Technology Products of the PHAiRS REASoN Project – Year 2 Web Services and Demonstration Interfaces Development

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***Abstract*— New technology development for the Public Health Applications in Remote Sensing (PHAiRS) NASA REASoN project consist of three components: web-based processing and data services; automated data acquisition and processing procedures in support of maintaining the data required by those services and the dust generation and propagation model being regionalized for the DSS as part of the Research component of our REASoN project; and sample client interface components based upon those data and services. The web services that provide the technical foundation for public health decision support systems enhancements are based upon two sets of standards: the Open Geospatial Consortium Web Map Services and Simple Features for SQL standards; and the W3C SOAP specification. Developed services include SOAP services that generate PDF renderings of specified data, geostatistical summarization for irregular polygons, and time series visualizations. OGC services have been developed for all datasets used within the application environment. Continued work on automated data acquisition and processing has resulted in capabilities to routinely execute the DREAM dust model with required initialization parameters while also yielding new data used in the visualization and assessment of those model outputs. Sample user interfaces that demonstrate the capabilities and products of DREAM model runs and project services have also been developed in order to facilitate their integration into public health decision support systems. In total, the products of the second year of technology development for the PHAiRS project have built upon the capabilities developed in our first year through the deployment of standards-based services and enhanced client interfaces that demonstrate those services.**

***Index Terms*— Public Health, Remote Sensing. Decision Support.**

I. Introduction

THE year two technological accomplishments of the Public Health Applications in Remote Sensing (PHAiRS) project, funded under NASA's REASoN program[1], have moved the project towards the twin goals of: 1) providing enhanced web-based visualization and analytic tools to public health decision makers relating to environmental factors influencing human health; and, 2) infusing NASA data and model outputs into the Dust Regional Atmospheric Model (DREAM) [1]–[3] in order to provide enhanced dust forecast capabilities for delivery to public health officials.

These activities relate to an overall goal of developing an application framework that enhances the current capabilities of existing public health decision support systems such as the Rapid Syndrome Validation Project (RSVP) Public Health decision support system (DSS)[2], a system developed and maintained by researchers at Sandia National Laboratory in cooperation with Los Alamos National Laboratories, the University of New Mexico Department of Emergency Medicine, and the NM Department of Health Office of Epidemiology, and the University of New Mexico's Earth Data Analysis Center; and the Syndrome Reporting Information system (SYRIS), a commercial public health decision support system developed by ARES Corporation. Ultimately these enhancements to public health decision support systems will be accomplished through the development of three related technologies. First, map data and image services that may be directly accessed from and integrated into DSS user interfaces. Second, through the development of a free-standing, web-based, interactive mapping environment that allows users to explore and analyze environmental and aggregated public health data. Third, the development of 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 the progress made in former two technology areas.

II. Development and Deployment of the PHAiRS Services Oriented Architecture

A major focus of the development efforts of the second year of the PHAiRS project has been the development and deployment of a services oriented architecture (SOA) as the foundation for the information delivery capabilities published for integration into public health DSSs. This architecture consists of several components (illustrated in Figure 1), each of which play one of three roles:

- Data storage/provision
- Data processing/product generation

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[2]All relevant web addresses are provided in Appendix I

