DEVELOPING WEB-BASED MAPPING SERVICES FOR PUBLIC HEALTH APPLICATIONS

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ABSTRACT:

Delivering data and information in a timely and efficient manner is imperative for providing decision makers crucial information that could impact the well-being of humans, especially in the event of a disaster. Equally important is providing data and information in forms that are easily used. Advances in web mapping and related technologies open new doors for data providers and users that, under ideal circumstances, can deliver data and information in near-real time. In the public health community these technologies are being used to enhance disease and syndromic surveillance systems, visualize environmentally-related events such as dust storms, and to provide focused mapping and analysis capabilities on the desktop.

While there are several decision support systems (DSS) in use by public health officials, many do not utilize geospatial technologies. These systems typically monitor syndromes and disease outbreaks by accessing databases that contain statistics collected from a variety of sources. Some of these data are provided by health care workers, while others are derived from surveys and similar sources. A few DSSs are beginning to integrate geospatial information technologies into their decision processes. The Rapid Syndrome Validation Project (RSVP), BioSense, and the Syndrome Reporting Information System (SYRIS) are early examples of decision support tools that include mapping components in their toolset.

Under a cooperative agreement funded by NASA, the Earth Data Analysis Center at the University of New Mexico is developing a web-mapping client and supporting data services for the Public Health Applications in Remote Sensing (PHAiRS) project. This mapping interface client will provide a toolset that allows public health officials to visualize and analyze data output from a regional dust forecasting model and other environmental datasets, and to produce reports and maps for further analysis. This toolset is designed to be integrated with existing DSSs through publishing web services and hosting a fully-functional internet mapping and analysis client.

This paper discusses development of the PHAiRS web mapping client and associated services and describes its attributes in context of public health applications. The discussion includes an overview of the programs and technology used to create the client.

1. INTRODUCTION

Environmentally induced health risks to populations with respiratory illnesses are a growing concern globally. Of particular concern are dust and smoke events carrying $PM_{2.5}$ (respirable) and PM_{10} (inhalable) particle sizes. Public health officials and authorities worldwide are making decisions concerning health risks to humans caused by these events based on the best available information. In some cases they rely upon reports received at clinics, hospitals, and other care facilities. Others may be accessing databases containing information on syndromes and outbreaks in local and regional areas. Some assess environmental conditions at a global scale such as dust storms originating in the Sahara (Westphal et al., 1987 and 1988; Goudie et al., 2001) or in China. Decision support systems (DSS) that provide early detection and analysis of these events enhance the ability of officials to warn populations at risk.

Many syndromic surveillance systems have been developed in recent years that provide electronic access to information on a variety of diseases and syndromes. A few, such as the Rapid Syndrome Validation Project (RSVP) (Sandia National Laboratories), the Syndrome Reporting Information System (SYRIS) (ARES Corporation), and BioSense (Centers for Disease Control and Prevention) (Bradley, 2004), have enhanced their tools with mapping and visualization capabilities. Evolving visualization and mapping technologies can improve these tools.

The Public Health Applications in Remote Sensing (PHAiRS) project, jointly executed by the University of New Mexico's Earth Data Analysis Center and the University of Arizona's Department of Atmospheric Sciences, is developing an application framework to enhance the capabilities of existing public health DSSs such as RSVP and SYRIS (Appendix A). Funded under NASA's REASoN program, the project will provide enhanced web-based visualization and analytical tools to public health decision makers; and, assimilate NASA data into the Dust Regional Atmospheric Model (DREAM) (Nickovic et al., 2001) to provide enhanced dust forecast capabilities.

Ultimately these enhancements to public health DSSs will be accomplished by developing three related technologies. First are map data and image services that may be accessed directly from, and integrated into, DSS user interfaces. Second is a free-standing, web-based, interactive mapping environment that allows users to explore and analyze environmental and aggregated public health data. Third are technologies that streamline the ingestion of new environmental data into the system, both as model inputs for DREAM and for presentation to end users. This paper describes progress made in the first two technology areas.

