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Development of an online hazards atlas to improve disaster awareness

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Understanding the causes, effects and geographic patterns of local hazards is important for helping individuals make educated decisions about how to respond to their threat. Unfortunately, it is often difficult to find comprehensive sources of information about local hazards. In this paper, we discuss the development of an online hazards atlas for the state of South Carolina. We have designed this atlas to facilitate awareness about the causes and effects of hazards. An effective method for communicating this information is through education and awareness programs for children, so we have designed this atlas primarily as an educational tool for K-12 students. However, we have also structured the atlas to ensure that it provides details of interest to the general population. In this paper, we focus on educational, methodological and technical aspects of development of the online hazards atlas to highlight both the benefits and challenges of this type of product and to emphasize where it fits as a tool for improving hazards education. In addressing these issues, we present a model that can be adapted for use in other geographic areas.

Keywords: hazards; geography education; online atlases; interactive maps; hazards preparedness

Introduction

The recent *Grand Challenges for Disaster Reduction* (NSTC [National Science and Technology Council – Subcommittee on Disaster Reduction], 2005) report suggested six broad challenges for reducing the impacts of disasters – one of these challenges was to "promote risk-wise behavior" through better communication of information about hazards (NSTC, 2005, p. 2). Learning about the causes, effects and geographic patterns of hazards is an important part of understanding the local environment. A population that is knowledgeable about hazards is critical so that individuals can make educated decisions about how to respond to the threat of different types of hazards; this can help to create a more "safe society" (Press, 1989). Thus, there is a need for focused educational materials designed to improve public awareness so that individuals can make more intelligent decisions about preparing for, surviving and recovering from hazards when they occur. Blanchard-Boehm and Cook (2004) have indicated that in order to motivate hazard preparedness and mitigation, we need resources that can communicate clearly to individuals with little to no personal experience with specific hazards. Even for individuals with personal experience, the reiteration of information about the risks of hazards is important. Unfortunately, it is often difficult to find comprehensive sources of information about local hazards (Thomas, Mitchell, Scott, & Cutter, 1999).

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To help improve risk-wise behavior and educate people about hazards, it is important to raise public awareness of local hazards (NSTC, 2005; Vitek & Berta, 1982). One way by which this can be done is through the development attractive, easy to use and up-to-date sets of materials that can clearly explain the causes and consequences of hazards and their geographic patterns (Blanchard-Boehm & Cook, 2004). Izadkhah and Hosseini (2005) have suggested that one of the best ways to do this effectively is to focus on education and awareness programs for children. Children tend to be more enthusiastic and receptive to education related to hazards and can serve as an educational conduit to transfer their new knowledge about hazard preparedness to their family and friends. Through children's educational programs, we also make it more likely that these students will grow up to be more educated and aware citizens. To accomplish this transfer of knowledge, we have concentrated efforts on developing an online atlas of hazards as an instructional tool for K-12 students; however, the atlas is also accessible to the general public.

In this paper, we discuss the process for developing an online hazards atlas. We started with the existing CD-ROM (compact disc read-only memory) *South Carolina Atlas of Environmental Risks and Hazards* (Cutter, Thomas, Cutler, Mitchell, & Scott, 1999) as a model and then moved toward a more accessible and flexible online format. Specifically, we discuss technical, methodological, educational and usability challenges and how we addressed them in order to ensure that this model for hazards atlases could be adapted by people in other geographic areas around the world with minimal funding and time required. We also discuss the benefits and the challenges of transitioning from a CD format to an online format.

Background

Hazards education

A number of factors drive teaching about environmental hazards: (1) the belief that understanding events might help us avoid their consequences; (2) their spectacular impacts interest students; (3) their routine occurrence makes for useful "current event" discussions; and (4) hazards allow for an integrative discussion of physical and social systems (Mitchell, Borden, & Schmidtlein, 2008). Hazards education has previously focused on two main areas. The first appraises the content of hazards instruction or methods of delivery (Lidstone, 1990, 1996; Mitchell et al., 2008). The second follows the creation of teaching materials, such as hazards maps, and their use (Anderson, 1987; Butler, 1988; Cross, 1988; Lewis, 2006).