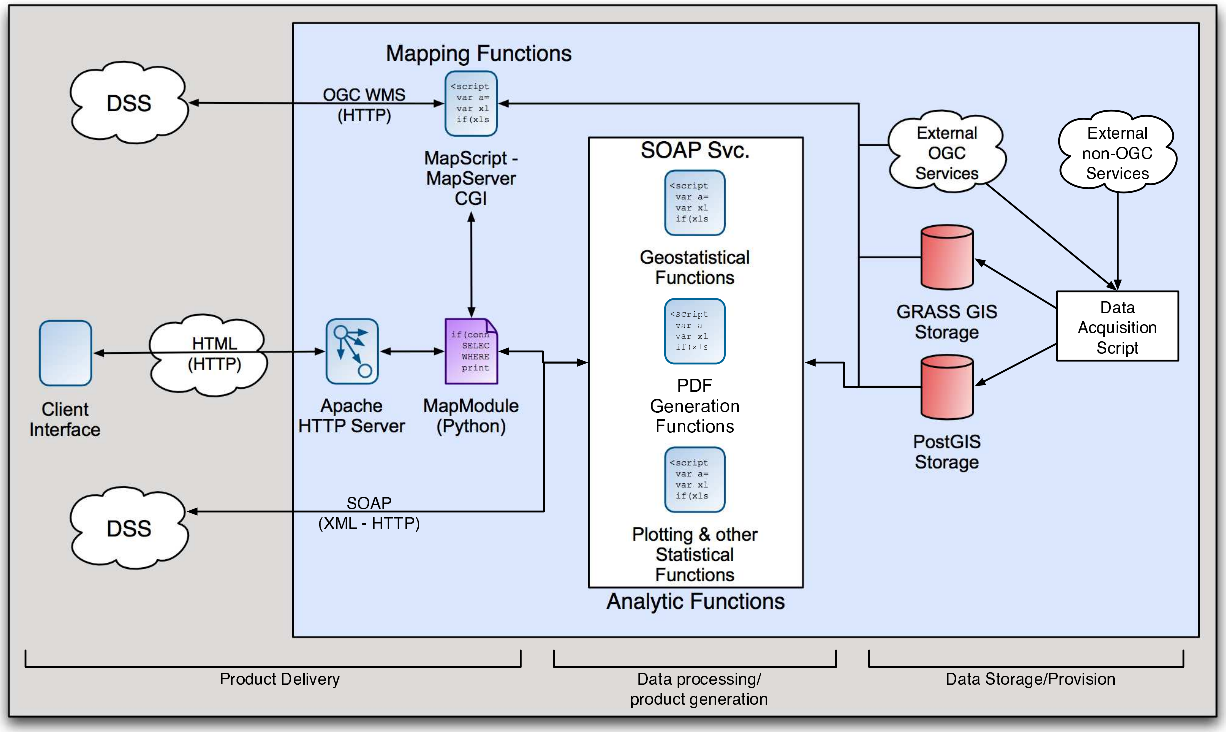

Fig. 1. Services Oriented Architecture components

- Product delivery

A. Data storage/provision

The data storage and provision components of the SOA represent the elements of the architecture that store geospatial and related attribute data and external data resources. These components consist of the following (and are displayed in the right side of Figure 1):

- GRASS GIS storage
- PostGIS storage
- External Open Geospatial Consortium (OGC) Service providers
- External providers of non-OGC services

Both the GRASS GIS and PostGIS components 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 where raster data may be stored, analyzed, and delivered through visualization and analysis services built upon the rich function library that makes up the GRASS environment. PostGIS[3] provides complementary storage, management, and delivery of vector data in support of the project.

[3]PostGIS is an implementation of the Open Geospatial Consortium Simple Features for SQL specification for storage and management of vector geospatial data [i.e. points, lines, polygons, either singly or as multi-feature entries] within SQL-based database environments. Specifically, PostGIS enables support for this specification within the PostgreSQL object-relational database environment. The current pair of applicable specifications are defined by [4], [5].

External data providers host both OGC and non-OGC services through a variety of protocols. Specifically, the PHAiRS project is making use of the EPA AIRNOW OGC Web Coverage Services (WCS, [6]) hosted by the DATAFED[4] project. Current and historic 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.

In addition to regular data acquisition procedures that obtain the above described data resources from external sources, the PHAiRS project also makes use of data products obtained through the EOS Data Gateway - Land Process DAAC.

B. Data Processing and Product Generation

The central functionality of the PHAiRS system is provided by the components that perform the work of processing the data stored in the previously described management system into products useful to public health officials and deployable within existing decision support systems. These components are represented by the SOAP services depicted in the center of Figure 1, with each service providing specialized products based upon the data stored within and accessed by the data storage and processing components.

Data processing and product generation is supported through the use of automated processes that are initiated through W3C Simple Object Access Protocol (SOAP, [7])

[4]Another NASA REASoN Project: http://capita.wustl.edu/capita/researchareas/NASAReason/ESEPMNASAReasonAbstr.htm

requests to the project server that perform one of three functions:

- Perform geostatistical functions
- Generate high-quality printable maps as PDF files
- Perform statistical and graphics generation functions

These services play two roles in the PHAiRS project. First, they are the primary means through which external decision support systems (such as RSVP and SYRIS) may gain access to and embed within their systems the products of the PHAiRS project. Second, they provide the functionality that is demonstrated in the sample client interface developed for the project as an example of how interaction with the project services might be integrated into a complete application framework. The examples provided below are based upon the demonstration client developed as part of the project.

