FLORIDA'S FIRE MANAGEMENT INFORMATION SYSTEM

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ABSTRACT

Florida has long been a national leader in wildland fire management. New Technologies are being investigated that will help maintain and perhaps increase that lead. In order to more accurately handle the largest open burning program in the country, Florida has designed a state-of-the-art wildland fire management system. Elements include an Oracle relational database, a comprehensive GIS database developed using ARC/INFO GIS software, a smoke dispersion model called V-Smoke GIS, and a meso-scale weather model that was developed by the National Center for Atmospheric Research (NCAR) called Meso-Scale Model number 5 (MM5).

This system was cooperatively developed by the Florida Division of Forestry, the US Department of Commerce Telecommunications Infrastructure and Information Program, the University of Florida's School of Forest Resources and Conservation, the Canadian Forest Service and Florida State University's Department of Meteorology. Considerable support has also been provided by Environmental Systems Research Institute, Inc. (ESRI); Oracle Corporation; and Silicon Graphics Inc.

Keywords: model, smoke, weather, burn, wildland fire

INTRODUCTION

The state of Florida has led the nation with respect to wildland fire management for many years. New technologies are being investigated that will help maintain and perhaps even increase that lead. In order to more accurately deal with the threat from wildfire, as well as manage the largest open burning program in the country, Florida has designed a GIS based wildland fire management system (Florida Fire Management Information System, FFMIS). This new system integrates some of today's most sophisticated technology. Elements include an Oracle Database, an ARC/INFO database, and a mesoscale atmospheric model that was jointly developed by the National Center for Atmospheric Research and the Pennsylvania State University (MM5).

This system was developed through the cooperation of the Florida Division of Forestry, the University of Florida's School of Forest Resources and Conservation, the Canadian Forest Service and Florida State University's Department of Meteorology. The contributions of all four agencies have come together to produce a unique product that will greatly assist wildland fire managers to more safely and accurately accomplish their respective jobs. This system will also help other emergency response and land management agencies obtain critical information needed for their day-to-day operations. As enhancements are added, we can expect that this system will be made more and more invaluable to the wildland fire managers in Florida. The possibilities for Florida and other parts of the country are endless.

OVERVIEW OF FFMIS

The fire weather and behavior module of FFMIS provides core GIS functionality to support the State's wildland and prescribed fire management programs. FFMIS spatially models the current and forecast atmospheric dispersion index, fire danger, fire weather index, fire behavior potential and surface weather conditions. The following provides a brief description of the fire science components of FFMIS along with data management issues, GIS processing and map production.

Atmospheric Dispersion Index

The Atmospheric Dispersion Index (ADI) reflects the efficiency of the atmosphere at transporting gaseous and small particulate matter away from a source region. The ADI is based on the Gaussian plume statistical model (Lavdas, 1986), where a Gaussian distribution of the pollutant concentration is expected in a finite box downwind of the source. The ADI uses surface and upper air (radiosonde) weather observations to estimate a mean wind vector (transport wind) and an upper bound (mixing height) for the surface layer in which turbulent mixing aids in pollutant dispersion. This information is important in determining whether conditions are favorable for prescribed burns and as a predictor of possible hazardous wildfire conditions (Figure 1).