This project builds on the lessons learned from this literature. First, we recognize that hazards can be useful in capturing a student's attention. Second, the visually powerful use of maps and other spatial representations improve our ability to help people understand the personal implications of local hazards. Additionally, maps and other spatial representations can do more than illustrate – they can lead to improved spatial thinking (National Research Council, 2006). By developing an online atlas, we can capture these findings and present them to students in a form that is reflective of the local environment that they know. Potentially threatening events can be analyzed along with other circumstances that may modify the severity of their impact.

In general, we can use hazards atlases, such as this one, to address many national or state educational standards. For instance, the type of information included in this atlas can be used to focus on hazards-specific standards, for instance that students understand human, agricultural and economic costs of various natural disasters that have impacted the local area. In addition, there are also numerous places where the materials used in a hazards atlas apply to general standards and can be used to incorporate hazards education while meeting other educational requirements, such as the numerous literacy and technology standards (e.g. learning use and interpreting maps, charts, diagrams and other reference information). Hazards education can also be used to encourage students to broaden their knowledge to other subject areas and to learn more about the environment in general (Measham, 2007).

Additionally, hazards atlases can be used to emphasize the global nature of hazards. As Lidstone (1996) has noted, geography is the main area in which hazards and disasters are taught and that "a good geographical education must also achieve good environmental education" (Lidstone, 1996, p. 1). For teaching about hazards at the local and global scale, we need to have quality, up-to-date resources that provide a variety of materials about relevant hazards (e.g. causes, consequences, risk, likelihood, etc.). This project addresses this need by presenting research that establishes a protocol and method for development of this type of up-to-date material.

Existing hazards atlas

In 1999, the *South Carolina Atlas of Environmental Risks and Hazards* (Cutter et al., 1999) was published as a CD-based resource to be used in K-12 classroom instruction, as well as to serve as a resource for the general public. This atlas reviews 15 types of environmental hazards that threaten the state of South Carolina. These include hurricanes, tornados, floods, earthquakes and the hazards of everyday life such as vehicle accidents. Each section of the atlas provides a general description of one environmental hazard and offers practical preparedness information. Detailed explanations and extensive maps and graphs illustrate the historical and geographical patterns of hazards that affect the state. The atlas also contains narrative sound files to aid young readers, or individuals with reading or vision problems, in using the atlas. The original version of the atlas is discussed extensively by Thomas et al. (1999).

While the CD atlas has been a benefit to South Carolina classrooms, the materials presented are now out of date and the format does not allow for easy updates without a complete re-creation and re-pressing of the material onto new CDs. While this method of distributing atlas materials was still novel and relevant in the late 1990s, due to improvements and cost reductions in hardware, software and technologies for distributing digital files, it is no longer an ideal medium for presenting data that benefit from frequent updates or modifications. Online distribution for educational materials, such as the atlas that we discuss in this paper, has become more feasible.

Online atlases

Why should we focus on the development of online atlases for natural and environmental hazard education? The cartographic community has been discussing the potential benefit of digital atlases for more than 20 years (e.g. Trainor, 1995; Waters & De Leeuw, 1987), though only in the past decade it has become practical for nonprofessionals to create successful online educational atlases. The lag between recognition of benefit and possibility of implementation has been largely due to limited availability of hardware, software and high-speed Internet connections that are necessary to develop and distribute the atlas to schools. As of 2005, the National Center for Educational Statistics reports that nearly 100% of public schools in the US have access to the Internet, with over 90% of instructional classrooms having access; almost all of these schools use broadband connections. This is a substantial increase from the 35% of public schools and 3% of instructional classrooms reporting Internet access in 1994 (US Department of Education, 2006).

Simply having the hardware, software and distribution abilities necessary for online atlases does not express why this is a format that we should consider over traditional print atlases or other forms of electronic atlas (e.g. distribution on CD or DVD [Digital Versatile/Video Disc]). There are many reasons for migrating to online formats for this type of educational material. Maintaining temporal relevance of content, connections to relevant digital materials (e.g. links to other material outside the atlas and curriculum content material for teachers) and providing multimedia and interactive capabilities are a few reasons.

