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Integration of Predicted Atmospheric Contaminant Plumes into ArcView GIS

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Abstract – *The Savannah River National Laboratory (SRNL) plays a key role in emergency response scenarios in which there may be a release of atmospheric chemical or radiological contamination at the DOE's Savannah River Site (SRS). Meteorologists at SRNL use a variety of tools to predict the path of the plume and levels of contamination along the path. These predictions are used to guide field teams that take sample measurements for verification. Integration of these predicted plumes as well as field measurements into existing Geographic Information System (GIS) interactive maps provides key additional information for decision makers during an emergency. In addition, having this information in GIS format facilitates sharing the information with other agencies that use GIS.*

In order to be useful during an emergency, an application for converting predictions or measurements into GIS format must be automated and simple to use. Thus, a key design goal in developing such applications is ease of use. Simple menu selections and intuitive forms with graphical user interfaces are used to accomplish this goal.

Applications have been written to convert two different predictive code results into ArcView GIS. Meteorologists at SRNL use the Puff/Plume code, which is tied to real-time wind data, to predict the direction and spread of the atmospheric plume for early assessment. The calculated circular puffs are converted into an ArcView polygon shapefile with attributes for predicted time, dose, and radius of the puff.

The meteorologists use the more sophisticated Lagrangian Particle Dispersion Model (LPDM) to predict particle dispersion and deposition. The calculational grid is brought into ArcView as a point shapefile and then interpolated to ARC GRID format using Spatial Analyst. This GRID can then be contoured into a line shapefile, which is easily shared with other agencies. The deposition grid is also automatically contoured for values that correspond to FDA Derived Intervention Levels for beef, produce, and dairy products.

Decision makers at SRS routinely use these predicted plumes to direct field teams. In the case of a strong release, this information can be used to decide whether to evacuate a particular area. Having this information in GIS format may aid the decision maker because other infrastructure information can be overlaid with geographic reference.

I. INTRODUCTION

The DOE's Savannah River Site, located southeast of Augusta, Georgia, produced nuclear materials from the 1950's to the 1990's and continues to handle a variety of hazardous materials, both chemical and radioactive. Consequently, emergency response to a potential atmospheric release of chemical or radioactive material has long been an issue of both operational readiness and research and development. For many years, the Atmospheric Technologies Group (ATG) at Savannah River National Laboratory (SRNL) has developed and maintained state-of-the-art measurement and predictive capabilities. These capabilities have culminated in the Weather Information and Display (WIND) System, which is a computer-based resource for predicting the consequences of an accidental release of hazardous material. The WIND System integrates measurements and predictive capabilities into a single, automated process. Local measurements are continuously collected from a network of monitoring sites, and various other regional atmospheric information feeds and forecasts are collected, including local Doppler radar. ATG has developed an operational configuration of the Regional Atmospheric Modeling System (RAMS) to produce near real-time predictions of complex three-dimensional atmospheric motion, generating detailed eight-hour forecasts every three hours. The measurements and operational RAMS predictions are integrated in the WIND System to be used by a suite of environmental transport models to support consequence assessments and protective action decisions during all phases of emergency response.

In the late 1990's SRNL developed the first site-wide ArcView GIS system at SRS that made typical GIS infrastructure data available over the site computer network. ATG was an early user of this GIS system and through ATG this GIS system was introduced to and adopted by the SRS Emergency Operations Center (EOC). ATG realized that the overlay of various types of data provided another useful tool for decision makers and began a program to integrate their predictive plume results into the ArcView GIS system.

In order to be useful during an emergency, an application for converting predictions or measurements into GIS format must be automated and simple to use. Thus, a key design goal in developing such applications is ease of use. Simple menu selections and intuitive forms with graphical user interfaces are used to accomplish the goal of ease of use. The automation is accomplished by developing a “handshake” with the predictive model in the WIND system so that output from the predictive model can be automatically converted into GIS format.

