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DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM BASED DUST DISPERSION MODELING SYSTEM FOR USE IN THE PLANNING AND IMPLEMENTATION OF MILITARY TRAINING EXERCISES

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ABSTRACT

As residential areas continue to develop near military sites, possible impacts from military traffic and exercises become of greater concern. Of particular concern is the effect of particulate matter and atmospheric dust dispersion on air quality caused by such maneuvers. To aid this problem, Pacific Northwest National Laboratory proposed a plan to develop, document, and test a modeling system in support of dust dispersion reduction and management near government sites. To accomplish this task a model interface was developed that would be user friendly yet sophisticated enough to accommodate the varying needs of the client. One such need was for the modeling system to be capable of providing data for diverse locations and varying sites. To accomplish this task, the dust dispersion modeling system needed to be integrated with a geographic information system (GIS). Through use of the GIS application, data maps contained within the application could be used to create new sites. The GIS application would also allow the user to enter the point, area, or line source required to run the dispersion modeling system. Incorporating the GIS with the model would allow the user to view plume rise and expansion over actual data maps of the desired site. By using historical, current, and user defined data, near real-time dust dispersion models will aid in estimating and managing the effects of military exercises on the environment and nonmilitary personnel.

INTRODUCTION

In arid regions of the world, dust dispersion has proven to be a continual problem for the military and civilians. Wind erosion, visibility, and deposition of dust on roads and buildings are but a few of the effects of dust dispersion [4, 5].

As residential areas continue to develop closer to military training sites there is increasing concern about how the dust generated by training maneuvers may impact civilians, the environment, and how future training exercises are planned and implemented.

Of particular concern is the dispersion of particles less than 10 micrometers in diameter. The danger associated with these particles is that they are small enough to enter into the human lungs causing respiratory disorders, bronchitis, increased asthma attacks, and aggravation of lung or heart disease. Larger particles may cause irritation to the eyes, nose,

and throat as well as reducing visibility, but do not pose as great a health risk as particulate matter under 10 micrometers in diameter [6].

During the calendar year of 2000 the Strategic Environmental Research and Development Program of the Department of Defense (SERDP) accepted a proposal by Pacific Northwest National Laboratory (PNNL) to develop a software modeling system that would allow users to model the dust dispersion generated by a planned training maneuver. This software modeling system would use historical, current, and user defined data within a geographic information system (GIS) application to generate simulations for use in managing dust generating activities and developing dust mitigation strategies [2]. This dust dispersion modeling system would be developed under the name DUSTRAN.

Because the DUSTRAN modeling system was developed as a tool to assist in the planning of training maneuvers and

dust mitigation strategies, it was imperative that the system be capable of adapting to different sites as needed.

Creating New Site Map Displays

The integration of the DUSTRAN modeling system with the Environmental Systems Research Institute's (ESRI) ArcMap application allows the user to quickly and easily create a digital map representation of the training site. Using standard GIS files, such as ESRI shapefiles and raster images, users are able to create a digital map representation of the training site by just adding the files to the project displayed within the ArcMap application. Each file added to the ArcMap project represents one layer of the map which can be turned on or off within the map display. Information such as local area maps, road systems, water systems, and population can be displayed as layers along with the results of a training maneuver simulation layered on top of the display [3]. This functionality allows different types of data to be viewed as a group, or individually, thus giving a more detailed understanding of the site.

Once the user has set the display of the digital map to their liking, it can be saved as an ArcMap project file. The ArcMap project can then be used by the DUSTRAN modeling system as the default map display each time the training site is selected