In terms of temporal relevance, print and electronic atlases produced in read-only formats are destined to become out of date almost immediately upon creation. In order to maintain student interest in the atlas, it is important that the information presented be temporally current and geographically relevant. The previous version of the hazards atlas was issued on CD-ROM and contained data that are now more than 10 years old. This meant that many of the students using it had no memory of any of the major hazards discussed since they happened either before the student was born or very early in their life. While maintaining relevance to the lives of the students using the atlas is important, it is possibly more critical to ensure that teachers have up-to-date standards-based curriculum materials to use in conjunction with the atlas. If this type of atlas is to make a difference in education, it must be carefully connected to the standards that teachers must address in their lessons (Mitchell, 2009). Using an online format ensures that as the standards are updated (the South Carolina standards were updated in 2005 and are presently being revised again), new materials can be created and distributed without having to re-create or re-print the rest of the atlas.

With respect to taking advantage of the multimedia capabilities of online materials, constructivist learning theory tells us that learning is more meaningful when the learner is allowed to select the information that is most relevant to the task at hand, organize it and integrate it with existing knowledge (Mayer & Moreno, 2002). Online atlases provide a medium where it is easier to provide this type of access to information. The developer can design maps and charts so that the reader can passively evaluate them (as one would read a traditional paper atlas map) or so that the reader can actively explore them through the use of interactive components that help the reader to select and organize information. This can be as simple as the reader moving the mouse over the graphic to obtain additional information about portions of the graphics, or through clickable maps and graphics that bring up photos, charts, videos or other relevant materials. All of these additional features provide readers with multiple cues (e.g. graphical and textual) to use in shaping their knowledge of hazards. Of course, we must still ensure that the learning materials do not present a situation of cognitive overload where the learner is overwhelmed by too many elements or a display that is too complex.

Specifically, from an educational standpoint, research demonstrated that Internet-based lessons have potential for improving teaching and learning, but that teachers are often unprepared to teach effectively with them (Wallace, 2004). By migrating to an online format and allowing the atlas to link to, and take advantage of, the vast resources available on the Internet, we add an additional dimension to the atlas. This can increase the educational potential for the atlas by allowing readers to expand their knowledge of hazard topics through further exploration (e.g. the Earthquake chapter can link directly to the United States Geological Survey [USGS] website with live updates of recent earthquake activity [USGS, 2009]); however, it may also increase the complexity of *teaching* with the atlas since the material is no longer a finite packet of information. Realizing that successful teaching with the Internet is made more complex by the vast amount of information that needs to be sifted through by the teacher in advance and that development of topic-specific activities is time consuming, the updated atlas was designed to include prepared curriculum materials that are standards based and grade specific.

Leveraging the technological improvements of the last decade, we have developed a model for online atlases of natural and environmental hazards that is simple to create, easy to tailor to meet specific state or national standards and requires limited technological skill and funding to develop. In the next section, we discuss the technical details of the creation of the atlas and how we have planned for future customization and expansion.

Atlas development

We relied on a multistep process to ensure that the atlas met the needs of our intended audience. In this section, we discuss the general design of the atlas and the software and data requirements that were necessary to develop the atlas.

Needs assessment

We first completed an evaluation of the CD version of the atlas to ensure that our update would meet the needs of its primary users (teachers and students). To evaluate the existing atlas, we worked with a focus group of seven in-service teachers that had extensive experience by using the CD version of the atlas in their classroom. As an incentive to participate, we offered reviewers a small monetary honorarium when they returned their evaluation. We gave each member of the focus group a new CD copy of the original atlas and an instruction document to guide their review. For the review, we asked each reviewer to review the atlas in three main categories: Content, Organization and Curriculum. Reviewers completed their reviews independently and returned their responses by mail. In their evaluations, we asked reviewers to indicate whether the information presented was complete and accurate (rating their agreement on a Likert scale from 1 to 5, with 1 being "Disagree" and 5 being "Agree"). In addition to indicating their perception of completeness and accuracy of the section, we asked for written comments for additions or suggestions for improvement.

