Building Tsunami Analysis Tools into a GIS Workspace

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Abstract

Scientists at the NOAA Center for Tsunami Research (NCTR) utilize a variety of software programs to develop and analyze tsunami propagation and inundation models results. NCTR software developers are developing tools and applications for ArcGIS and OpenGIS for data management, visualization, and analysis to enhance our capabilities. The ability to directly read netCDF into ArcGIS opens up the opportunities such as analyzing time series of propagation runs and integrating data sets such as critical infrastructure and census information that are not available using traditional tools. NCTR has developed a suite of tools in python and Model Builder and help streamline our work process. In this paper, we will discuss the merits of using Python and model builder for building robust analysis tools for modelers and analysts who have traditionally used home grown visualization tools or software packages such as Matlab.

Introduction

NOAA's Center for Tsunami Research is located at the Pacific Marine Environmental Laboratory in Seattle, WA. NCTR's mission is three-fold. NCTR works to design and develop tsunami detection devices and build monitoring systems. Secondly, NCTR provides research, development and implementation of numerical models to increase the speed and accuracy of tsunami operational forecasts and warnings. Lastly, NCTR also conducts research and development to improve methods of predicting tsunami impacts on population and infrastructure of coastal communities. All three of these goals require some dependence on geospatial infrastructure - whether we are building a site suitability map or designing a model to determine at risk population within an inundation zone. NCTR has long recognized the need to provide information in a GIS format to emergency managers and state partners. Since 2005, we have increased the use of ArcGIS into the daily workflow of our products and projects. Currently, GIS is being used in buoy siting optimization studies, static maps for briefings and updates, database applications for data dissemination and storage, and development of stand alone tools. Additionally, GIS data and technologies are currently integrated into the NCTR development of the Short-term Inundation Forecasting for Tsunamis (SIFT) software used at NCTR for analysis and deployed to NOAA Tsunami Warning Centers for operational use. In this paper, we will outline different case studies of how we use python and model builder to integrate GIS into NCTR's research and development work.

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It is well known that models do not operate independently of their data. In the case of hazard mitigation; modelers need to start integrating real-life data into their workflow. While there has been a disconnect between science and management or response, the integration of GIS into disaster response and mitigation as shown in Hurricane Katrina response and mitigation techniques for other large scale recoveries has proven its necessity and utility.

In most cases, it is the lack of standard data formats that make model output integration difficult to bring into GIS for analysis. Many scientific modeling outputs are in netCDF and HDF formats with time steps for all runs in one file. File sizes can be big, irregularly spaced or unstructured and file management can be unwieldy. The advent of multidimensional tools into the ArcGIS 9.2 product allows NCTR propagation and inundation data to be easily integrated into ArcGIS opening up new methods of analysis and visualization.

With the release of ArcGIS 9.0, ESRI has supported the use of python as a scripting language. Python is an object-oriented programming language that is widely used for a variety of applications. Its simple syntax and flexible, dynamic nature make it easy to learn, and there are libraries available to support many scientific analysis tasks. [2] The base level of code and libraries is extensive and extendible. In ArcGIS, anyone can write python scripts to call different functions and interact with data. The ability to call scientific python to do more complicated spatial functions brings a level of complexity to standard GIS processing that makes it more appealing to the modeling community.

Python tools for converting data and data management

The Python tools that NCTR has developed that are most closely integrated with the ArcGIS environment are mostly simple extensions to support specific legacy data formats. For example, an early tool suite imported and exported data in the proprietary format the MOST tsunami model uses its bathymetry data. Python programs can greatly benefit from being integrated into the ArcGIS interface, such that the user does not need to know whether the tool they are using is native to ArcGIS, is a Model Builder model, or is a Python application.

Used in this manner, Python is primarily working as a “glue” language, providing the control structures to call subroutines, such as ArcGIS’s geoprocessing tools, that do the actual analysis. The interface to ArcGIS that is exposed to Python generally encourages this. Aside from the Describe interface that allows access to some details of feature datasets, the ArcGIS geoprocessing environment assumes that most actual analysis will be performed in the “black-box” geoprocessing tools, not within Python.

There are a number of third party libraries that greatly enhance Python’s value as an analysis environment itself, instead of merely as a framework for calling external

[2] G. van Rossum. *Python Tutorial.* Python Software Foundation, 2006; http://docs.python.org/tut/

subroutines.[3] ArcGIS's Python interface could be improved by further exposing more details about the data being processed, which would allow the integration of ArcGIS with some of the other libraries available for Python. For example, a standardized interface that allowed an ArcGIS raster to be manipulated with the well-established NumPy and SciPy library[4] for processing numerical arrays would allow the user to choose the tools best suited for each analysis. Lacking this interface, when we need to do complex raster analyses that would require a cumbersome series of geoprocessing tool calls, we sometimes write standalone tools outside of the ArcGIS environment.