Year 1 of the PHAiRS project developed a capability that allowed end-users to select an arbitrary rectangular region for which a raster dataset would be summarized. Year 2's continued development of this capability has resulted in an ability, through a SOAP service, for a user to select a pre-defined irregular polygon (i.e. a county boundary) in the user interface, have that selection converted to an appropriate SOAP client call to the geostatistical and graphics generation SOAP service, and have a density plot of the value of interest (PM2.5 concentration in this instance) returned to the user (Figure 2). This functionality is supported through use of a combination of 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 capability illustrates a more general capability to provide statistical summary functions of raster data over irregular areas to public health professionals through the SOA enabled by PHAiRS.

The delivery of high-quality (i.e. printable) reports and mapped data is another capability that is of great interest to the public health professionals that have provided feedback and guidance to the development of the capabilities of the PHAiRS system. In response to that need, the project has progressed through two phases of development of a capability to generate and deliver, again through a SOAP service interface, high-resolution renderings of mapped data as PDF files that may be downloaded and printed for hardcopy distribution (Figure 3).

Finally, a SOAP service has been developed that provides the information required to generate a time-series representation of both regional data (in the form of a series of maps) and values for different times at a specified location. The provided information includes a series of OGC Web Map Service URLS that represent individual map images that represent separate time steps in a specified sequence, with those individual maps combinable in any manner desired by the requesting application. A URL for a PNG file representing the time series values for a user-specified point location is also included in the data returned as part of the SOAP response. A sample implementation of a web-based animation viewer is included in the demonstration interface described in the next section, and illustrated in Figure 4, with the regional map appearing in the left side of the interface, and the point-specific time-series plot appearing in the right side of the interface.

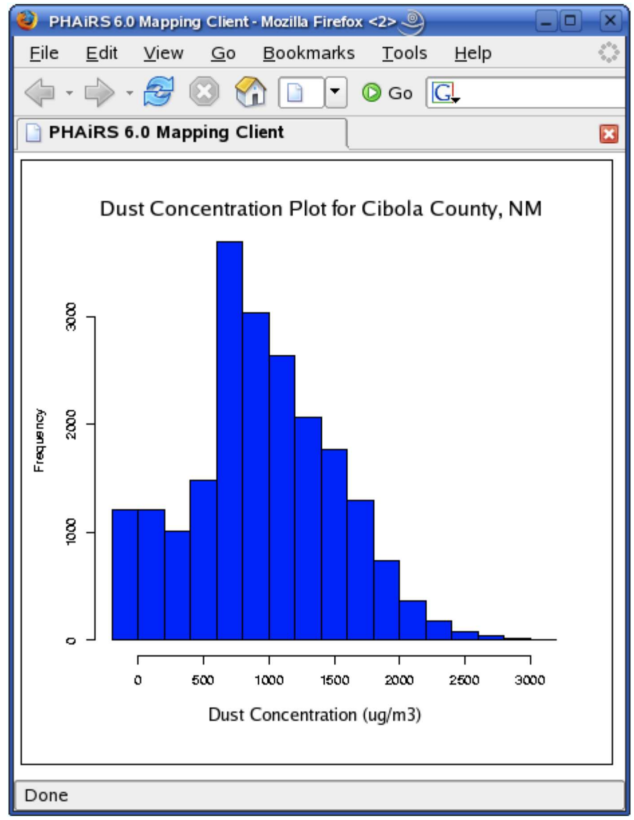

Fig. 2. Sample PM2.5 dust concentration density plot for Cibola County, NM

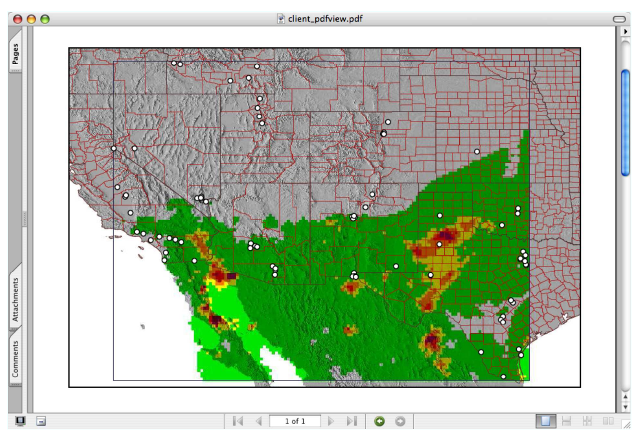

Fig. 3. Sample mapped region from a generated PDF File

C. Product Delivery

The products of the PHAiRS project are delivered through three distinct mechanisms:

- OGC Web Map Services (WMS, [8])
- The aforementioned SOAP services
- A sample client interface

with these three mechanisms being represented by the components in the left side of Figure 1.