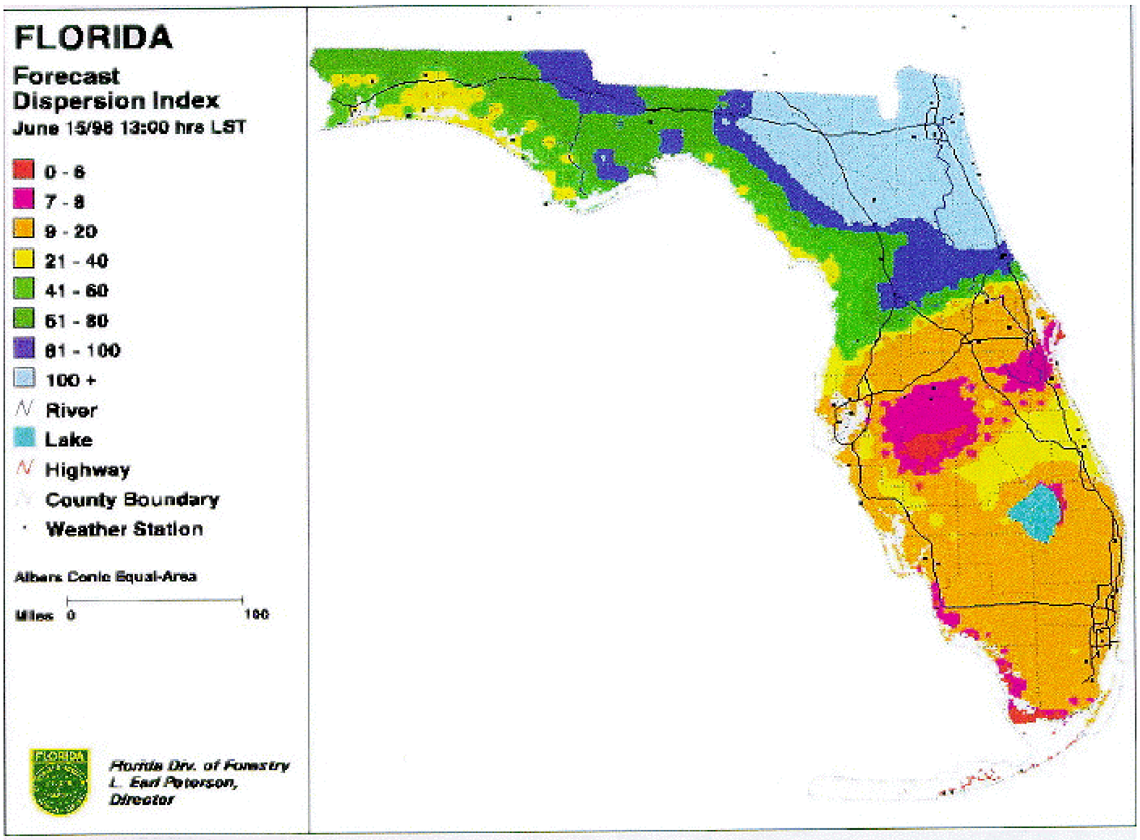

Figure 1. During the 1998 wildfire outbreak, the Division of Forestry was closely monitoring the Dispersion Index and found that when MM5 forecasted a dispersion in excess of 80, the areas in question experienced a dramatic increase in fire activity.

Fire Danger Rating

This component partially implements the 1988 version of the National Fire-Danger Rating System (NFDRS) (Deeming, et al 1978, Cohen and Deeming, 1985, Burgan 1988). Outputs implemented for the State of Florida include the 10, 100 and 1000 hour dead fuel moistures; Keetch-Byram Drought Index (KBDI), Woody Greeness Factor, Ignition Component, Spread Component, Energy Release Component and Burning Index.

Fire Weather Index

The Canadian Forest Fire Weather Index (FWI) System (Canadian Forest Service, 1984; Turner and Lawson, 1978; Van Wagner, 1987) is the basis for modeling and interpreting fire weather. Figure 2 illustrates the components of the Canadian Forest Fire Weather Index System. Calculations of these components are based on consecutive daily observations of temperature, relative humidity, wind speed and 24-hour rainfall.

The six standard components provide numerical ratings of relative wildland fire potential. The first three components are fuel moisture codes that follow daily changes in the moisture contents of three classes of forest fuel with different drying rates. The last three components are fire behavior indexes, representing rate of spread, amount of available fuel, and fire intensity; their values increase as fire weather severity increases.

Fire Behavior Potential

In contrast to the NFDRS and FWI systems, the modeling of fire behavior potential provides absolute rather than relative measures of fire business. Using weather (FWI), fuels, and terrain information as inputs, quantitative predictions of fire growth, intensity, fuel consumption and crowning potential are derived. This component is based on empirically developed equations from the Canadian Forest Fire Behavior Prediction (FBP) System (Forestry Canada Fire Danger Group, 1992).

