Towards a Community "Playground:" Connecting CyberGIS with its Communities

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Abstract While high-performance computing is a fundamental component of CyberGIS, equally important is establishing a fundamental connection between CyberGIS and the various user communities requiring it. This involves the sharing, communication, and collaboration of authoritative, relevant spatial science not only among GIS specialists within their respective organizations, but across related scientific disciplines, between government agencies, and even to interested citizens seeking easy access to complex spatial analysis through a tailored, simplified user experience. In order to best to achieve such effective sharing and collaboration, one must also seek to understand the advantages and limitations of cloud computing in the context of spatial computation. We briefly introduce some key concepts of cloud GIS, followed by several use cases ranging from optimizing community resource allocation decisions, to coastal and marine spatial planning, to assessing solar energy potential in urban areas, to understanding river and watershed dynamics. These examples underscore the great potential for CyberGIS to provide as a fundamental component an environment for users of varying background and abilities an environment in which to perform and evaluate spatial analyses in a "community playground" of datasets, maps, scripts, web-based geoprocessing services, and GIS analysis models. Indeed, exposing the power of spatial analysis to a larger audience (the non-GIS audience) may be the biggest long term value of CyberGIS, helping it toward the ultimate goals of facilitating communication and collaboration, breaking down barriers between institutions, disciplines and cultures, and fostering a better connection between CyberGIS and its many communities.

Keywords Cloud computing, geoprocessing services, community collaboration, SaaS

9.1 Introduction

High-performance computing, especially by way of parallel and distributed processing, constitute a fundamental core for CyberGIS. There is also a clear need for understanding and improving scalable and sustainable software ecosystems. However, equally important is the fundamental connection of CyberGIS to the user community that requires it, in order to optimize domain science, and to communicate and collaborate with scientists in related disciplines. This involves the sharing of authoritative, relevant spatial science not only within organizations, but across disciplines, between agencies, and ultimately with scientists from other domains who need this kind of capability, but lack the knowledge, the time, and/or the skills to access it. This extends further to the broader domain of non-GIS specialists, including interested citizens who want to ask spatial questions in a simple way and obtain answers they can understand. Hence, this chapter posits that the real paradigm shift and value of CyberGIS may be in exposing geospatial data, inquiry, and analysis to the non-GIS community.

But how best to achieve such effective sharing and collaboration? Overcoming the key technical challenges of CyberGIS such as managing a growing array of sensors and platforms (e.g., Goodchild 2007, Heavner et al. 2011), bigger and faster data streams (e.g., Yang et al. 2011, Berriman and Groom 2011, Allen et al. 2012), and an unrelenting evolution in computing architecture (e.g., Wang and Liu 2009, Yang and Raskin 2009) is a critical first step. This is coupled with the opportunities presented by CyberGIS for achieving more comprehensive answers to larger and more important spatial problems, as well as the expanded use of spatial analysis for informed decision making (Wright and Wang 2011). One must also seek to understand the advantages and limitations of cloud computing in the context of spatial computation, including analysis integration and service chaining, moving algorithms to data, and identifying and targeting key analytics and data of high value.

In facilitating easier access to CyberGIS, the chapter will first briefly establish some foundational concepts of cloud GIS, including the provision of easy-to-use, scalable, targeted services bound to authoritative, curated data (i.e., "intelligent web maps"); simplifying the practice of authoring and consuming services; making GIS accessible through a growing array of platforms (browser, mobile, and cloud); and developing easier modes of sharing not only maps and data but the analyses (i.e., the geoprocessing workflows, the "tradecraft" of the specialist). These concepts are further illustrated via several brief use cases: the Community Analyst software as a service (SaaS) platform for optimizing resource allocation decisions; the SeaSketch SaaS platform for coastal and marine spatial planning; Solar Boston which tracks the city's reduction of greenhouse gas emissions; and the StreamStats application for obtaining stream flow statistics, drainage-basin characteristics. All of these use cases aim toward the ultimate ability of the user to perform and evaluate a wide array of spatial analyses in a "community playground" of maps, scripts, web-based geoprocessing services, and GIS analysis models, thereby facilitating communication and collaboration.