The publication of PHAiRS data as OGC WMS follows upon a long-standing approach to the delivery of mapped data to public health DSS as developed in the original RSVP application. This model proved very effective in facilitating the

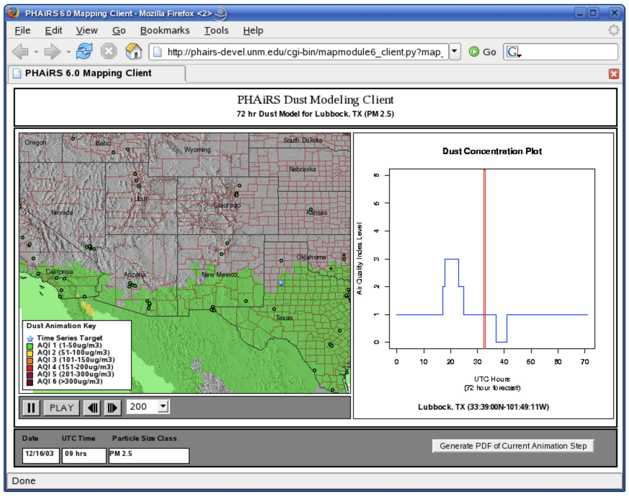

Fig. 4. Sample of the animation interface, with content provided by the animation SOAP Service

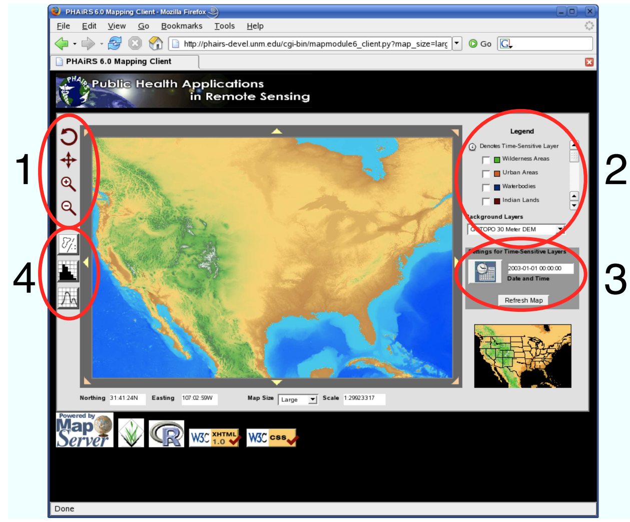

Fig. 5. Demonstration client interface, with: 1) mapped extent management tools (zoom, previous extent, maximum extent); 2) layer selection and legend interface; 3) date and time specification for time-sensitive layers (i.e. EPA AIRNOW values, DREAM model outputs); 4) buttons to active analytic tools.

deployment of dynamic map content into external applications without those application developers (i.e. the developers of public health DSS applications) having to become expert in online geospatial application development. Instead, the DSS developers are able to embed maps developed by the PHAiRS system in their interfaces. An important advance in the PHAiRS WMS capabilities was achieved in this year's work through the implementation of the WMS TIME specification for the acquired EPA AIRNOW historic data and modeled DREAM outputs. This achievement allows for the efficient management and delivery of time-stamped measurements of particulate densities and corresponding DREAM model outputs.

The previously described SOAP services provide a more sophisticated service interface for the delivery of complex data structures and binary products (i.e. PDF files, lists of WMS and image URLs, PNG files). This increased capacity for the delivery of complex data and products to requesting applications facilitates the delivery of high-end capabilities to public health DSS applications without the DSS developers having to write the, often complex, code necessary to generate the returned products. The selection of 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.

As a demonstration of how the products of the OGC and SOAP services might be embedded within a client interface, a sample client has been developed that integrates these services, and provides an interactive user interface for them. This client interface is illustrated in Figure 5, and contains a combination of standard interactive mapping components, and access to the more sophisticated analytic capabilities provided by the underlying SOAP services. Additional client interface components have already been illustrated in Figure 4 (the animation viewer) and Figure 2 (the density plot graphic).