In response to the statement that "the information presented is complete and accurate", the average response for all chapters was 4.74/5; the teachers in the focus group agree that the content of the existing atlas was complete and accurate. The lowest rated chapter, "Winter Hazards", received a score of 4.25. While the reviewers rated all of the chapters very highly, they also indicated that the information presented needed an update in order for it to continue to be effective as an educational tool. There were also suggestions that an updated atlas would benefit from the inclusion of specific information about recent severe events.

In terms of the mapped content, the feedback that we received indicated that the maps were of high quality and sufficient for describing the spatial patterns of hazards in South Carolina. Most of the written feedback received on the mapped content was how we could *add* more information to the existing materials. It was mentioned by reviewers that they would like to be able to obtain specific values for counties shown in classed choropleth maps and would like to control what base data are available on maps (e.g. adding and removing layers of data that were relevant to the map theme).

Outside of the feedback from the focus group, we also examined the review written for the original CD atlas (Monmonier, 2000). The primary criticism in the review was with respect to cartographic design. While most of the maps were identified as being sound in their adherence to good practices in data representation, there were several instances where choropleth maps were used inappropriately or where symbol choices were thought to be confusing. Additionally, Monmonier noted that there were areas in which the educational benefit of the atlas could be enhanced through additional maps or references. Our design decisions for content and format of the new online atlas were guided by the praise and criticism that we received in response to the original atlas from our initial focus group of in-service teachers, as well as by the suggestions for additional materials and methods of interaction that were received during a larger evaluation of the preliminary design of the atlas (reported below in the “Follow-up evaluation and refinement” section).

General design

We designed the atlas to be easily navigated by students. When a reader “enters the atlas”, the reader first encounters general information about environmental hazards; lists of common natural, social and biological hazards; and the frequency with which these hazards might occur. Readers can also easily access information about general ways to prepare for hazards (e.g. the creation of disaster supply kits, the contents of these kits and the creation of family disaster plans). The hazards selected for inclusion are specific to South Carolina and include 12 hazards (drought, earthquakes, flood, hail, heat, hurricanes, lightning, severe storms, tornados, wildfire, wind and winter hazards). Currently, the atlas emphasizes natural hazards; however, the number and type of hazards that can be included is unlimited and depends on the hazards that impact the local area for which the atlas is developed. For each hazard, the atlas has five sections: General Information, What You Can Do, About SC, Links, and Lessons (see Figure 1). The main page for each hazard starts with general