9.2 The Emergence of the Cloud

Until fairly recently, GIS has been leveraged in a traditional platform capacity with respect to its relationship with computing. Geospatial analyses; data generation, cleansing and management; map production; and document sharing – to name a few – have been performed on-premise, within an internal data center, via a local- or wide-area network. These tasks were typically executed on single purpose systems in a client-server environment, dedicated to a finite user base or a specific group or perhaps just one individual. The resulting output was often a paper map, or data locally rendered visually on a desktop, or a static image, and with limited channels to share the results in a timely fashion.

With the advent of cloud computing and web mapping as a new platform for geographers, there is an opportunity to reinvent the GIS application, as well as extend the discovery and availability of spatial data and geospatial analyses. Cloud computing provides the potential for access to and publication of dynamic data, as well as the consumption of real-time information for analyses and modeling. Cloud GIS allows one to use GIS over the web without the cost and complexity of buying and managing the underlying hardware, software and/or web server capabilities. In principle, it is always on, always available, and provides state-of-the-art functions that are supposed to be highly reliable and flexible enough to handle large volumes of Internet traffic. Further, there is the notion of an “intelligent web map,” a medium by which to integrate multiple map services, data services, and analytical model services together, and to embed them in a browser or a web site, share them on a mobile device, or integrate them into social media (Ralha et al 2005, Esri 2011b). Such services support editing, pop-up windows, time-enabled slider functions, and the building in of additional analytics and workflows so that changes made to the original data, to the analytic model dependent on the data, and to the cartographic map layers properties, are immediately updated in the web map, in near-real time.

Systems architected as multi-purpose infrastructure allow for the hosting numerous applications and extreme data storage (petabytes), limited only by your organizations’ budget. Designed for scalability, the elastic nature of cloud system resources– the ability to rapidly grow and dynamically shrink based upon demand – satisfies potentially unpredictable high volume traffic, over a ubiquitous network. With access to seemingly unlimited compute capacity using cloud infrastructures, analytical calculations can be performed in a fraction of the time as traditional processes, and may potentially offer more economic viability as a result of the economies of scale that public cloud hosted services affords. And for a large number of users, cloud GIS is more cost-effective, as the foundational services are available free to users (e.g., ArcGIS.com) or may evolve to a “pay-as-you-go” structure with costs that are much lower than licensing fees required for desktop software.

Three core options make up the service deployment models within the cloud computing environment (for an excellent review see Garrison et al 2012). SaaS comprises access to software and its functions delivered as a web service rather than traditionally as desktop software. Platform as a Service (PaaS) provides an application platform, or middleware, as a service on which developers can build and deploy custom applications. Common solutions provided in this tier range from application programming interfaces (APIs) and tools to database and business process management systems to security integration, allowing developers to build applications and run them on the infrastructure that the cloud vendor owns and maintains. Infrastructure as a Service (IaaS) primarily encompasses the hardware and technology for computing power, storage, operating systems, or other infrastructure, delivered as off-premises, on-demand services rather than as dedicated, on-site resources.

9.3 Use Cases of CyberGIS Collaboration

9.3.1 Community Analyst

Community Analyst (Esri 2015) is a cyberGIS application, hosted in the cloud as a SaaS, and designed for government agencies, policy makers, non-governmental organizations, civic organizations with little or no technical GIS experience. The application provides several tools that allow users to: (1) determine where target populations are located; (2) determine where to allocate scarce community resources in order to produce the most impact; (3) communicate important information about a community to colleagues and constituents; (4) understand why legislators are likely to support a particular policy based on the characteristics of their districts; (5) improve community outreach to both inform the public, as well as garner support for policy decisions; and (6) identify trends in population, land use, ecological resources and similar variables for creation of alternative scenarios of future land development and conservation. Thousands of metrics are available for creating thematic maps and performing targeted searches based on specific demographic, economic or other criteria (Fig. 9.1). Web map points and polygons may be converted to sites in order to create study areas and drive-time, donut, and ring analyses (Fig. 9.2). The user may perform simple to advanced attribute queries, along with the optional ability to retrieve the resulting associated polygon geometries of the output area set.

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Fig 9.1. Community Analyst screen shot resulting from a user querying for % of households in the Washington, DC area with income < $15,000. Darker areas show where this is true in the eastern Washington DC region, suggesting that economic development funds show flow to this region rather than to the already gentrifying areas of west and central Washington, DC.

<insert Fig 9.2 here>

Fig 9.2. Community Analyst screen shot showing two separate drive time regions in the Washington, DC area, which can be helpful in planning for and responding to emergencies especially when coupled with reports on the demographics & vulnerability of the people living within the vicinity of high risk locations or any areas affected by an emergency event.

