississippi that remodeled a bus into office space and equipped it with workstations and printers.

Securing Continuity of Operations

Useful datasets were stored on computers that flooded or that were left behind in the evacuation. Data back-ups at multiple secure locations and mobility of hard- and software are to be established to enable continuous operations under emergency conditions and to avoid loss of data. Data accessibility was not only hampered by disrupted networks and flooded computers but also by logistical issues. In one case, important files were passport-protected and the responsible administrator could not be reached.

Preparing for Power and Network Disruptions

Power, network, and internet outages were frequently encountered. Ideally, alternative power supply solutions are identified beforehand, including generators and uninterruptible power supplies (UPS) which are battery backups that can be added to hardware devices to avoid data losses during power disruptions. Since it is not advisable to rely on network connectivity, sufficient data sharing devices are necessary for an efficient response. Moreover, regular back-up mechanisms proved to be valuable.

Administering Networks

Not only GI skills were vital for successful operations but GI staff installed intermittent network routers, virtual private networks and other network connections. Ideally, a network administrator is appointed who is in charge of connectivity issues.

2.2.3 Data Lessons

Acquiring Relevant Data

Base datasets, for example about pumping stations, utility networks, and power plants, were not always readily available. Especially for rural areas, geo-information was scarce. Information that proved to be of focal interest during the emergency can be divided into two categories: information that should to be collected before the disaster and information that is to be collected after the disaster.

Before the Disaster

Datasets that were vital during the response and that can be acquired before the disaster include but are not limited to:

- Pumping stations
- Street maps
- Elevation models
- Points of interest
- Fire stations
- Cadastral data
- Medical centers
- Geomorphology
- Land use
- Power plants
- Satellite imagery
- Hazardous materials
- Building footprints
- Helicopter landing places
- Special needs population
- Evacuation routes
- Population densities
- Day and night population
- Utility networks
- Emergency resources
- Address dataset

After the Disaster

Datasets that were frequently requested in the EOCs providing information on the extent of the catastrophe include but are not limited to:

- Wind fields
- Power outages
- Debris estimates
- Daily dewatering
- Power restoration
- Flood fatalities
- Satellite imagery
- Deceased victim locations
- Restored power
- Crime scenes
- Oil spills
- Flood depths
- Levee breaks
- Road restoration
- Emergency shelters
- Flood extent
- Fire outbreaks
- Points of dispensing
- Pollution
- Damage estimates

Sources need to be established for information that becomes available after the disaster. This can be accomplished with data sharing agreements, which should be set up prior to the emergency. These agreements determine which data will be provided by which organizations and who holds copyrights. For instance, uniform, useful, and complete image datasets were in high demand after Katrina. Therefore, contracts with companies providing aerial photography should be in place, specifying resolutions, area coverage, formats, geo-correction procedures, and accompanying metadata. Agreements need to include how often datasets will be updated since some of the mentioned data layers require daily updates. For instance, shelter locations opened rapidly in the immediate aftermath and then, after a few weeks, closed or moved. Information on flooded roads also needed daily updating, as did the locations of crime scenes.

Clarifying Copyrights

The clarification of data copyrights and privacy laws was time-consuming. It was difficult to reach those in charge to get permission for data dissemination because communication networks were interrupted, electronic address books were inaccessible due to flooded and left behind computers, and officials were dispersed because of the evacuation or not available during the weekend and at night. It is of advantage to negotiate data dissemination agreements, data sharing policies, and specifications of data custodianship before the disaster.

Collecting Metadata

After Hurricane Katrina, a multitude of datasets were disclosed and created rapidly. Maps showing the newly available information were requested, produced, and distributed in extremely short time spans. A central problem that arose from this incoming data stream and the stressful situation was that metadata tended to be neglected. However, crucial information is rendered unemployable if datasets are not properly documented. Moreover, metadata helps to maintain standards for data quality. Finally, missing metadata causes delays since valuable time is spent struggling to find out, for example, on which date an aerial photo set was taken and which area it covers. A metadata standard should be chosen that answers questions of data timeliness, source, accuracy, and coverage. Although metadata collection is time-consuming, GIS staff receiving data must be dedicated to metadata collection, ensuring that a predefined form is completed for all incoming datasets. A data manager should be assigned whose responsibilities include documenting metadata.