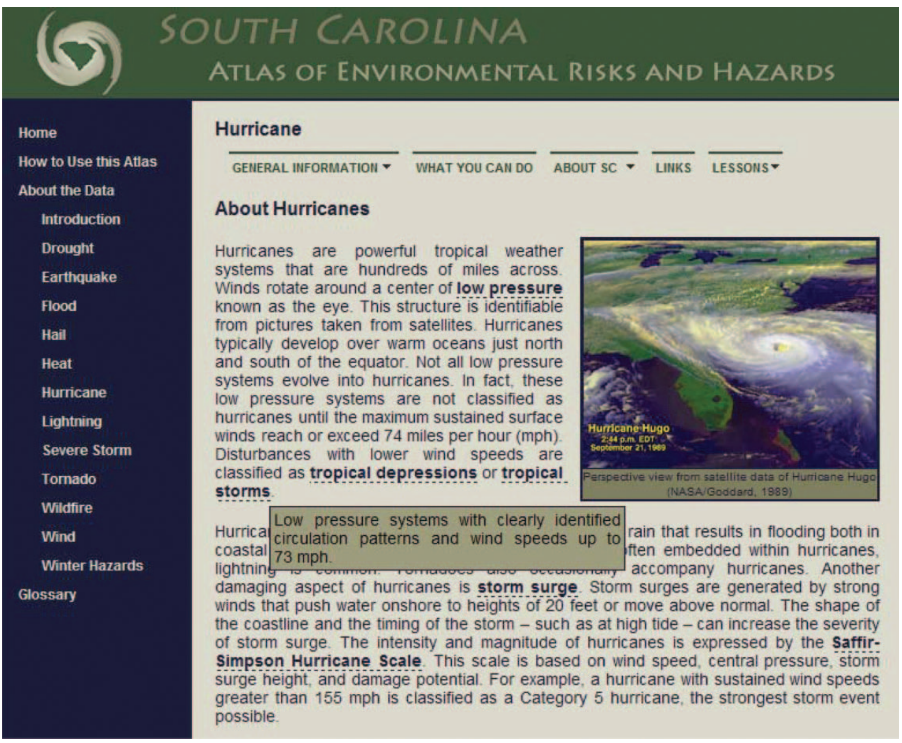

Figure 1. Hazard information page. For each hazard, the atlas contains five main sections: General Information, What You Can Do, About SC, Links and Lessons. Key terms are highlighted in this graphic with a "mouse-over". The term “tropical storms” is defined in the graphic.

information, including how the hazard and/or how it occurs and information about how scientists typically measure or quantify it (e.g. the Mercalli scale for measuring earthquakes). In these introductory sections, we highlight key terms and provide mouse-over definitions to help students interpret the material (definitions are also included in the atlas glossary). The "What You Can Do" section provides information on what you can do in advance or during a hazard event, how or where you may encounter event warnings and what different warnings mean (e.g. "hurricane watch" vs. "hurricane warning"). The "About SC" section consists of a series of interactive maps, charts and video clips documenting the impact of each hazard to depict specific issues related to the hazard's occurrence in South Carolina. The "Links" section provides links to online resources related to each hazard, and "Lessons" links to lesson plans for elementary, middle and high school grade levels.

Follow-up evaluation and refinement

Following the development of a prototype of the atlas, further evaluation was done by in-service teachers interested in using the atlas in their classroom. Fifty teachers – all attendees at two geography education conferences (25 at each event) – were shown a demonstration of the atlas and allowed to explore, ask questions, and make suggestions for improvement. Key changes that resulted from the follow-up evaluation were the addition of video clips and captions. The videos typically show news footage covering a local disaster event. For example, news stations often provide fly-over video after a hurricane to show the extent of damage. Captions were also added to explain interesting patterns present in the maps and graphs. Functional suggestions provided by the teachers, such as an easier "entry" point into the atlas, were also considered to improve the usability of the atlas.

Information resources

While there are countless sources for hazards data, they are not all equal in quality or coverage (Gall, Borden, & Cutter, 2009). These issues were a primary constraint in our development of this online atlas. With respect to data quality and coverage, we felt it was important to ensure that the data used in this atlas relied on the same (or very similar) methods for data collection and that the geographic and temporal coverage of the data were also comparable. By ensuring that the data sources met this requirement we were able to develop an atlas where users are able to make *comparisons* between hazards to assess their impact on the local area. For fostering knowledge about different hazards that impact a geographic area, this ability to make comparisons is important – and it is not possible unless the data represented are for the same time and represent the same attribute. For example, to compare the cost of damage caused by hurricanes versus tornados requires that the two data-sets represent the same time period and geographic area, rely on the same method for compiling cost of damage, the costs have the same inflation adjustment to ensure they are reported in current year dollars and the symbolization and classification methods are consistent across both maps.

To meet these requirements, the atlas relies primarily on data from the Spatial Hazard Events and Losses Database for the United States (SHELDUS). SHELDUS was developed by the Hazards and Vulnerability Research Institute (2009) at the University of South Carolina. The database is a county-level hazard data-set for the entire US that records 18 different natural hazard events types such as thunderstorms, hurricanes, floods, wildfires and tornados. For each event, the database includes the date, location (county and state), property losses, crop losses, injuries and fatalities that affected each county.

SHELDUS allows for adjustment of dollar values for losses; this makes it possible to report all loss values using a constant year (e.g. in 2008 dollars). SHELDUS was selected as a primary data source since the data are available for free through the SHELDUS website (http://webra.cas.sc.edu/hvri/products/sheldus.aspx) and is geographically and temporally comprehensive – containing more than 600,000 records for the entire US and spanning the years from 1960 through 2008.