II. CONVERSION OF PUFF/PLUME RESULTS

Within the suite of predictive models in the WIND System, the Puff/Plume code is used for early assessment in an emergency. Puff/Plume is a highly flexible trajectory Gaussian model that provides an initial, reasonably conservative estimate of downwind concentration or dose. Release trajectories are constructed for up to 12 hours based on observed and/or forecast winds. Puff/Plume is easy to run and runs quickly, typically taking less than a minute to compute. Puff/Plume is a PC Windows application with a graphical user interface (GUI) for user choices. Puff/Plume contains its own graphical output in which the computed plume is overlaid on a static basemap, with several different choices of basemaps. One of the user options is to export a text file for conversion to ArcView GIS format.

An ArcView extension was written to process the text file that is written by Puff/Plume. The “handshake” between Puff/Plume and the ArcView conversion is created by insuring that the text file has a consistent format, which is as follows. Line 1 is a header line with time and date of release, the time step between puffs, a flag of 1 for radioisotope or 2 for chemical, and the name of the radioisotope or chemical. Line 2 has the longitude and latitude of the release location. Subsequent lines are for each successive time step in the calculation and each line has a flag for display of the puff (0=no, 1=yes), the longitude and latitude of the puff center, the radius of the puff, and the concentration or dose.

The ArcView extension reads this text information and creates two shapefiles. One shapefile is a line shapefile that shows the plume path by connecting the puff center points. The second shapefile is a polygon shapefile that shows the puff circles with the radius of each puff as read from the text file at its time step. The attributes of the puff shapefile include the time step number, the date, the time, the dose or concentration, the distance from the source along the path, the radius of the puff circle, and a flag for display. Note that in the conversion the lat/lon center coordinates are converted to UTM coordinates before the pathline and puff polygons are created.

The ease of use of the application is shown by the form in Figure 1. All that is required is for the user to browse to locate the text file written by Puff/Plume and then specify the location and basename of the shapefile. Buttons with preset directories for input and output quickly guide the user to the default locations. When the Convert button is clicked, the application processes the text file information into the shapefiles previously described.

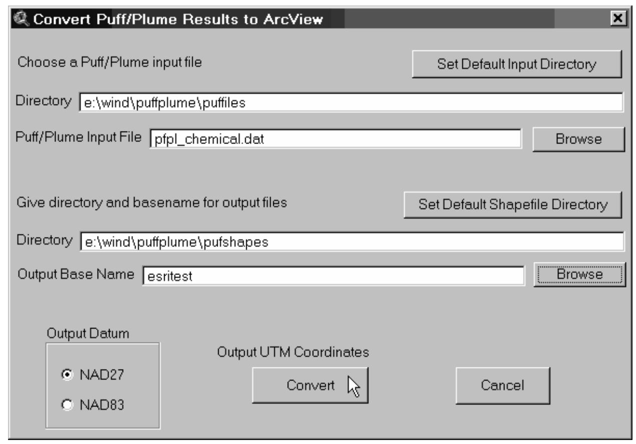

Fig. 1. Form for Conversion of Puff/Plume.

In addition to creating the shapefiles, the shapefiles are automatically loaded into the view and classified (color coded) to match the legend in the Puff/Plume output interface. For radioisotopes, the dose is broken into five ranges of decades including 0-1 mrem, 1-10 mrem, 10-100 mrem, 100-1000 mrem, and above 1 rem. For chemicals, the concentration is classified into four ranges that are predetermined according to the chemical. A dictionary lookup is used to assign these ranges. The dictionary is created from the ranges contained in the Puff/Plume code and must be updated if the ranges in Puff/Plume are changed. Figure 2 shows an example of a chemical plume that has been converted into shapefiles and added to a view (note that the GIS view would use colors; grayscale is used here for publication).