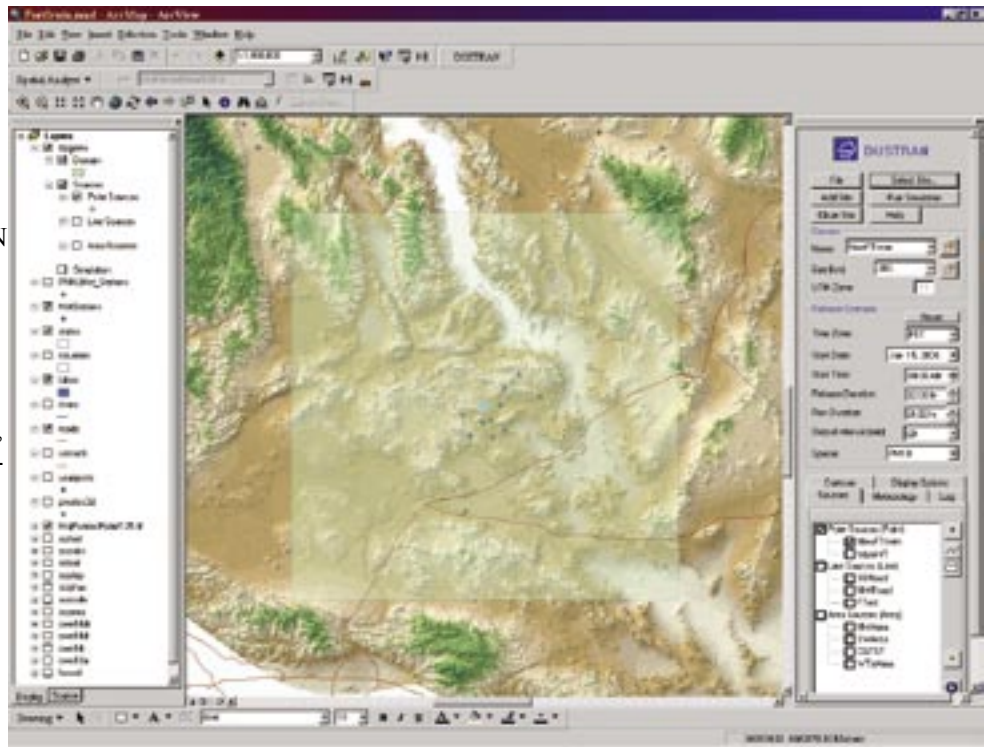


Figure 1. Example ArcMap project displayed within the ArcMap application.

for modeling. Figure 1 shows an example of an ArcMap project displayed within ArcMap application.

In most cases, using the standard GIS files also eliminates the need for users to create map files, as standard GIS files are readily available from a wide range of sources for most locations within the United States.

The integration with ESRI's ArcMap application also allows the user to quickly and easily create new source locations for the training site. During the course of a training maneuver, dust dispersion sources can occur as different geometry and types as well as at multiple locations. Within a training maneuver, point sources can result from munitions explosions such as grenades and mortar rounds. There may also be various camps established for the specified exercise with numerous vehicles traveling between them. This would result in area sources for the camps, and line sources for the vehicles that are traveling between the different camps [1]. Using the draw shape functionality provided by the ArcMap application, new source locations can easily be added to the training site by drawing the shape of the source directly onto the map using the computer's mouse. Once drawn onto the map, sources are readily viewable by making the appropriate selections in the DUSTRAN modeling system interface. Figure 2 shows an example of multiple sources present in the map display of the ArcMap application.



Figure 2. Example of multiple sources displayed within the ArcMap application.

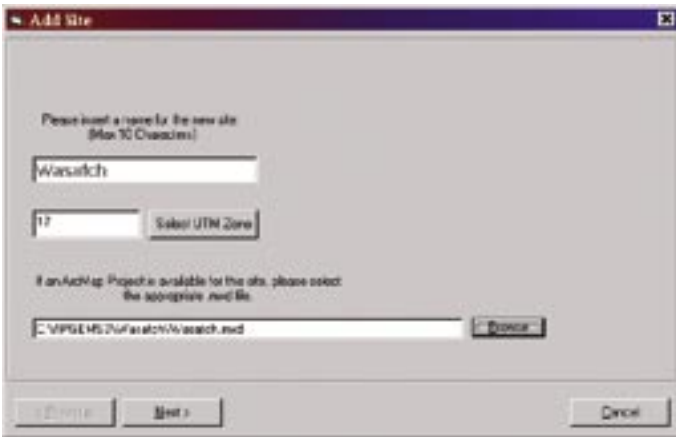


Figure 3. Wizard input screen for entering the site name, UTM zone, and ArcMap project file.