In addition to using SHELDUS as a data source for the atlas, we also obtained county-level data from the USGS and the National Oceanic and Atmospheric Administration (NOAA). We used these resources for specific data on earthquake location and intensity, drought indices and storm data that were not otherwise available through SHELDUS. Both USGS and NOAA provide county-level or other appropriate regional levels of data for the entire US; they also provide data at the global scale, so can also be good resources for hazards information relevant to regions outside the US. The data from USGS and NOAA are available for the same time period as the SHELDUS data.

Outside of standardizing the databases, we also standardized our classification schemes so that they are consistent across all maps of the same type. Only by standardizing the classification methods and class breaks for each map type (e.g. dollars of damage, number of events, etc.), and by using consistent symbolization does it become possible for a reader to make valid comparisons across the maps.

Software and distribution issues

In our design process, we recognized that the availability of specific computer hardware and software will vary between schools. To address this, we needed to ensure that the final atlas would be accessible regardless of operating system (i.e. Windows or Mac), speed or lack of Internet connectivity or software. With these requirements in mind, we opted to focus on an HTML and Adobe Flash-based model for creating the atlas. HTML and Flash files can be viewed online or locally if the atlas files are distributed in a CD format. They are also platform independent so the readers can view them using any operating system. The software required for viewing these files is typically preloaded on computers or the reader can downloaded it for free.

An atlas developer can create HTML files with any number of free (or for cost) programs, but to develop Flash files, one needs to purchase the Adobe Flash program and, more importantly, learn how to use it. This posed a problem for us in that we wanted a model that was *easily accessible* for anyone who wanted to develop this type of atlas. We found a solution for this problem in a standalone program called FusionMaps (2009). FusionMaps is an inexpensive program that provides premade maps for all counties and states in the US (and all continents and major countries in the world) and allows for easy creation of animated and interactive maps with no knowledge of Flash required. The maps in FusionMaps are all based on an XML (Extensible Markup Language) file that the developer can create using a graphical user interface provided by FusionMaps, or the values can be typed in by hand. While using XML files with FusionMaps may sound complicated, we were able to follow the well-written documentation and were creating our first maps within 15 minutes of purchasing the software. Using FusionMaps, we were able to easily create choropleth maps with basic interactivity such as mouse-overs that provide readers with detailed information about locations and attributes without any programming required. To create the interactive maps, we linked the attribute data that we collected from SHELDUS, USGS and NOAA to the FusionMaps. On the basis of the data available, we used choropleth maps to show the amount of damage (in 2008 dollars), number of injuries, number of fatalities and number

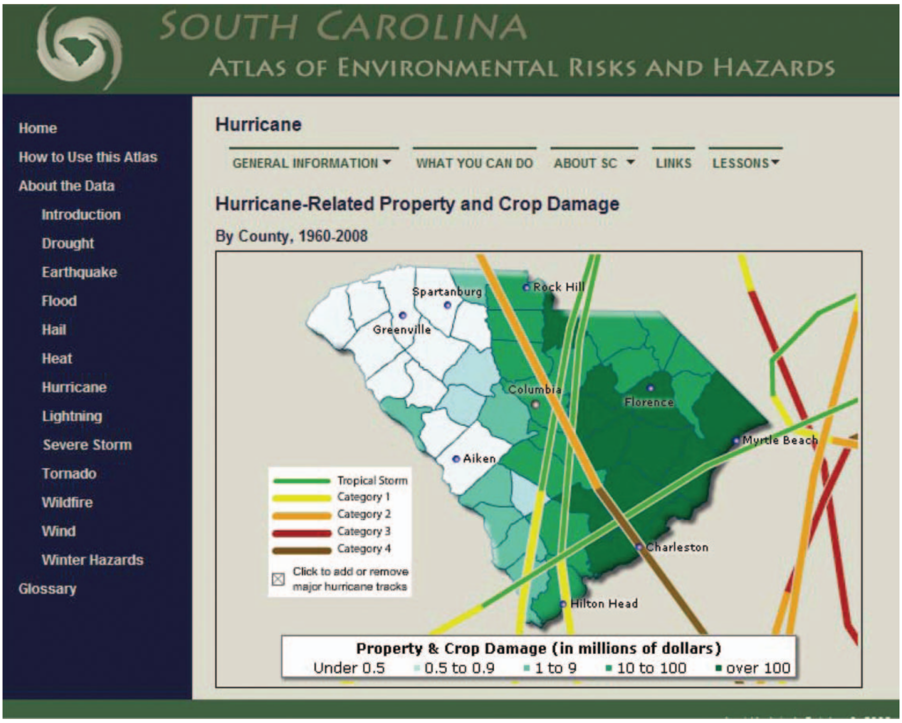

Figure 2. Hazard map page. Hurricane tracks are shown over hurricane-related property and crop damage.