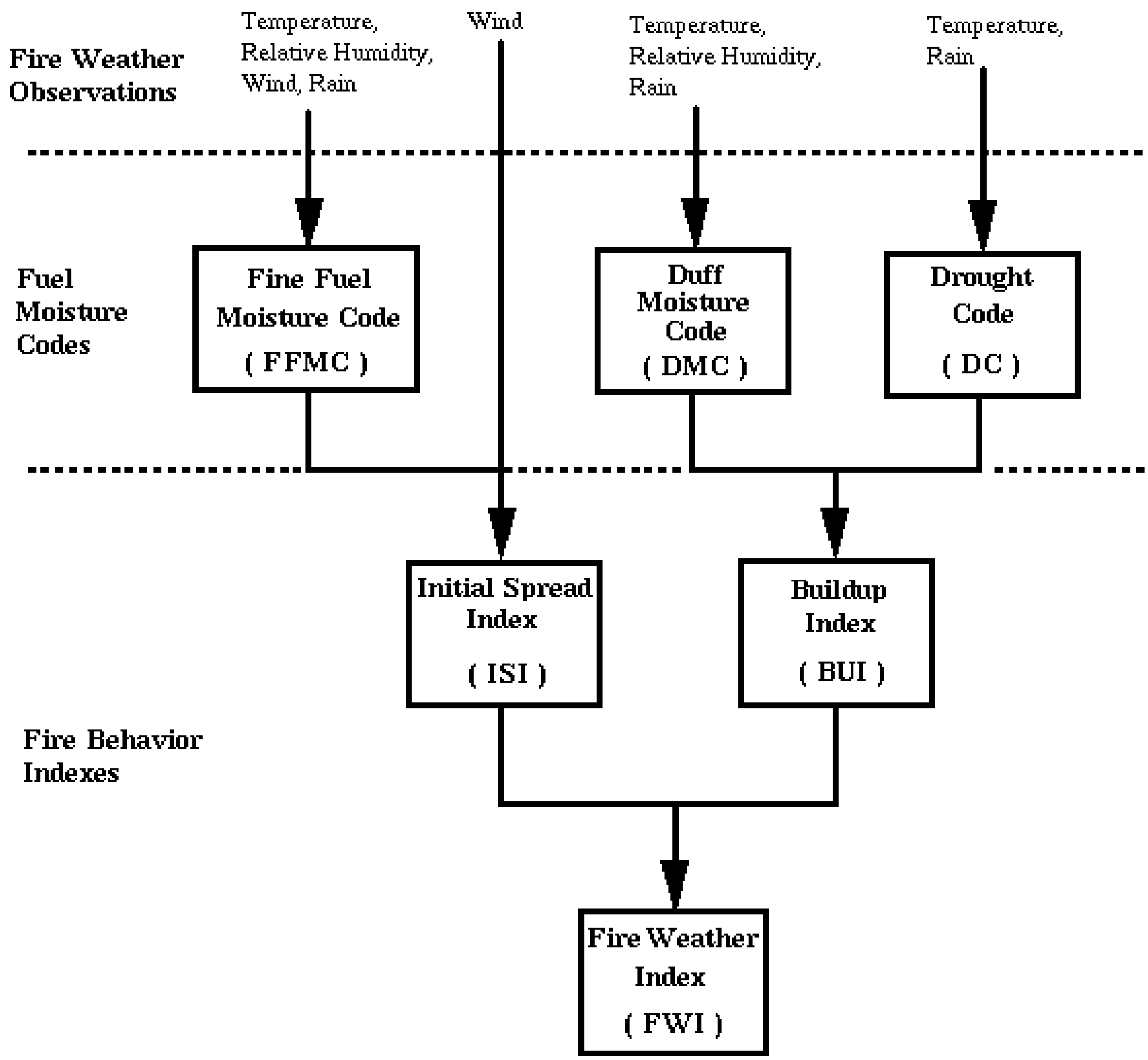

Figure 2. Diagram of components to the Fire Weather Index.

Surface Weather Modeling

Weather data is critical to all of the above components of FFMIS. The surface weather component provides both observed and forecast values of temperature, relative humidity, wind speed and wind direction across the state. The source of observational weather data is from 110 weather stations located in and around the state of Florida. Forecast data is provided to FFMIS from the MM5 model at a regular grid spacing of 16 kilometers (Figure 3a&b).

Forecast models currently in use by both the National Weather Service (NWS) and the National Center for Environmental Prediction (NCEP) do not have sufficient horizontal resolution to capture all of the atmospheric features of interest in Florida (i.e. the sea breeze). In addition these models have been optimized to provide optimal performance for the nation as a whole, leading to some sacrifices in the quality of regional forecasts. By using a high resolution regional mesoscale model such as MM5, we can optimize the model resolution and parameterizations to best stimulate Florida weather.

MM5 CONFIGURATION AND PERFORMANCE

Currently the Florida Division of Forestry is running MM5 on a Silicon Graphics Origin200 with 2 CPUs. The model domain consists of 23 vertical levels and 67 grid points in the north-south direction by 63 grid points in the east- west direction. The horizontal grid spacing is 16 kilometers. The model is configured to use nonhydrostatic dynamics, a multilevel planetary

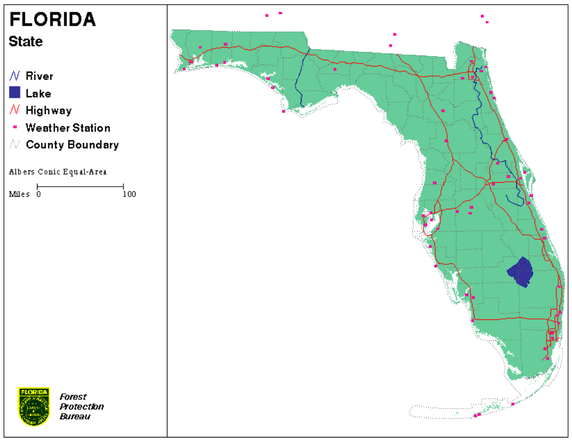

Figure 3a. Location of weather stations used for collecting surface weather observations.