In addition to providing a demonstration interface for how the products of the PHAiRS project may be integrated into existing DSS applications, some stakeholder groups that we have presented our results to have expressed interest in directly linking to the demonstration interface as their initial deployment of our project's products into their systems.

D. Component Interaction

While Figure 1 illustrates the generic relationships between PHAiRS system components, specific application use scenarios involve more specific component interactions, two of which will be discussed as an illustration of how the general model is implemented for a specific use case.

First, the interaction diagram for the simple use case for the generation of a PNG density plot for a specified polygon (i.e. county) is represented in Figure 6. This diagram illustrates a simple round-trip interaction between four PHAiRS components:

- Client interface (this could also be a DSS client interface): the interface presented to the end user
- DSS CGI: the server-side application that performs interaction with the rest of the PHAiRS system components. In this case, the DSS CGI acts as a client to the polygon SOAP service.
- Polygon density SOAP service: the continuously running SOAP service that is listening for polygon density requests, taking action on those requests based upon the parameters provided as part of the request
- Raster DB: the GRASS GIS-based collection of raster data required for satisfaction of the request.

The interaction between these components is a basic linear sequence of requests propagating from left to right in Figure 6 and a corresponding sequence of responses propagating from right to left in the figure, ultimately resulting in the delivery of a product to the user interface.

A second, much more complex interaction diagram (Figure 7) represents the interactions between the system components

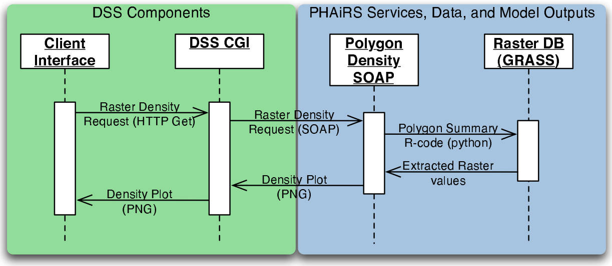

Fig. 6. Interaction diagram for the density plot use case.

related to a time-series request. Specifically, the components involved in the time-series use case include the client interface, DSS CGI, and GRASS GIS components of the previous diagram in addition to the following:

- Animation SOAP service: the continuously running SOAP service that is listening for requests for time series component urls
- Air quality WMS: a TIME-enabled OGC WMS that provides map images that are a combination of vector and raster data derived from the PostGIS and GRASS GIS components
- PostGIS: the spatially-enabled PostgreSQL database that contains the vector datasets (including over 1.5 million point measurements of PM2.5 concentrations from the EPA AIRNOW network) collected for use in the PHAiRS project.

Interaction between these components is initiated by three separate requests that originate in the client interface, two of which are based upon the results obtained in response to a previous request. The initiating client is submitted to the DSS CGI which then acts as a SOAP client in submitting a SOAP request to the animation SOAP server. This request results in the delivery of a set of URLs to the DSS CGI that then returns an HTML document to the requesting client that has all of the provided URLs embedded in a series of HTML image tags that are sequentially displayed and hidden to create an animation effect. Each image tag is populated with an WMS request that is directed to the air quality WMS server, resulting in the delivery of a custom map for the specific time step represented by the WMS request. In the case of the demonstration client, 72 individual WMS requests are submitted to the WMS server, one for each hour of the 72-hour dust model forecast. The client interface is also provided with a URL for a time series plot (saved as a PNG file on the DSS CGI server). This image is requested from the DSS CGI to provide the time series plot depicted in the right half of the client interface displayed in Figure 4.

III. Conclusion

Overall, the progress made in the second year of the New Technology component of the PHAiRS project reflects both a rapid development cycle and closely linked integration of these new technologies into the products of the PHAiRS project. During this year of work, the visualization and mapping capabilities of the client interface have evolved to provide a Python-based, modular, multifunctional client that provides access to the capabilities of multiple data and image services based upon two core standards: the W3C SOAP specification, and the OGC WMS specification. The creation of services supporting these protocols provides a streamlined means for public health decision support systems to integrate the enhanced DREAM model outputs and related environmental data products into their application frameworks while the developed demonstration client interface both demonstrates potential client interactions with these services and provides an initial client that DSS users may directly interact with.