Staff at the Epidemiology and Program Evaluation Branch of the Riverside County (California) Department of Public Health are using Community Analyst as they apply for federal health reform grants for low-income community clinics (Betancourt 2011). The grant applications require an analysis of how long it takes for members of these communities to travel to the clinics. To fulfill the deliverables of the grant, the staff produced a map showing a 60-minute drive time of the "catchment" area surrounding each clinic under their jurisdiction. The staff are greatly aided in their collaboration with local ambulance companies, local schools, and law enforcement, as they are able to easily develop and share maps of ambulance service areas, as well as maps that show these colleagues and the entire community where schools with high pedestrian traffic are located, as well as areas that have had past incidents (Betancourt 2011).

In addition to community exploration using maps, more than fifty preformatted reports allow users to extract and summarize data on counties, congressional districts, cities, zip codes, block groups, hand drawn areas (via a polygon drawing tool), drive time areas, and more. Users may also create their own custom comparison reports using the available metrics, making it possible to evaluate multiple areas at once to determine which areas are in most need. These maps and reports can be freely shared among all users in the cloud, or exported to Excel or portable document format files (PDFs) for the desktop, email, or social media.

Of paramount importance in a cyberGIS such as Community Analyst is the quality of the data available, especially for non-technical users who are not well-versed in data quality issues or spatial data infrastructures. Community Analyst includes, for the U.S. only, a wide variety of business, consumer spending, and demographic datasets are updated quarterly, semiannually, annually, and decennially in the case of U.S. Census data. The demographic database includes population, households by type and average size, age and sex, race and Hispanic origin, household income, per capita income, housing by occupancy and tenure, and more. Several public and private sources are included as well. A team of demographers, statisticians and econometricians at the Environmental Systems Research

Institute (Esri) produces high-quality current-year and five-year projections of demographic data.

An important issue is that of the American Community Survey (ACS), which provides data that are updated more frequently than the U.S. Census (National Research Council 2007). In 2010, the U.S. Census Bureau changed how it collected data, eliminating the traditional "long form" and opting only to release data collected from the short form. Hence, the ACS is the replacement for this "long form" and is thus a better source for data on income, education, employment, language, migration, citizenship, marital status, and housing characteristics, such as value and rent. However, the ACS data are gathered on a much smaller percentage of the population, therefore the sampling error is relatively high (compared to the decennial census). To help users to know how much they can rely on the ACS estimates, a "reliability" measure is available in Community Analyst, developed by Esri in collaboration with the U.S. Census Bureau (Esri 2011a). The measure enables the user to understand the range of uncertainty for each estimate with 90% confidence: for example, if the ACS reports an estimate of 100 with a margin of error of +/- 20, then one can be 90% certain that the value for the whole population falls between 80 and 120.

For example, in Fig. 9.3, the map on the left indicates the density of people who take public transportation to work from ACS data, while on the map on the right shows reliability measure for the same area. Users can easily toggle back and forth to see the reliability measures and mouse over the map to see additional details. For custom areas, reliability measures are also provided in the ACS reports.

<insert Fig 9.3 left and right here>

Fig 9.3. The ACS reliability measure available in Community Analyst applied to the map on the left showing density of people taking public transportation to work, and map on the right showing the reliability of the ACS data for the same area. The colors represent threshold values established from the coefficients of variation to indicate the usability of the estimates where high reliability (dark colors, center of map) indicates that the sampling error is small relative to the estimate (i.e., coefficients of variation are less than or equal to 12%); medium reliability (light colors) advises caution (i.e., coefficients of variation are 12-40%); and low reliability (outlying areas on the map) indicates the sampling error is large relative to the estimate (i.e., coefficients of variation are greater than 40%) (Esri 2011a).

For more advanced users wishing to integrate the data, reporting and analysis functions of Community Analyst into their own custom web or mobile applications, hosted application programming interfaces (APIs) are available via Representational State Transfer (REST), Flex, Microsoft Silverlight or Simple Object Access Protocol (SOAP) interfaces. These APIs include methods to rapidly develop of custom web sites and mashups, create trade areas, run demographic reports, run comparative analytics and the like. As an example, a web developer at an economic development agency may wish to quickly create a web site to determine the characteristics of a city/county or a particular neighborhood therein, especially to recommend optimal locations for new businesses based on the lifestyles, interests, and spending habits of potential customers. If set up as an internal web site, employees within the agency would use the web site to service requests from urban planners or prospective businesses to determine site suitability for development. If set up as a public web site, there might be the additional provision of an up-to-date list of properties that are available in the city, allowing the end-user to generate reports on any of the selected properties of interest by simply selecting a property from the list.