Organizing Data

In the response phase, geographic information must flow upstream and downstream between players in real-time. An effective means of accomplishing this dissemination of data is a spatial data infrastructure (SDI) which enables an efficient, reliable, and secure way for the search, exchange, and processing of relevant information. An SDI is a framework that subsumes a collection of geospatial data, technologies, networks, policies, institutional agreements, standards, and delivery mechanisms. Creating an infrastructure subsuming both general and emergency-related data with clearly laid out directory structures and logical names is critical for effective emergency response where many applications occur in real-time. The SDI datasets need to be updated continuously, and data integrity has to be maintained. The responsibility of data creation and maintenance for the SDI cannot lie with one individual organization; it must rather be a joint effort of many organizations.

2.2.4 Operational Lessons and Workflows

Avoiding Duplication of Efforts

Duplication occurred when maps, conveying identical information (e.g. damage levels, road flooding, or power outages), were created by several agencies. Coordination via the implementation of a map depository where central players submit and download maps is a possible solution to this duplication.

Tracking Requests

Keeping track of map requests was conventionally handled by means of paper files. A team from the Louisiana State University implemented an online tracking system that largely improved the paper system. This tracking system not only documented the actual request but also associated information including contact information of the client, file locations, and map products. The system allowed efficient communication with all members of the response team, which was particularly important due to the high staff turn-over and geographically distributed mapping operations. The documentation of file locations and templates was especially helpful for the preparation of the daily updates of certain maps such as road flooding and emergency shelters. Another feature of the system allowed personnel to be assigned to the various projects. Such a record system for requests, associated files, documents, staff, clients, and products proved to be useful and should be implemented before the disaster strikes.

Preparing Paper Maps

Despite increasing digitalization, paper maps were still essential for the response teams. A high demand of paper maps and only limited printing and plotting capacities caused delays in fulfilling requests and disseminating information. Base maps, especially street maps on different scales, can be prepared beforehand. Ensuring access to sufficient amounts of paper, printers, and plotters is crucial.

Creating Templates

Map templates were found to be useful in the response activities. In the case of daily updated information, consistent templates accelerated the creation of maps and facilitated the comparisons of changes. Predefined map templates containing many data layers, which are turned on and off according to specific needs, saved a considerable amount of time. The templates should be well documented and logically stored within the data structure.

Disseminating GIS Resources

It proved valuable to disseminate GI operations. While staff on site in the EOC took requests, promoted geo-technologies, offered solutions, and generated quick maps, staff in remote locations was able to create more sophisticated maps and provide analysis away from the whirl in the EOC. This approach also guaranteed access to hardware, especially printers, that were not backlogged as was often the case in the EOC.

Using Online Tools

Web-based tools such as Mapquest or Google Earth, were used intensively in the response operations. Not only the GI staff but many of the involved responding agencies and rescue workers applied especially Google Earth for their operations. Google Earth and Google Maps created satellite imagery overlays of the devastation in the affected region, which helped to understand the scope of the disaster. Single houses and addresses could be looked up in Google Earth, and a built-in transparency slider, which allowed to switch between before and after images, enabled to see if and how much damage a place experienced. The accuracy, ease of access and the ease of use at the time and point of need of these online tools that can be operated by non-GIS staff contributed to the wide usage of the tool. This experience highlighted the potential of a web-based community approach to disaster operations.

Promoting Geo-Information

Since rescue workers were often not versed in the potential of geo-information it was useful to have a GI staff member attend official EOC meetings to offer GI-based suggestions and solutions. Another way to convey the GI services to official was by means of fixing frequently requested maps on the walls or collecting them in a map book for display.