Visualizing Propagation and Inundation – Python for batch processing

NCTR uses the Method of Splitting Tsunamis (MOST) model to calculate propagation and inundation of tsunami generation. The modeling framework consists of three steps. The first step is the initiation phase; this involves setting up a source with a magnitude and slip. Secondly, the model calculates the transoceanic propagation using a suite of numerical simulations. Lastly, using a more detailed grid of merged bathymetry and topography, the model calculates the standing inundation or run up onto land. The models can be run on desktop system or in a web application. The resulting propagation and inundation files are in netCDF format. Modelers have in the past used Matlab and Ferret to visualize the results. As a result, NCTR modelers and programmers have developed custom code to streamline the output to work with model results. This is especially critical during an actual tsunami event when fast response is crucial. While Matlab and Ferret are excellent for building animations and creating 2-d maps, the results are static in that there is no way to interrogate the data, add in real time data or perform any analysis on the fly.

Model builder and the integration of multidimensional tools in ArcGIS allows NCTR modelers to add their data to a ArcMap, build a model to grid and resample their data, create rasters and interpolate the results and then display their data. The addition of iteration, feedback loops and automation allows researchers to process their data using ArcGIS. Outputting the model builder results into Python and adding extra code to have it place output into certain directories and cleanup temporary files allows the user to make processing and running of the tsunami output simpler.

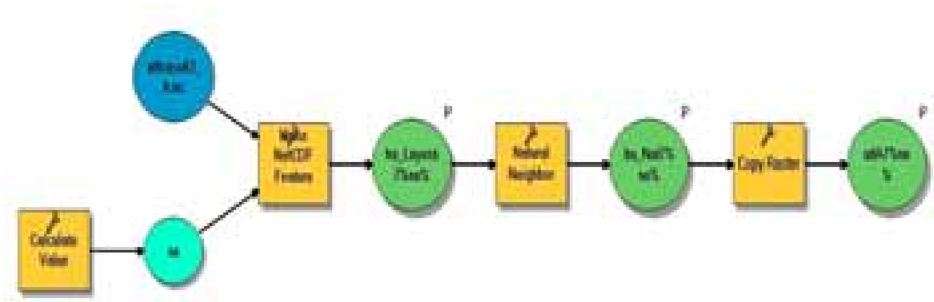

Figure1. Example of model used to generate images for tsunami animations

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[3] T.E. Oliphant. Python for scientific computing. *IEEE Computing in Science and Engineering* May 2007.
[4] http://numpy.scipy.org/

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Resulting images or raster data sets can easily be added to raster catalogs and animated to display the results of tsunami wave propagation or inundation for different scenarios. Creating a 3-d view of the inundation or propagation event and combining this with building footprints, topographical features and hazardous areas make planning and mitigation easier. The ability to perform geoprocessing on the rasters, add vector data such as shorelines, population centers and densities and critical infrastructure and interact with the data makes this a much richer application than standard 2-d animations and static maps. The drawback is that it may take longer to generate than a Matlab animation, so it may not be as valuable in real time situations, but still useful for post-event processing. Additionally, placing the animation into ArcGlobe will give researchers the opportunity to show the public and policy makers the global impact of certain tsunami events.

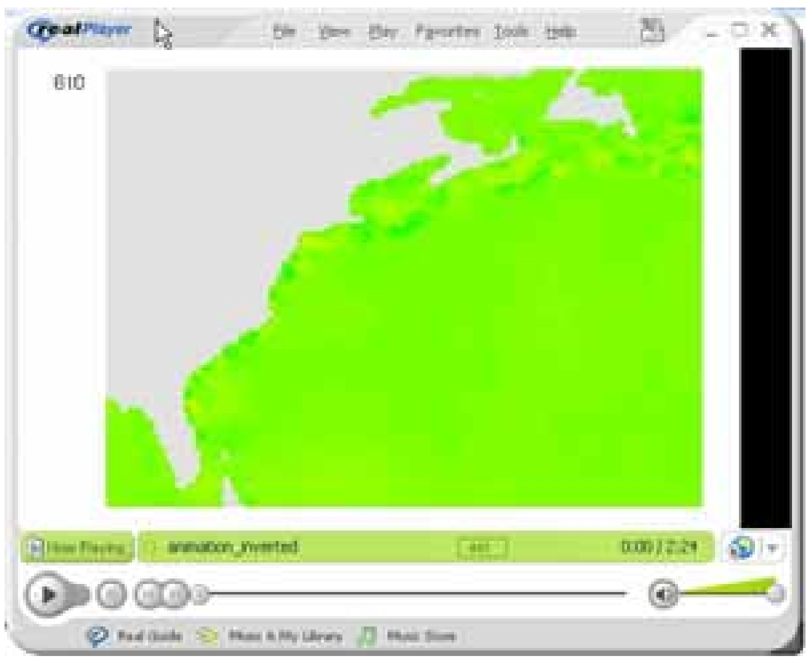

Figure2. Resulting model animation output from a python/model builder script of tsunami propagation test case for the Atlantic Ocean.