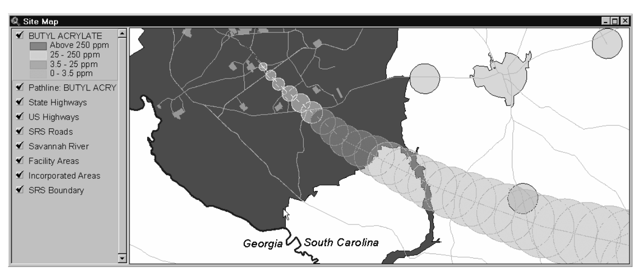

Fig. 2. Example of Puff/Plume Conversion.

Note that having these predicted plume results in shapefile format allows for easy sharing with other agencies that use ArcView GIS. The legend classification discussed above is shared by creating a legend file with ArcView 3.x or by creating a layer file with ArcGIS.

III. CONVERSION OF LPDM RESULTS

For the case of radionuclide contamination, once the early assessment has been established a highly refined transport and dispersion analysis can be performed with the Lagrangian Particle Dispersion Model (LPDM). LPDM utilizes the three-dimensional winds and turbulence fields generated by RAMS. LPDM is a three-dimensional stochastic model that calculates particle dispersion and deposition of radiological isotopes from the three-dimensional flow field. Outputs include transient instantaneous surface concentration, integrated surface deposition, initial exposure dose, dose rate, and total dose equivalent for 4-day, 1-year, and 2-year exposure. LPDM has an input graphical user interface written in IDL (Interactive Data Language) and also has sophisticated graphical output capabilities.

As with Puff/Plume, the advantage of converting LPDM output to GIS format is for easy overlay with other information used in the GIS system. The conversion to GIS format is not as straightforward since we are now dealing with three-dimensional fields. However, for consequence analysis the deposition at ground level is of most importance, so that the two-dimensional results at ground level can be converted to GIS format.

There is now significantly more information but the "handshake" strategy is the same. That is, text files are written from post-processing of the LPDM results and the text files are in a standard format that is read by the ArcView application. There are six text files written with standard names and formats as follows.

IDL_header	XY cell ID and lat/lon of cell location
ddep1.xxxx	Cell ID, integrated deposition (pCi/m^2)
conc1.xxxx	Cell ID, concentration (pCi/m^3)
dosei.dat	Cell ID, 50-year Dose Equivalent Initial Exposure (Rem), Dose Rate (μRem/hr)
doseo.dat	Cell ID, 4-Day Total Dose Equivalent (Rem), 1-yr TDE (Rem), 2-yr TDE (Rem)
autotime-pc.dat	Number and lat/lon location of sources

Note that the extension xxxx denotes a time and there may be outputs at multiple times. Each time result would be processed separately in the ArcView conversion.

The strategy for the LPDM conversion is to convert the cell locations to a point shapefile with an output value as an attribute, convert the point shapefile to GRID format using Spatial Analyst with the value interpolated onto a grid of specified cell size, and then contour the grid to get a line shapefile of contours. This contour shapefile is easily shared with other agencies and is convenient to use in the GIS display. The GRID format is also useful for display but is more difficult to share. The main menu for the conversion is shown in Figure 3 and follows the strategy just outlined.

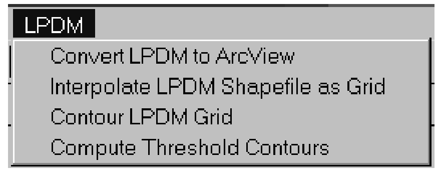

Fig. 3. Menu for LPDM Conversion.

When the first menu option is chosen to Convert LPDM to ArcView, another form appears that is similar to the form in Figure 1. The main difference is that there are now six input files and six output files. The application is written so that the standard names for input files are automatically populated when the user browses to find the IDL_header file. Likewise, standard names for the output files are automatically populated when the user browses to an output directory location. The user normally performs these two browse operations and then clicks the convert button to perform the processing. The processing performs the following steps.