Add New Site Wizard

Along with the creation of an ArcMap project there are a number of additional steps that have to take place in order to add a new site to the DUSTRAN modeling system. These steps include the setting of a Universal Transverse Mercator (UTM) zone, selecting terrain and land-use files, setting meteorological station data, and creating site directories. To accommodate users with little or no GIS or atmospheric science experience, an easy-to-use interface called a software wizard was developed using the Visual Basic programming language. The purpose of the software wizard is to take a user step by step through the process of adding a new site. Integrated with the graphical user interface of the DUSTRAN modeling system by means of a software button labeled “Add Site”, the software wizard presents to the user three simple input screens asking the user for input pertaining to the site. This user input data includes site name, UTM zone, ArcMap project file path, meteorological station data, terrain file paths, and land-use file paths.

The first input screen of the wizard prompts the user to enter a name for the new site as well as selecting the appropriate UTM zone and ArcMap project file for the site. Site names can be up to a maximum of ten characters in length and can not duplicate the name of a site already present in the DUSTRAN modeling system. Figure 3 shows an example of the first input screen with example data entered.

To assist the user in the selection of an appropriate UTM zone, the wizard provides an option where the user is able to select the UTM zone by clicking on a digital map which displays the available UTM zones overlaid onto a map of the

United States. Figure 4 shows the digital map from which the UTM zones may be selected.

For entering the name and path of the ArcMap project file, the wizard provides a browse option from which the user can navigate to the desired file and then select it by double clicking on the file’s name. The selection of an ArcMap project is optional at the time a new site is created and can be added to the site at a later time.

The second input screen of the wizard prompts the user to enter data that is associated with the meteorological stations that provide real time meteorological data to the dust dispersion models. Data associated with the meteorological stations that can be entered in this screen include the station name, station ID, location coordinates of the station in latitude and longitude coordinates of the station in UTM easting and UTM northing, and the elevation of the station. If there is no information available to the user concerning meteorological stations, the user has the option of electing not to use real time meteorological data and leave this screen blank. Figure 5 displays the input screen for entering the meteorological station data.

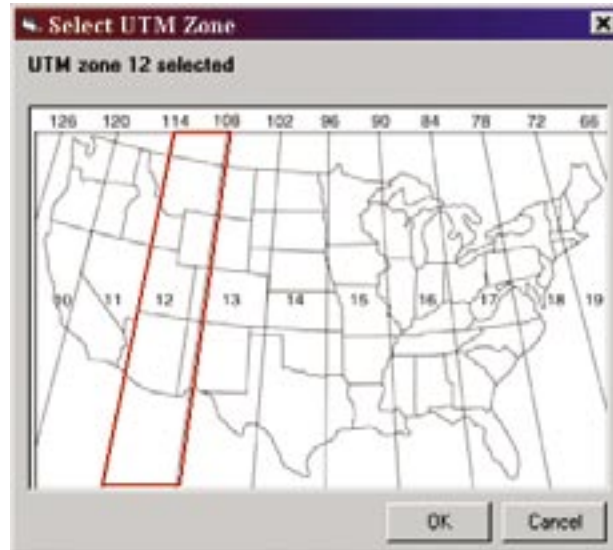


Figure 4. UTM zone map selection.

The third and final input screen of the wizard prompts the user to enter the paths and names of the terrain and land-use data files that will be used with the site. The screen is initially loaded with a default set of terrain and land-use files that are installed with the DUSTRAN modeling system. The user can elect to use the default files or select different files using the “Add” and “Browse” options found on the screen. An example of values entered for terrain and land-use data files is displayed in figure 6.

Following the completion of the third screen, the user has the option of finishing or canceling the creation of the new site.

If the user elects to finish the creation of the site, the wizard then proceeds to register the new site with the DUSTRAN modeling system. In order to register the new site, the wizard

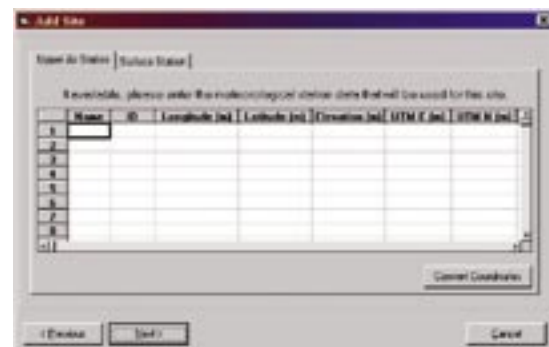


Figure 5. Meteorological station data input screen.