Developing At-risk population algorithms – adjusting parameters without being a coder

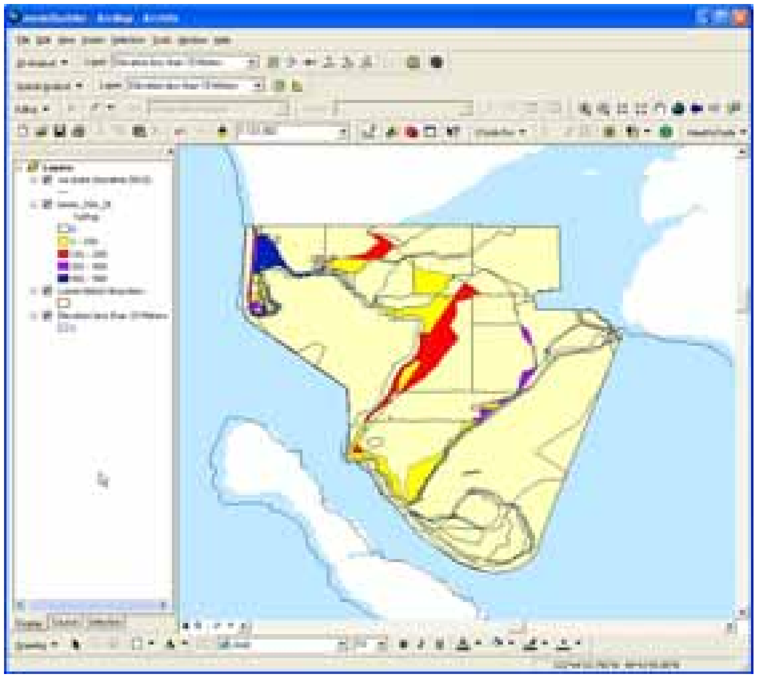

Figure3. Developing At risk population tool for Washington state coastal communities.

Developers at NCTR are building at-risk tsunami tools to work with state partners and emergency managers to determine the level of risk from a tsunami event on coastal communities. NCTR and the NOAA Tsunami program have identified sites for further study and inundation modeling for the United States and territories and we are trying to determine what determines an at-risk population. Scientists work with developers to decide what parameters to use for an at risk algorithm. Geoprocessing in ArcGIS simplifies the process of selecting, projecting, processing, buffering and converting data into forms that work well with each other. Creating models and using batch processing, scripting formulas for converting for population calculations and outputting the files to the correct locations with easy modifications that can be made in the human readable python code allows users to rerun the population at risk calculations for areas that may have not been analyzed yet or if they decide to change the parameters of the algorithm to better suit their area of interest.

Discussion

The move from having to write custom code or programs to integrate model data into ArcGIS by using standard ArcGIS tools such as netCDF readers has made working with tsunami modeling results much easier in GIS. The ability to try things out using model builder first, and then adapt the code in python brings the scientist who is more comfortable in a scripting environment into the world of GIS. Tsunami tools that allow for reformatting of data and bridges to our data bases allow for quick retrieval and formatting of data which is crucial when results are needed. The importance of bringing geospatial data into the modeling world including being to interact with the data without having to build a custom viewer or custom software. Lastly, the ability to add remote data layers such as through python enabled openDAP or through web services allow for modelers to interact with data that may be delivered in real time and not necessarily available to them on their desktop.

While python has made GIS more palpable to many scientific modelers, it requires some training and with that comes the need for using data sets and case studies that work towards their goals of data exploration, visualization and interrogation. For modelers that are comfortable at writing and reading code, working with python is a good introduction to the power of geospatial processing and ArcGIS.

Conclusions

The move to use GIS within the modeling community is a slow one. [5] The use of scripting languages such as python that encompass scientific and numerical modeling into their libraries help create bridges and links that allow scientists that a few years ago would have been hesitant to use GIS as a research or visualization tool, more appealing. NCTR has managed successfully to use python to integrate cumbersome data formats, batch process large data files and create easy to read scripts that can be altered to work with any data.

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