Web-based Educational Tools for Understanding Climate Variability
Final Report – submitted 13 April 2009

Dylan Keon
Northwest Alliance for Computational Science and Engineering
Oregon State University
keon@nacse.org   Phone: 541-737-6608
Project website: http://gis.nacse.org/nwacc08

Statement of project goal

The primary goal of this project was to combine web-based technology in innovative ways to make complicated time-series datasets more accessible to users, ultimately helping them understand the dynamics of the system(s) represented by the data. We proposed to develop new tools for analyzing climate variability across a wide range of spatial and temporal scales and make the data easily accessible via sophisticated, yet user-friendly, web-based tools that will enable educators and students to incorporate climate information into their teaching and research.

Project Results

This proof-of-concept interface demonstrates a model for visualization of time-variant and time-invariant layers in a single view, including the ability to animate the time-variant data. The project was successful due to the development of several new methods:

- Tying automated backend simulation processes to web-based display and exploration of the resulting datasets.
- Using open source GIS tools not only to display time-invariant layers, but also to animate and display time-variant layers within the same mapping interface.
- Enabling real-time navigation and querying (forthcoming) of the time-variant layers during animation.

The bulk of the research work was spent devising an automated backend system for simulating changes in scenario data at each time step, and generating output to be used in visualizations. We quickly realized that the backend processing work would take up much of the research time. To speed the process, we decided to utilize existing tsunami simulation data rather than starting with raw climate data; however, we but built the system in such a way that time-series

climate simulation data can essentially be "plugged in," with some minor modifications. The backend system consists of custom-developed Python and C++ code that examines output from a tsunami simulation model and generates GIS layers (georeferenced TIFF images) representing the wave runup at each time step of the simulation. Using other custom code, a PostgreSQL/PostGIS database, and information on human casualty models, we calculate a random starting population distribution and the movement and status of each person at each time step. This information is stored in the PostgreSQL/PostGIS database and can be mapped as GIS layers directly from the database.
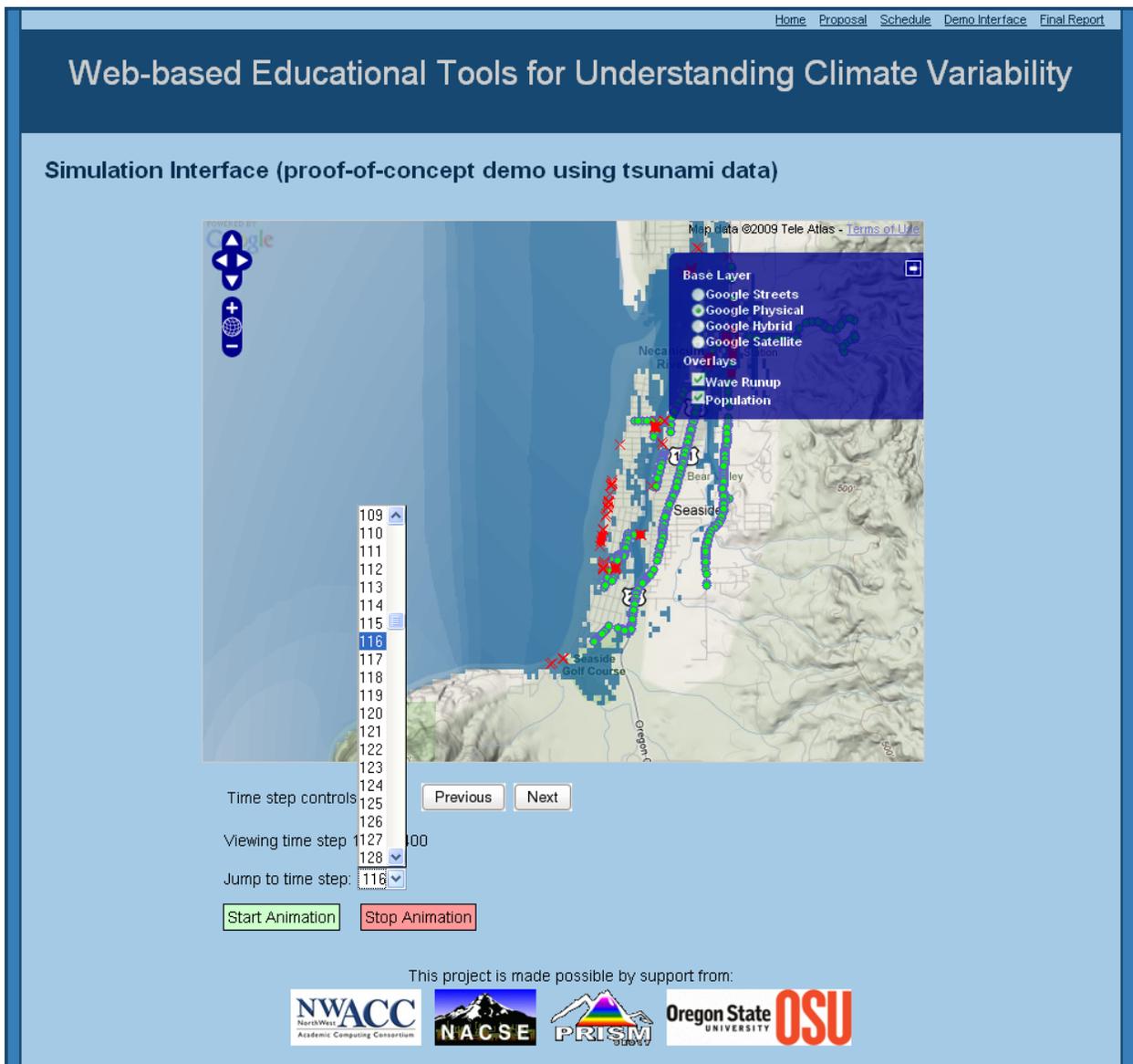
Figure 1. Proof-of-concept page displaying the mapping/visualization interface for examining time-series tsunami data and the simulated movement of evacuees.