1. The IDL_header cell location data is converted to a point shapefile with the cell ID as an attribute for each point.
2. This point shapefile is projected to UTM coordinates. An example of cell locations is shown in Figure 4.

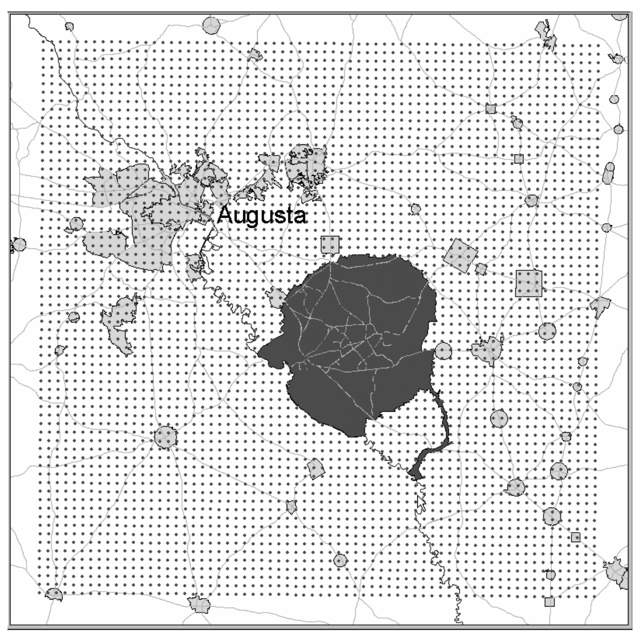

Fig. 4. Example of LPDM Grid Cell Locations.

3. Each of the value files is converted to a DBF table, e.g. dosei.dat is converted to dosei.dbf. In addition to the value field, a field with the log of the value is added.
4. The point shapefile with cell locations is added to the view and the value table is joined to the point shapefile using the cell ID for joining.
5. The log of the value field is used to classify the value over five decades starting from the maximum value. Figure 5 shows an example of deposition values classified over five decades. Note that cells with zero deposition are not displayed (transparent).

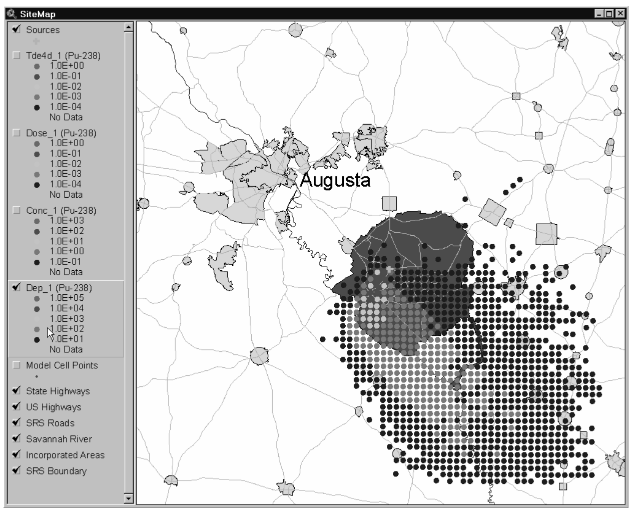

Fig. 5. Example of LPDM Deposition Values.

6. Each of the value fields are automatically joined to a point shapefile and classified into five decades so that all data is available for viewing or further processing. Note that in Figure 5 that Conc, Dose, and Tde4d have been added to the view in addition to deposition.

At this point the user has the LPDM results converted into point shapefiles and can proceed to grid the values of interest. Usually deposition is of most interest and the following steps will use deposition as the example. With the deposition theme selected, the user chooses the second menu option in Figure 3 to interpolate the values into GRID format. The user is given an option to choose the cell size for the interpolation, which is presented with a default value of 1/16 of the cell spacing. Usually the user takes the default and the grid is created. The grid is automatically added to the view and classified into five decades. Figure 6 shows the grid corresponding to the point values in Figure 5.