9.3.2 SeaSketch

SeaSketch (McClintock et al 2012) is another cyberGIS application, hosted in the cloud as a SaaS, and designed as a collaborative decision-support tool for effective coastal and marine planning, for government and non-government organizations, industry, citizen science groups, community organizers and planners, conservationists, and academics, regardless of their skill level in either GIS or marine science. A partnership between Esri and the McClintock Lab of the University of California at Santa Barbara Center for Marine Assessment and Planning is the impetus for SeaSketch, which is the successor to the well-known Marine Map, initially used in support of marine protected area network planning throughout California (Gleason et al., 2010). At the time of this writing, SeaSketch was still in beta production and testing, but scheduled for worldwide release in the coming months.

Users start by pulling in geospatial data from authoritative local-, regional-, and global-scale web map and web feature services as appropriate for their study area (e.g., distributions of habitats, alternative energy resources, infrastructure, maritime boundaries, etc.), and overlain on an appropriate basemap. Then using the web map as a reference, they are able to sketch, save, and share lines and polygons representing desired zones or management plans, see the immediate impact of their plans in terms of economic costs and benefits, habitats newly protected or other metrics, and discuss these with other users via a facilitated chat forum tied directly to their maps (Fig. 9.4).

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Fig. 9.4 Screen snapshot from a prototype version of SeaSketch showing a collaborative, web-based ocean design process aimed at reducing the risk of ship strikes on endangered whales in the Santa Barbara Channel. Users could be in the same room or separated by great distances and time zones across city, state, and national boundaries. The panel on the left shows a sketch of potential shipping lanes digitized by one user in concert with point locations of existing oil platforms and whale sitings. A second user has sketched in real-time an area of conflict among these locations. The middle panel displays immediate reporting by SeaSketch of the various species of whales present, areas of sensitive habitat and implications of the planned shipping lanes in terms of distance and fuel costs. The panel on the right shows a live discussion forum where users can send chat messages back and forth in real-time. Esri (2012) shows a live demo of this process.

Collaboration among small or large groups of users is a primary emphasis of SeaSketch as users are not only able to map and chat at the same time, but may bookmark the discussion, which saves the sketches, as well as the map extent and any GIS map layers that were used at the time. Sketches (aka designs) may be posted in either public or private forums for others to view, copy, and discuss further, especially as the rationale for designs may change with the discovery of additional data or in the context of new regulations, laws, or opinions of stakeholders. These discussions will likely involve conflict as users (e.g., commercial fishermen, conservationists, scientists, government officials, indigenous tribes, politicians, etc.) struggle to agree together on possible solutions. Therefore, it is useful for planners and process facilitators to have the ability within SeaSketch to view whether or not individuals and groups are sharing their sketches and ancillary information, and where communication is breaking down. Fig. 9.5 shows a group network analysis capability planned for SeaSketch that allows facilitators to trace the lineage of sketches among groups and individuals, thus revealing where more effort may be needed to foster greater collaboration.

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Fig. 9.5 Conceptual diagram of social networking analysis capability in future development for SeaSketch to help process facilitators trace the lineage of sharing among individuals and groups, organize discussion forums, and ultimately to encourage cross-interest discussion and collaboration (McClintock et al 2012).

SeaSketch is based largely on the ArcGIS API for JavaScript and ArcGIS Server, as well as supporting open source technologies, all of which provide a functional starting point upon which to build a host of customized analytics, reports, and data survey tools according to the specific planning needs of future projects. For example, a customized prototype of SeaSketch has been developed for use by the use by the Department of Conservation in New Zealand, to support comprehensive marine spatial planning in the Hauraki Gulf near Auckland. This project may require the development of a much larger suite of spatial analytics, including spatial dimensions of tradeoffs where users submit sketches to a biological-economic model of tradeoffs between ecosystem-services (tourism, conservation, wind energy potential, lobster fishing, whale migration corridors, etc.) in relation to potential management strategies (White et al., 2012). SeaSketch will be available to all users with a web browser, but customized implementations are planned to support specific spatial planning projects in the Cook Islands of the southwest Pacific, the Galapagos Islands of the east equatorial Pacific, the Barbuda Blue Halo Initiative in the Caribbean, Canada's Beaufort Sea, multiple coastal states within the US, and many other parts of the world.