On the interface side, significant advances were made in the use of open source software to provide the dynamic display, navigation, and querying (forthcoming) of time-series datasets. Visualizations of time-series data benefit from the inclusion of interactive capabilities. This gives users the ability to control what they see. Even more importantly, it enables them to query and retrieve details about the simulated data, which in turn creates confidence in the numerical models. In a visualization of this sort, it is important that the user to be able to view the unchanging core data (topography, roads, etc.) as well as the simulated time-series data reflecting the progression of waves and their effects on structures and humans. We developed a spatiotemporal visualization interface using a mix of open source software toolkits (MapServer, Open Layers, GDAL, GEOS, PROJ.4) that allows the user to view the simulated data across all time steps in a web-based mapping interface (Figure 1). The underlying map layers are provided by the Google Maps API, and the user can choose among the typical Google base layers of street view, satellite view, or shaded relief topographic view. Additional layers representing wave runup and population distribution are generated on the server side via MapServer, which connects to the PostgreSQL/PostGIS spatial database to extract necessary data and render them as a map layers. This is a powerful combination, because custom layers can be constructed dynamically and placed on the map, with an automatic background layer (e.g., the Google satellite or terrain view) available for virtually any location around the globe. The client-side proof-of-concept interface visible on the website was constructed using OpenLayers and also functions as a fully-enabled Web Mapping Service (WMS) client, with the ability to pull GIS layers from remote servers into the interface and render them into the overall map image viewed by the user.

As mentioned above, a key feature of this interface is the ability to animate changes in wave runup and population distribution and status over time, directly within the mapping interface. The interface provides the user with controls to start and stop the animation, as well as jump to any time step within range. All map control actions can still be used during the animation, so that the user can zoom, pan, or load/unload layers while the animation is underway. Combined, these capabilities provide a powerful set of controls for data visualization and exploration.

Additional Usage

The project has been demonstrated to research and teaching faculty from other universities, as well as to students in the Dept. of Geosciences at Oregon State University. As the project is still under development, it is not being actively utilized or demonstrated in teaching or research, other than by the developers.

Future Work

In the near term, we plan to enable querying of both the population and wave runup layers – users will be able to click on any point and retrieve data about that object at that particular time step. Querying will be able to occur while the animation is active.   Later, we plan to (1) develop more detailed query mechanisms, such as the ability to "bracket" a particular period of time and query all information within that bracketed period, and (2) create a test case using climate data, as originally intended. At that time, all further work will utilize time-series climate datasets.

Because this project is a proof-of-concept implementation of the visualization interface, very little work was done to optimize the interface for client-side performance. In addition to the goals mentioned above, future work will center on the optimization of the interface:

- Possible implementation of the tilecache system (www.tilecache.org) for on-demand pre-rendering of map images. This project presents a special case since tilecache is designed to work with data in the spatial dimension, but not in the temporal dimension.
- Exploration of FastCGI for optimization of CGI-generated MapServer images.
- Optimization of animations in a client/server architecture, with clients distributed across the Internet.

Presentations

Publications describing this work have not yet been prepared, as the work is actively continuing. Portions of this work were presented in talks given by Keon at:

- **GIScience 2008** - The Fifth International Conference on Geographic Information Science, September 23-26, Park City, UT.
- **AAG 2009** - The Association of American Geographers 2009 Annual Meeting, March 22-27, Las Vegas, NV.

Closing Financial Statement

All NWACC-provided funds were expended on this project, with salaries comprising 100% of the expenditures. Additional in-kind contributions were provided by NACSE and OSU in the form of web and database server access, backups, software versioning, and additional use of computational infrastructure.