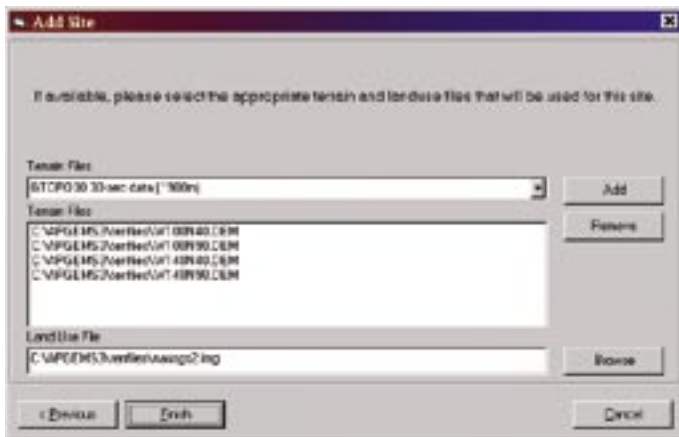


Figure 6. Example input values for terrain and land-use files

first creates a site directory with the same name as the new site within the parent directory of the DUSTRAN modeling system. Within the site directory, additional directories are created in which input and output data generated by the DUSTRAN modeling system during the execution of a simulation is stored. Once the directory structure has been created, text files used as inputs into the dispersion models as well as meteorological data files are created using the data entered into the wizard by the user. The final step that the wizard performs in the creation of the new site is to update the configuration files used by the DUSTRAN modeling system in order to track the sites that are present in the system.

Viewing the Results

Since the software would be used by people of different backgrounds with varying experience in meteorological and atmospheric data, the data generated by the modeling system needed to be displayed in a manner that could be understood by all. Using ESRI's standard shapefile format, information such as local area maps, road systems, water systems, and population can be displayed as layers within the map display with the results of a simulation layered on top of the display [3]. This functionality has given users more versatility in project development through the use of ESRI's data maps to create new sites for use with the DUSTRAN modeling system. It also allows the output of the modeling system to be displayed visually within the ArcMap application. Different data types can be displayed within the user interface denoted by specified shapes and colors for simplified data interpretation. For example, the results of a simulation run are displayed as contour lines. These contour lines denote the differing concentration values associated with the plume rise and expansion generated by the DUSTRAN modeling system. The DUSTRAN modeling system was also designed to display time step animations of the contours. This allows the user to view the path a release will follow over a set amount of time. Figure 7 displays an example of a set of plume contours that has been generated by the DUSTRAN modeling system.

The modeling system is also capable of showing the wind vector fields generated by the modeling system in the

same manner as the contours. These features allow for a more detailed view of the actual effects different site characteristics, such as terrain elevations and land-use, have on dust dispersion in a given case. An example of a wind vector field displayed in the map display is presented below in Figure 8.

The Future of DUSTRAN

While the original purpose of the DUSTRAN modeling system was to model dust dispersion generated by military training maneuvers, it has become apparent that the DUSTRAN modeling system's ability to easily change and add sites could be used in a diverse range of tasks. While these tasks vary in nature, each is dependant upon the ability to create new sites from within the modeling system.

Arid agricultural environments such as the United States Mid-West are severely affected by dust dispersion. Problems such as wind erosion are of concern to farmers in such areas [1]. The DUSTRAN modeling system could be used in these agricultural areas to manage dust dispersion from crop fields. Utilizing the ability to create new sites, different locations across a farm could be watched to see changing wind patterns and discover which areas are most susceptible to negative effects caused by dust dispersion. This could mitigate crop damage from erosion, and be beneficial to help plan for field irrigation management.