of events for the hazards. We also created maps showing point locations of earthquakes reported in the state and hurricane tracks (see Figure 2).

In addition to the mapped content, which primarily focuses on aggregated impacts of hazards over time, we also created charts to show the impact of each hazard over time. For example, Figure 3 shows details of the number of tornado events over a 20-year span. We created yearly charts to show the number of events, injuries and fatalities and amount of damage. For hazards that tend to show seasonality in their occurrence, we also created monthly charts (see Figure 4) to better show those patterns. To update the files that create the maps and charts when new data are released in SHELDUS or the other databases used, we only need to make simple modifications to the data values in the XML files.

To design the nonmapped portion of the atlas, and to manage all of the content that was developed, we used the Adobe Dreamweaver web development software. We then uploaded the entire contents of the atlas onto the http://www.hazardsatlas.org website. If needed, we can copy these files onto CDs so that teachers in classrooms without Internet access can still use the atlas.

Discussion

This paper has discussed some of the issues that are of concern to the creation of an online, interactive version of the *South Carolina Atlas of Environmental Risks and Hazards*. While the translation is between two digital formats, the move to an online format allowed us greater flexibility in the type of content that can be included, increased the audience

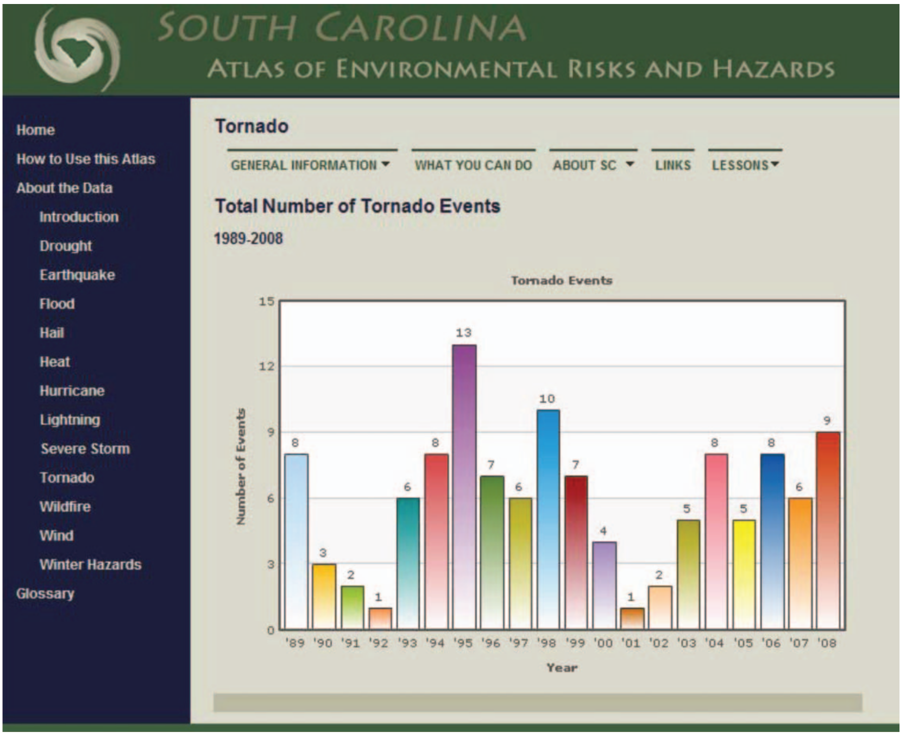

Figure 3. Hazard event chart. Tornado events are shown for 1989–2008.

to whom it can be distributed, decreased the cost of distribution and, most importantly, improved our ability to update the detailed information about each hazard as well as the educational materials that can be distributed to teachers. The ability to maintain an up-to-date, easily accessible set of educational materials about local hazards is critical for facilitating awareness. The fact that it is challenging to find comprehensive sources of information about local hazards, their frequency and severity makes the development of this type of atlas a necessity.