2.2.5 Map Products

Requests from Emergency Responders

The large majority of requests from emergency responders were related to street atlases and area overview maps. Commercial maps in stores sold out quickly or flooded and therefore, responders relied on the GI community. Great numbers of street maps were handed out after the storm. The acquisition of digital copies of city maps from commercial companies was helpful. Emergency responders who were not familiar with the area requested maps with photos of landmarks such as the New Orleans Superdome. Checkpoints, which were still standing after the storm, were included in the produced maps. This concept proved to be remarkably helpful for an orientation of the area especially since many street signs were flooded or destroyed. Another crucial orientation and communication means is a grid system for ground reference. After the disaster, some responders considered missing grids in maps as one of the central problems. It would be helpful if map books in compact sizes with the standardized US National Grid, street indices, landmarks, and elevation levels are produced before the disaster. Overlaying street and area maps with satellite inundation maps that outline the extent of the flood and the flood depth was another frequent request. For instance, by means of this data, rescue missions determined whether boats or high-water vehicles are used in a certain area. For the search and rescue operations, mapping of addresses and coordinates of victims was of major importance in the first days after the disaster. Ideally, this process would be automated. Coordinates from a mobile phone placing a 911 call could be tracked automatically and then transferred to handheld computers of emergency responders. Geo-technology can calculate the best routes for accessing victims' locations.

The Needs of the Public

Accurate and timely information for the public is necessary. The questions of if a house was damaged plagued the evacuees. Days after the disaster, in order to find out if and how deep a house was flooded, the evacuated population relied on photos from television and the Internet to recognize neighborhoods and the levels of flooding and destruction. The uncertainty added to stress and anxiety. This information could be conveyed using web mapping and aerial photographs taken after the disaster. Vector layers with flood depths and levels of wind damage can complement the information. A system could be established that allows people to enter the address of a building to find out water depths, damage levels, when and how they could travel to the building, and nearest emergency supply centers. Moreover, the public requires detailed knowledge about the assigned evacuation routes and the traffic circumstances, evacuation shelters, kitchens, health facilities, and other public services.

Requests from Government Officials

Government officials asked for maps with various contents, including shelter locations, deceased victim locations, power outages, water systems, maps of state-owned land, pumping locations, and others.

2.3 Conclusions

This paper identifies lessons learned from the application of geo-technologies in the response to Hurricane Katrina. The main challenges in the operations were not related to the often discussed literature themes such as interoperability and semantics but rather to trivial issues such backlogged printers, network disruptions, and missing metadata. Aloof from Virtual Reality applications, one of the most frequent tasks of GI personnel was to print street books and visualize search and rescue coordinates. Truly analytical GI applications going beyond simple map displays were sparse. Experience shows that the suitability and use of GI technology in the response phase differs from the planning phase because of the urgency, uncertainty, the magnitude of stakeholders, some of whom are unfamiliar with geo-information, and the real-time data needs.

Among the most useful GI products created were inundation maps and map books with landmarks, detailed elevation figures, and unified grid systems. Web-tools such as Google Earth proved to be helpful due to their relevancy, ease of use, and open access. There are reasons to believe that the field of geo-information for disaster management will eventually benefit from further developments of visual environments, semantic interpretations, and other current research topics. Most likely, the future use of geo-technologies will extend beyond mapping and move towards analytical processes. This will especially be the case when emergency managers gain knowledge in geo-information and its capabilities. Currently, however, improvements on the ground are necessary on basic levels. Other analyses of geo-information in disaster management (Kevany 2003; Zerger and Smith 2003; Curtis et al. 2005) report similar experiences, stressing the practical impediments of implementations. Existing knowledge about best practices need to be translated into action, programs, and relevant policies. To enhance the response, the often separate discourses of geo-technology on the one hand and emergency management on the other need to converge.

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