Architects and designers in arid areas utilizing the DUSTRAN modeling system could plan methods to offset negative dust dispersion impact on their work. Creating new sites within the modeling system would allow developers to see the effects dust dispersion may have on their project not only when completed, but also in the building stages. For example, civil engineers must be concerned with dust dispersion when developing roads and highways. In arid regions, poor visibility

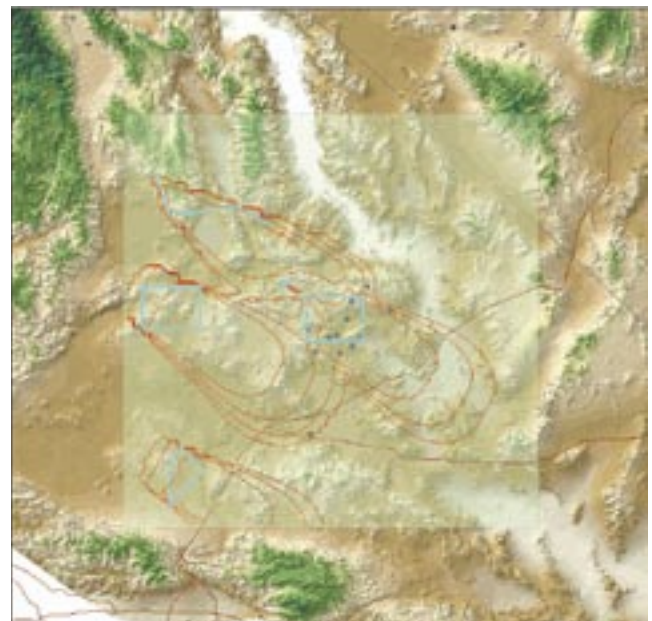


Figure 7. Contours generated by the DUSTRAN modeling system for various source types.

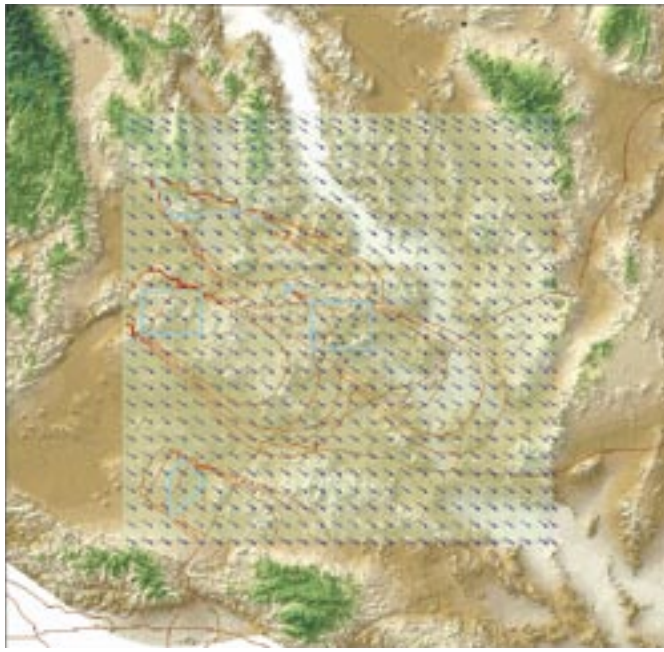


Figure 8. Wind vector field generated using surface station and upper air station data.

due to dust dispersion is a severe problem, but through proper planning, this problem could be minimized. Architects in arid regions also must take dust dispersion into consideration when constructing a new building or home. If not developed to resist the negative effects generated by dust dispersion, many problems can arise. Without proper planning, issues such as dust deposition on the roofs or sides of homes can become severe. Through use of the DUSTRAN modeling system, effects such as erosion and poor visibility due to dust dispersion could be minimized through strategic landscaping and architectural design [4].

The DUSTRAN modeling system has the possibility to serve as an emergency preparedness tool as well. In case of an emergency chemical or gas release, emergency response times could be decreased. By creating sites that cover large metropolitan areas, the plume path of such a chemical or gas could be quickly mapped allowing evacuation plans to be drawn and put into effect.

Weather report improvements are also possible. Using the DUSTRAN modeling system, sites could be developed in historically windy areas allowing for particulate air quality to be measured. This would allow individuals with health issues to be informed of possible risks due to particulate air quality. Adverse weather conditions such as poor visibility, or road closures due to wind blown dust would be easier to predict and manage through appropriate use of site development within the modeling system as well.

Dust dispersion is a problem throughout the world and while the DUSTRAN modeling system is currently being created to aid the military in dust dispersion management, it has great possibilities for future projects and development [4].

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