The grid in Figure 6 is useful as a backdrop in the GIS view and this is used in the WIND ArcView System. One example of how this grid is used is to direct field teams that are deployed to gather field measurements to verify the predicted plume and deposition. This information could also be used by decision makers to determine if certain areas should be evacuated.

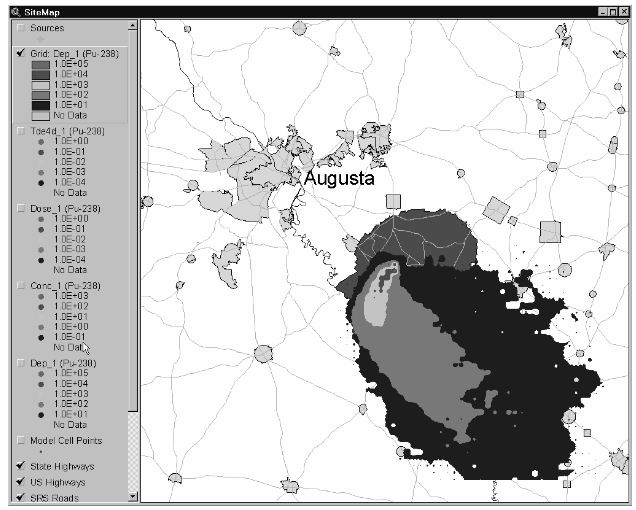

Fig. 6. Example of Grid of Deposition Values.

While the grid is useful, it is not easily shared with other agencies. The third menu option in Figure 3, Contour LPDM Grid, can be used to automatically generate a contour shapefile with five contours at the same decade intervals as shown in the grid legend. The contour shapefile is automatically added to the view and classified with the same colors as the grid. Figure 7 shows an example of the contours of the grid in Figure 6.

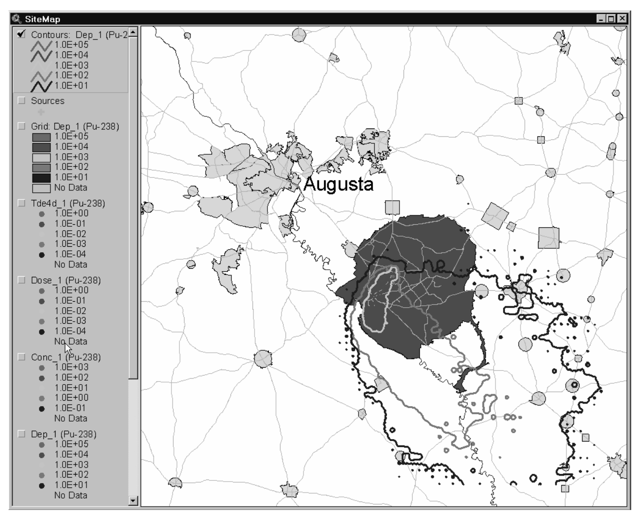

Fig. 7. Example of Contours of Deposition Values.

Figure 3 shows a fourth menu option, Compute Threshold Contours. This option is used with the deposition grid and produces contours for deposition values that correspond to FDA Derived Intervention Levels for beef, produce, and dairy products. A dictionary lookup for the radionuclide automatically provides the threshold levels and generates the contours.

A message tells what the threshold value is and whether it is exceeded. If the value is exceeded, then the shapefile is automatically added to the view.

IV. CONCLUSIONS

During an emergency, decision makers rely on integrated information, and having spatial information in a GIS system may be beneficial to the decision makers. Complex calculations such as atmospheric plume predictions can be integrated into the GIS system for overlay with other information. Key design goals in developing a conversion application are ease of use and automation to minimize manual operations. Examples have been given for the conversion of two atmospheric plume computations used at Savannah River National Laboratory. "Handshake" between the computational code and ArcView is easily accomplished using text files in a defined format. The Puff/Plume and LPDM conversions to ArcView are routinely used at SRNL during emergency response situations.

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