2. DEVELOPING AND DEPLOYING THE PHAIRS SERVICES-ORIENTED ARCHITECTURE

A services-oriented architecture (SOA) is the foundation for information delivery capabilities that are published for integrating into public health DSSs. This architecture consists of several components (Figure 1), each of which plays one of three roles: (1) data storage / provision; (2) data processing / product generation; or (3) product delivery.

2.1 Data storage/provision

Data storage and provision components of the SOA represent elements of the architecture that store geospatial and related attribute data, and external data resources. These components

GRASS GIS and PostGIS (Appendix A) contribute data storage, management, and analysis capabilities, while the external data providers contribute already-processed data, either as data services, or as mapping services that provide images of data. GRASS GIS provides an environment for storing, analyzing, and delivering raster data through visualization and analysis services built upon the rich function library in GRASS. PostGIS provides complementary storage, management, and delivery of vector data.

External data providers host both OGC and non-OGC services through a variety of protocols. Specifically, the PHAiRS project is using the Environmental Protection Agency (EPA) AIRNow OGC Web Coverage Services (WCS) (Evans, 2005), hosted by the DATAFED project. Current and historical meteorological forecast data are obtained from the HTTP-based download services hosted by the National Oceanic and Atmospheric Administration's (NOAA) National Operational Model Archive & Distribution System (NOMADS), and the National Weather Service's, FTP-based, operational forecast delivery system. Also used are products obtained from the Land Processes Distributed Active Archive Center (DAAC) via the Earth Observing System (EOS) Data Gateway. Appendix A provides URLs for these sources.

2.2 Data Processing and Product Generation

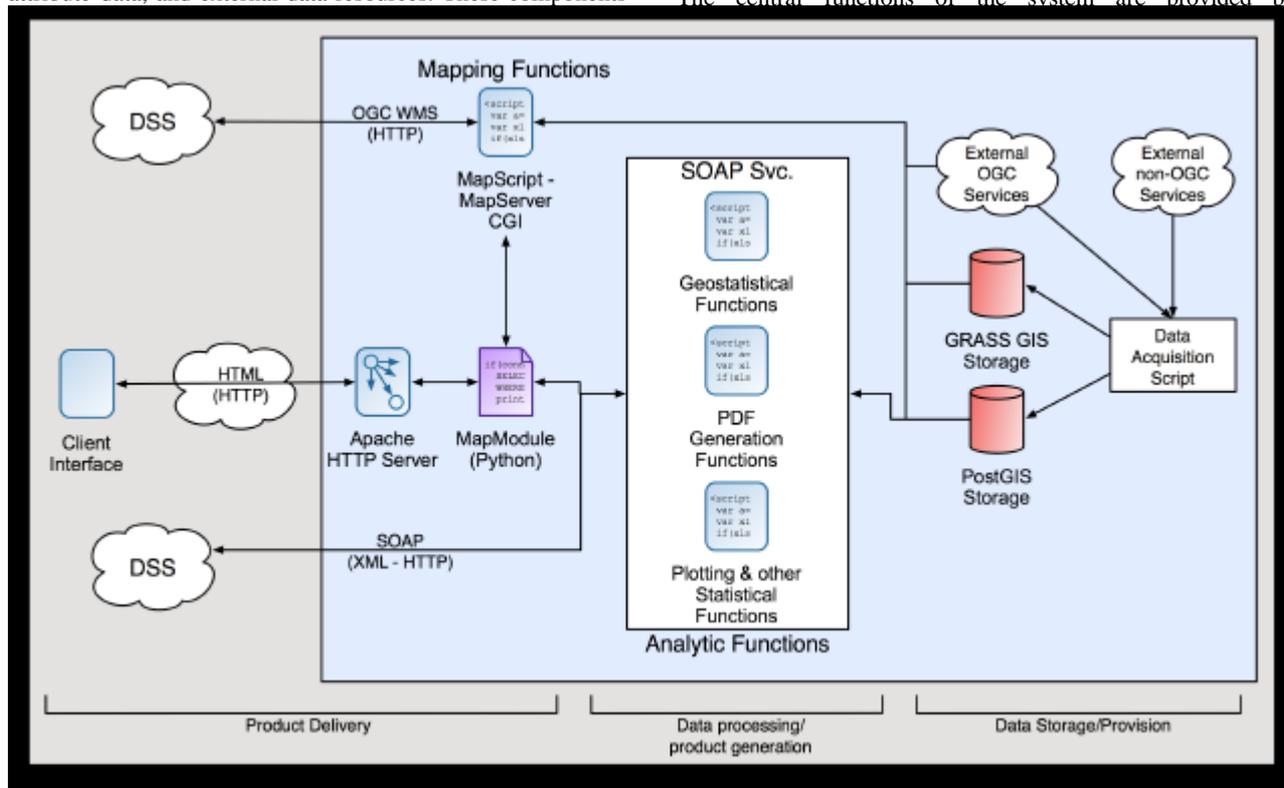The central functions of the system are provided by