While this particular atlas has focused on the state of South Carolina, it is not a project that is only relevant to this one location. The methods and process discussed in this paper can be used to develop similar atlases for any region of the world. This would allow for an exploration not only of the local impacts of hazards but also about the global nature of hazards – a goal of geographic education (Lidstone, 1996). Comparisons between regions and the world would give students opportunities to identify global patterns of occurrence for different hazards, as well as for examination of the differences in relative impact of hazards due to social, economic, geographic or other conditions of the regions.

While the need for hazards atlases is apparent, developing an online atlas of hazards – or any educational atlas – is not a process that can be done without careful thought. In our development process, it was important to us that the atlas be designed to ensure that it meets the needs of the end users and is designed in such a way so that it supports the educational process. This means that there needs to be careful consideration of the state and/or national educational standards, identification of the most likely users, design to meet the knowledge and skill level of these users and development of protocols to ensure timely, and seamless, updates to the atlas materials.

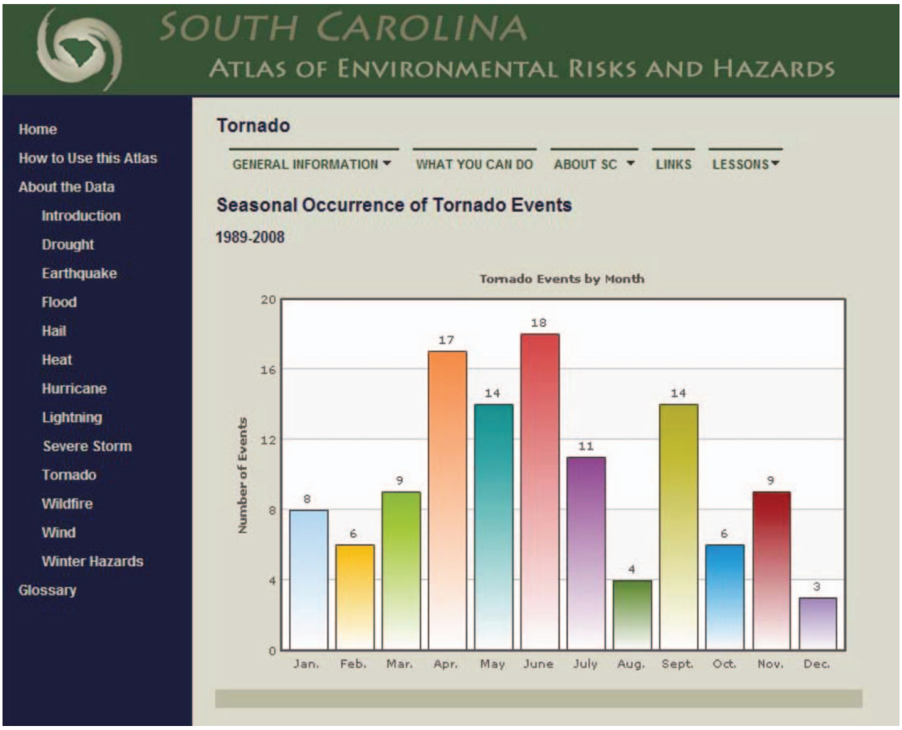

Figure 4. Hazard seasonality chart. Severe storms seasonality is shown for 1989–2008.

Through our design process, we took care to incorporate a user survey to ensure that the final product meets the needs of its primary audience of K-12 students and teachers. We also made a substantial effort to find methods for developing content that would be easily reproducible by others so that the concept behind this atlas can be used in other states to help improve hazards education. We hope that this atlas will be able to serve as a prototype for other states and that eventually we will be able to develop a nation-wide hazards atlas, and that others will take up the educational goals of developing similar atlases to educate students about hazards in other countries around the world.

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