Appendix I
Resources

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

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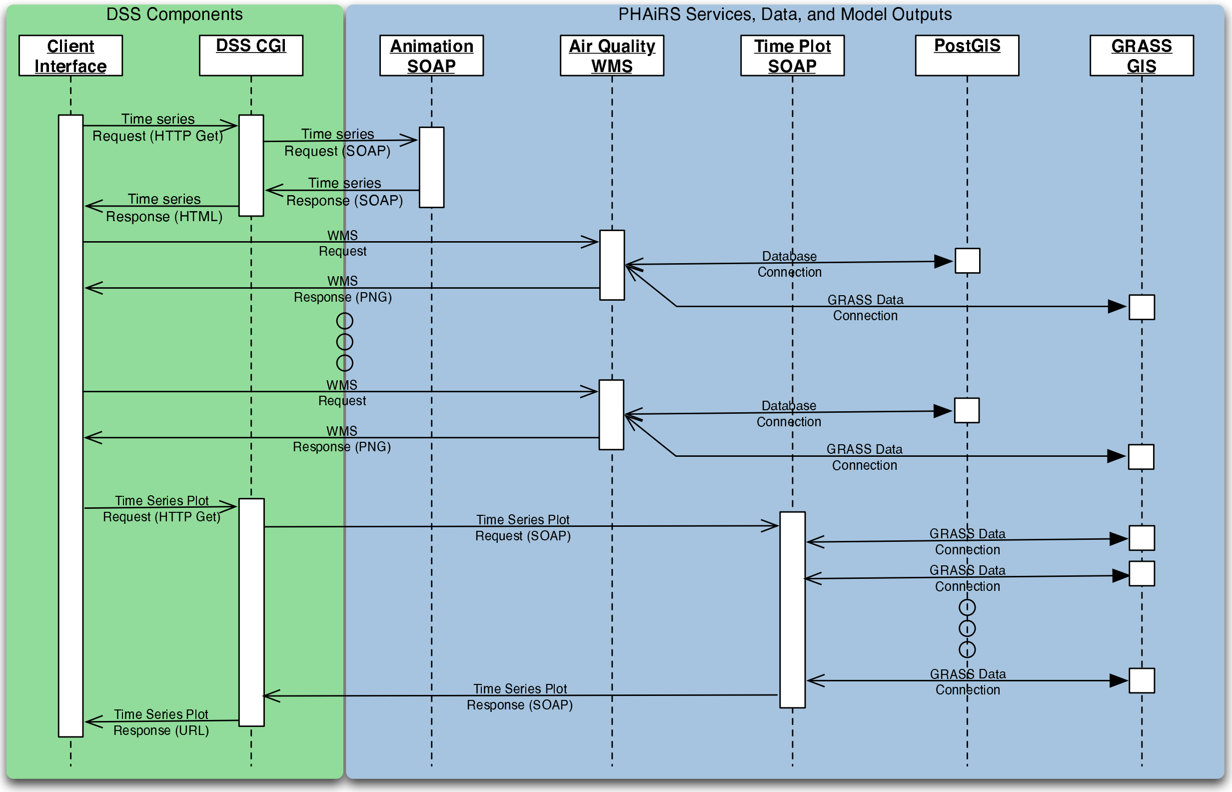

Fig. 7. Interaction diagram for the time series use case.

Karl Benedict Dr. Benedict's technical background includes 19 years hands-on computer solution implementation experience including: relational database design and administration; information needs assessment; network design, implementation, and administration; system specification, configuration, and administration; end-user support provision; multiple system and application integration; and Internet application development employing a combination of commercial and open-source server applications based upon Perl, PHP, Python, ColdFusion, Zope and Plone. Dr. Benedict has worked with applications running under AIX, Linux, Microsoft Windows, and the Macintosh OS, and currently is a Senior Research Scientist at and manages the IT program for the Earth Data Analysis Center at the University of New Mexico.

William Hudspeth Dr. Hudspeth has ten years experience in Geographic Information Technology and has spent the last four years participating in developing various applications that employ web-based database connectivity, display and analysis of geospatial datasets, interactive web-based mapping, and data delivery. This work has involved both proprietary and open source software and includes Cold Fusion, PHP, Python, Grass GIS, ArcGIS, Minnesota Mapserver, and R.