Figure 1. Services Oriented Architecture components

Protocol (SOAP) services depicted in the center of Figure 1. Each service provides specialized products based upon data

stored within, and accessed by, the data storage and processing components.

Data processing and product generation is supported through automated processes that are initiated through W3C SOAP (Gudgin, et al., 2003) requests to the project server that executes one of three functions: (1) perform geostatistical functions; (2) generate high-quality printable maps as PDF files; or (3) perform statistical and graphics generation functions. These services are the primary means through which external DSSs (such as RSVP and SYRIS) gain access to, and embed within their systems, the products of the PHAiRS project.

These SOAP services also provide the functionality that is demonstrated in the sample client interface developed for the project. One of the functions in this interface permits users to select, onscreen, a geographic extent represented by an irregular polygon, such as a political boundary, which converts that selection to an appropriate SOAP client call to the geostatistical and graphics generation SOAP service. A density plot of the value of interest (e.g. $PM_{2.5}$ concentration) is returned to the user (Figure 2). This functionality uses the R statistical programming language and its ability to access raster data stored in GRASS to perform geostatistical analyses. While only an initial step, this illustrates a more general capability to provide statistical summary functions of raster data over irregular areas to public health professionals through the SOA.
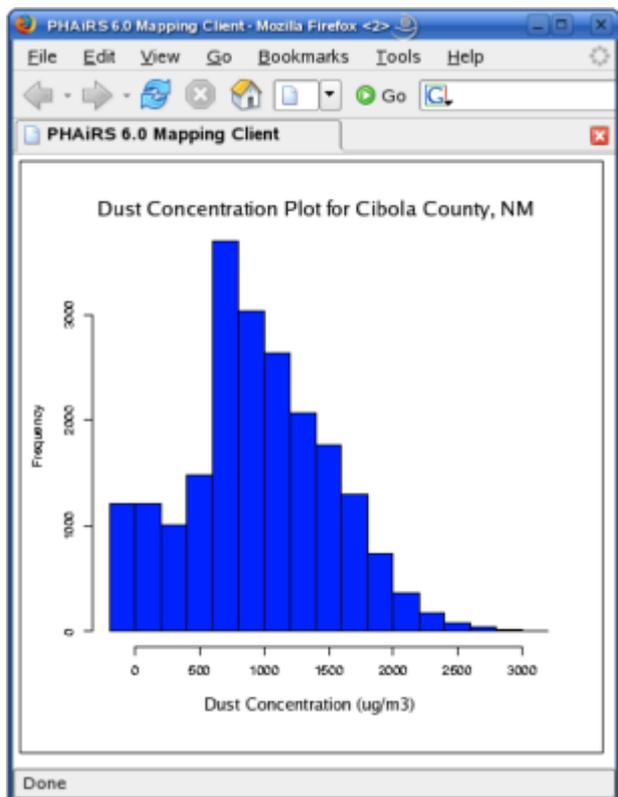

Figure 2. $PM_{2.5}$ dust concentration density plot

Delivering high-quality printable reports and mapped data is another feature that interests public health professionals who provided feedback and guidance in developing the PHAiRS system. Heeding this feedback, the project developed a

capability to generate and deliver, again through a SOAP service interface, high resolution renderings of mapped data as PDF files that can be downloaded and printed for hardcopy distribution (Figure 3).