9.3.3 Solar Energy Modeling for Local Government

The City of Boston hosts a very good example of how complex geospatial analysis can be presented in a very approachable way to a broad audience. They provide a public cyberGIS to assess solar energy potential in their city. Their goal is to generate 25 megawatts of solar energy per year in Boston by the year 2015. It is one of twenty five major cities participating in the US Department of Energy's Solar America Initiative.

The application allows citizens, business owners and city officials, to select buildings for which the solar energy potential has been precomputed, or alternately to interactively digitize a polygon of a custom area on a roof and calculate its solar energy potential (Fig. 9.6). The application uses ArcGIS for the mapping and analysis and is written in FLEX. The solar energy tools in ArcGIS are based on Rich et al (1994) and Fu (2000). The tools calculate total solar energy in watt hours per m squared and account for sun position, surface slope, and shadowing from adjacent terrain and buildings.

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Fig 9.6 Interactive modeling of solar energy potential in Boston.

The developers of the Boston application created a simple end-user experience by determining an appropriate set of default values for their location and purpose, and the only input required by the user is the polygon of the area of interest. All the other parameters of the underlying tools such as handling atmospheric conditions and configuring the timespan and temporal frequency of calculations are hidden from the user, making it very easy for the non-expert to use.

An evaluation of the calculations of the Solar Boston website and other similar sites can be found in Dean et al (2009). The source code this application was based upon is available on ArcGIS.com and GitHub, and has been the basis for numerous similar applications build for other cities such as Salt Lake City and New Orleans.

9.3.5 Estimating Stream Flow

StreamStats is a United States Geological Survey (USGS) web application that provides location-specific summary stream flow information (Ries et al 2008). The first version of the application became publicly available in 1999 and is now in its 3rd release and continues to evolve as the IT and GIS industries evolve.

The application is used to calculate stream flow information such as the 100-year peak flow, mean flow, and 10-year low flow, which are used in many applications including bridge design, water-use permitting, establishing minimum in-stream flows, and culvert design. It has a high level of use and professional status, and has become recommended (Pennsylvania Department of Environmental Protection, 2009) or mandated for use by law in some states. For example, in Massachusetts it is the required tool for calculating the probability of perennial stream flow (Massachusetts Department of Environmental Protection, 2008). In many situations there is not a flow measurement gauge nearby, so values need to be estimated. These estimates in StreamStats are calculated using regression equations that are specific to certain geographies. The regression equations rely upon descriptive information about the landscape that contributes flow to that location, such as the size of the area, average slope, soil characteristics, land cover, and precipitation.

To collect the information needed for the regression equation, the user interactively picks a location in the map, which is then used to delineate the upslope contributing area or watershed for that point (Fig. 9.7). Watershed delineation from any user specified point requires the use of a digital elevation model (DEM), and a series of analysis steps to calculate the direction of flow across the landscape. This is a time-consuming process so the flow direction raster has been calculated in advance, along with additional processing to ensure conformance with known stream network and watershed boundaries.

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Fig. 9.7 Custom watershed delineation and flow estimation with StreamStats.

A unique and crucial feature of StreamStats is a preprocessing step that allows the calculation to scale to large areas. The underlying watershed delineation algorithm execution time increases with increasing watershed area. To maintain scalability with varying watershed size, a subset and selection technique is used to divide the landscape into a collection of hierarchical sub basins with the smallest unit being approximately 4000 square kilometers. When the user selects a drainage point, the analysis of the flow direction raster is only required to calculate the contributing area to the nearest upslope predefined watershed boundary, then the already known upslope watershed areas are aggregated.

The user then has the opportunity to interactively edit the watershed boundary. After the watershed is defined it is automatically overlaid with the other needed data layers such as slope, soil, and land cover. These numbers are summarized for the areas and sent to the regression equation. The result of the calculations is a table of flow statistics. The user can compare these estimated flow values to nearby gauges upstream and downstream, and optionally save the watershed boundary with its characteristics and stream flow statistics to a file for later use. As of March 2011, StreamStats was available for 24 states, 11 more states were in development. In 2010 StreamStats was used to delineate 187,000 watersheds and generate 150,000 reports (Guthrie personal communication 2011).