Finally, a SOAP service was developed that provides information for generating a time-series representation of regional data (as a series of maps) and values for different times at a specified location. This information includes a series of OGC Web Map Service URLs that represent individual map images for separate time steps in a specified sequence. These maps may be combined in any manner desired by the requesting application. The SOAP response also includes a URL for a PNG file representing the time series values for a user-specified point location. A web-based animation viewer is included in the interface with the regional map in the left side of the interface, and the point-specific time-series plot in the right side of the interface (Figure 4).
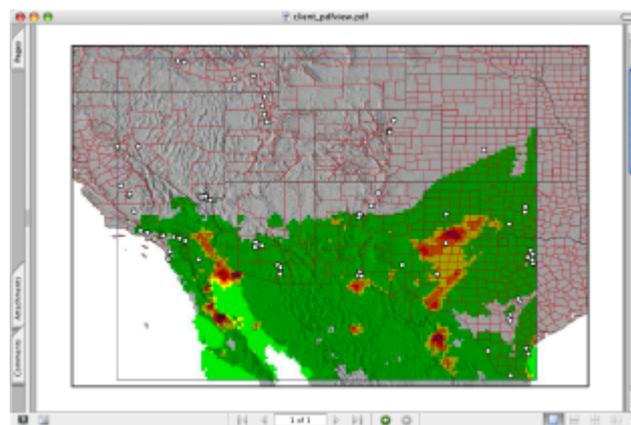

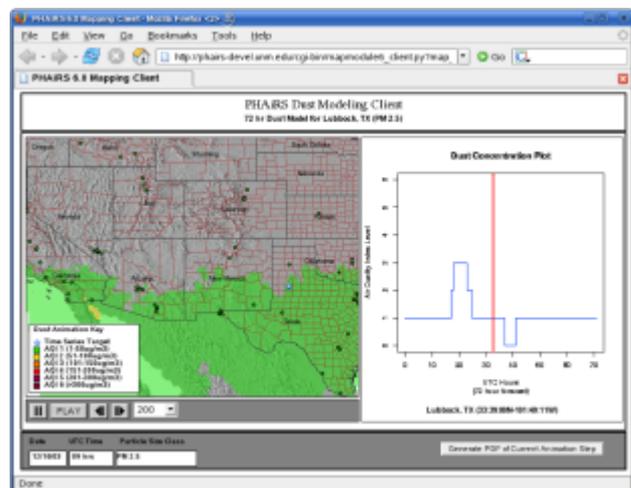Figure 3. PDF output of a mapped region

Figure 4. Animation interface

2.3 Product Delivery

Products of the PHAiRS project are delivered through three distinct mechanisms: (1) OGC Web Map Services (WMS) (de la Beaujardiere, 2006); (2) the aforementioned SOAP services; and (3) a client interface with these three mechanisms represented by the components in the left side of Figure 1.

Publishing PHAiRS data as OGC WMS for delivering mapped data to public health DSSs follows a model developed for

RSVP. This model proved effective in facilitating the deployment of dynamic map content into external applications. Developers of public health DSS applications do not need to be expert in online geospatial application development. Instead, they can embed maps developed by the PHAiRS system in their interfaces. An important advance in the PHAiRS WMS capabilities was achieved by implementing the WMS Time specification for the EPA AIRNow historical data and modeled DREAM outputs. This achievement allows for efficient management and delivery of time-stamped measurements of particulate densities and corresponding DREAM model outputs.

SOAP services (described in an earlier section) provide a more sophisticated service interface for delivering complex data structures and binary products (i.e. PDF files, lists of WMS and image URLs, and PNG files). This increased capacity facilitates delivering high-end capabilities to public health DSS applications without developers writing the often complex code necessary to generate the returned products. Using SOAP as the standard service protocol also provides maximum flexibility to DSS developers since SOAP is widely supported by numerous programming languages and host platforms as a standard web service model.