9.4 Discussion and Conclusion

The prior use cases serve to underscore how, with a low barrier to entry, a cloud-hosted environment for users to leverage as a platform for sharing, communication, and collaboration is achievable, and currently available in a variety of forms. Although many cloud consumers are most familiar with public cloud services and offerings, organizations are increasingly crafting or adopting their own personalized and customized private cloud, tailored to a particular part of the geospatial science community – or specific to a time-based project or program. Regardless of the number of members in the collaborative group, or their individual locations, assuming an Internet connection can be obtained, geospatial workgroups can establish a secure and familiar environment that can be hosted as a private cloud on-premise in an organization, or dedicated as private cloud space hosted in public infrastructure. Maps, tasks, applications, models, data and services can be shared dynamically through these cloud-hosted portals, offering continuous communication and teamwork despite multiple time-zones or differing operating systems.

By further example in terms of geoprocessing models (aka GIS analytical models), if Colleague A has expertise as a crime analyst and builds a tool to generate hot spots for crime points, he can share a geoprocessing "*package*," consisting of the analytical tool, the data and environment settings used by the tool, and the workflow (e.g., ArcGIS ModelBuilder). This can be shared in the cloud for Colleague B to access and download, in order to refine or edit, or modify based on her specific requirements. In this manner, Colleague B can leverage the core expertise of her collaborator, without wasting time generating a nearly-identical model simply for customization purposes. Further, if there are improvements to be made, she can return to the cloud geospatial portal in order to share his modified package, or to validate it for accuracy with others in her workgroup through testing and quality assurance/quality control. In essence this allows GIScientists to easily share their tradecraft with other GIScientists (Fig. 9.8), and ultimately with scientists from other domains who are conversant with GIS.

<insert Fig 9.8 here>

Fig. 9.8 Diagram illustrating the concept of sharing of geoprocessing models and workflows as both packages and as services, where packages serve to share from specialist to specialist and services facilitate sharing from specialists to everyone.

This may extend further to the broader domain of non-GIS specialists, including interested citizens who want to ask spatial questions in a simple way and obtain answers they can understand. Geoprocessing packages may be too advanced for these users, but geoprocessing *services* that allow a specialist to share with non-specialists a map service displaying the results of an analysis would be more appropriate (Fig. 9.8). And since the service would be SaaS-based, it is immediately available for consumption and discovery by others, including those permitted in a workgroup, and in adherence to whatever public or private access was agreed upon and configured initially. This map service would leverage geoprocessing models running on the server, but the complexities of the models need not be fully absorbed by the non-specialist user at that instant. An excellent example is the Climate Wizard online tool (Girvetz et al 2009), that provides non-climate specialists with maps based on complex general circulation models conveying how trends in temperature and precipitation have and are projected to change within specific geographic areas throughout the world. While the user does not have to be an expert in these climate models, she is strongly encouraged on the site to read the documentation about the various climate models, including caveats about error, uncertainty, and faulty assumptions. In a similar vein, the Global Stream Discharge online tool as part of World Water Online (Kisters 2015) enables time series of precipitation over a watershed from a user-selected point to be connected to the stream flow and water level at its outlet, all run in the background via a geoprocessing service.

In conclusion, we posit that CyberGIS should provide for the user as a fundamental component an environment in which to perform and evaluate a wide array of spatial analyses in a "community playground" of datasets, maps, scripts, web-based geoprocessing services, and GIS analysis models. The “playground” may be in the context of an *Intranet* within organizations (e.g., private clouds), as well as the broader Internet (public clouds). And when consuming various cloud services, it is clearly important to recognize the potential hazards and risks ahead, as with any new or existing information technology endeavor. Concerns about security and data privacy; inquiries around a cloud provider's maturity and reliability; and political and regulatory issues are all topics for discussion and clarification among both providers and users (for a helpful review see Gallagher et al 2015). But in the broader scheme, exposing the power of spatial analysis to a larger audience (the non-GIS audience) may be the biggest long-term value of CyberGIS. And as barriers to entry into CyberGIS environments continue to fall away, confidence in consuming and leveraging both public and private clouds for non-GIS audiences will be bolstered through the successes, ease of collaboration and agility that on-demand cloud-hosted services can offer. This is ultimately one of the goals of CyberGIS: to integrate and synthesize data and information from multiple sources, thereby facilitating communication and collaboration, and breaking down barriers between institutions, disciplines and cultures, fostering a better connection between CyberGIS and its many communities.

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