To demonstrate how the OGC and SOAP services products might be embedded within a client interface, a sample client was developed that integrates these services and provides an interactive user interface. This interface contains a combination of standard interactive mapping components and provides access to more sophisticated analytical capabilities enabled by the underlying SOAP services (Figure 5). Other client interface components are illustrated in Figure 2 (density plot graphic) and in Figure 4 (animation viewer). In addition to integrating PHAiRS products into existing DSS applications, some stakeholders prefer linking directly to the interface as an initial deployment of PHAiRS products into their systems.
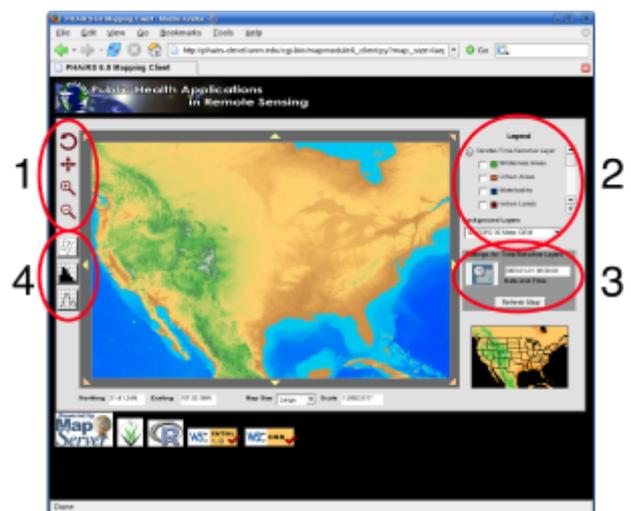

Figure 5. Client interface tools: (1) geographic/mapped extent; (2) layer selection and legend interface; (3) date and time specification for time-sensitive layers; and (4) active analytical tools

3. CONCLUSIONS

Accomplishments discussed in this paper toward developing the web-based mapping services to enhance existing public health DSSs represent the first two years of a five-year project. This progress reflects both a rapid development cycle and closely linked integration of new technologies into the products of the PHAiRS project. Visualization and mapping capabilities of the client interface have evolved to provide a Python-based, modular, multifunctional client that provides access to the multiple data and image services based upon two core standards: the W3C SOAP specification, and the OGC WMS specification. Creating services to support these protocols provides a streamlined means for public health DSSs to integrate the enhanced DREAM model outputs and related environmental data products into their application frameworks. The client interface demonstrates potential client interactions with these services and provides an initial client with which DSS users may directly interact.

4. REFERENCES

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5. ACKNOWLEDGEMENTS

6. APPENDIX A. RESOURCES

This appendix provides web addresses for some of the resources accessed and used in developing the technical capabilities for the PHAiRS project. These links were checked for currency by the author in June 2006.

GRASS GIS – http://grass.baylor.edu
DATAFED Project – http://datafed.net
Land Processes DAAC –
    http://edcimswww.cr.usgs.gov/pub/imswelcome
NOAA NOMADS – http://nomads.ncdc.noaa.gov/data.php
NWS Operational Forecast Delivery System FTP site –
    tgftp.nws.noaa.gov
PostGIS – http://postgis.refractions.net
PostgreSQL – http://www.postgresql.org
SYRIS – http://www.arescorporation.com/products.
    aspx?style=2&\%20pict_id=189&menu_id=103&id=87

7. APPENDIX B. GLOSSARY OF ACRONYMS

DAAC – Distributed Active Archive Center
DREAM – Dust Regional Atmospheric Model
DSS – Decision Support System
EOS – Earth Observing System
EPA – Environmental Protection Agency
FTP – File Transfer Protocol
GIS – Geographic Information System
GRASS – Geographic Resources Analysis Support System
HTTP – Hypertext Transfer Protocol
NASA – National Aeronautics and Space Administration
NOAA – National Oceanic and Atmospheric Administration
NOMADS – National Operational Model Archive & Distribution System
OCG – Open Geospatial Consortium
PDF – Portable Document Format
PHAiRS – Public Health Applications in Remote Sensing
PM – Particulate Matter
PNG – Portable Network Graphics
REASoN – Research, Education, & Applications Solutions Network
RSVP – Rapid Syndrome Validation Project
SOA – Services Oriented Architecture
SOAP – Simple Object Access Protocol
SYRIS – Syndrome Reporting Information System
URL – Uniform Resource Locator
W3C – The World Wide Web Consortium
WCS – Web Coverage Services
WMS – Web Map Services