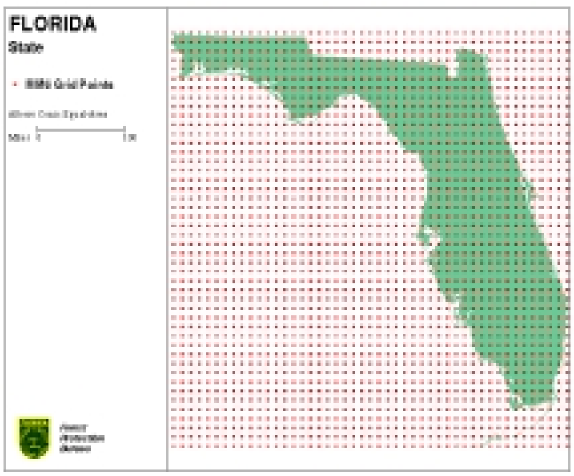

Figure 3b. Density of MM5 grid points.

boundary layer, and the Grell cumulus scheme with simple ice physics. Initial and boundary conditions for MM5 are provided by data generated by forecasts made by NCEP using the Eta model. Large-scale information is passed to MM5 from the Eta model data via the domain boundaries every 6 hours.

Figure 4 is an example of the output from MM5 for 00 UTC on October 8, 1998. The arrows represent the surface wind field while the contours show the amount of precipitation that occurred during the simulation. The wind vectors are plotted at alternating grid points to reduce clutter. The main precipitation features are the band extending down the East Coast of the peninsula, strong showers in the Valdosta area and heavy rainfall in the western part of the model domain. These general features are also seen in precipitation estimates generated from Doppler radar data (Figure 5).

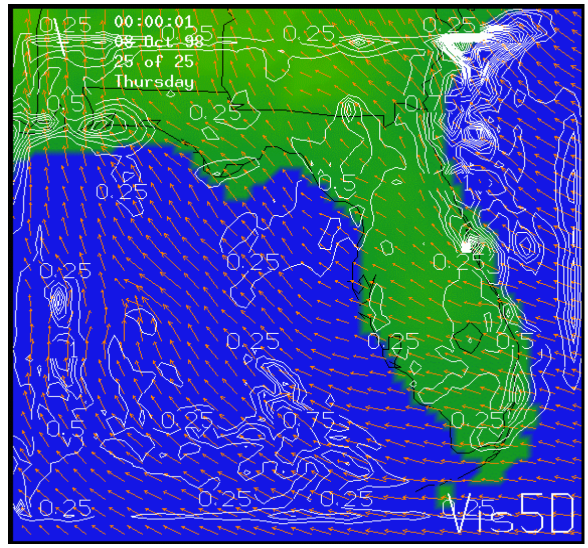

Figure 4. Output from MM5 for 00 UTC October 8, 1998. Vectors represent surface winds and contours show precipitation that occurred during the simulation (contour interval is 0.25 inches).

The above example is a qualitative comparison of the model output to real data. The model is obviously not perfect. There are regions where the model did a poor job of estimating the rainfall, such as the area surrounding Lake Okeechobee and the southwest tip of the peninsula.

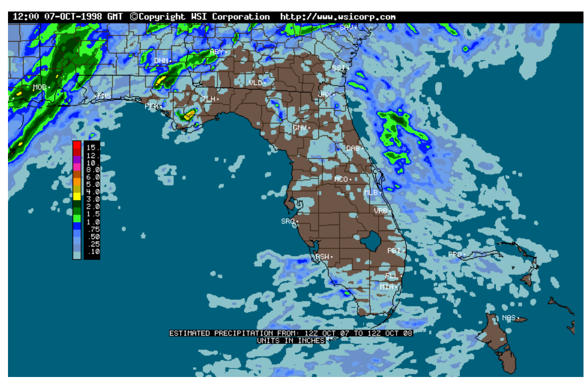

Figure 5. Estimated precipitation from 12 UTC October 7 through 12 UTC October 8, 1998.

Hurricane Georges passed over the Florida Keys on September 24, 1998 and entered the Gulf of Mexico. As another qualitative comparison the structure and location of Georges predicted by MM5 is compared to satellite imagery (Figures 6 and 7). MM5 did a good job of predicting the path of the storm as well as showing the structure of the rain bands that spiral outward from the storm. These rain bands were associated with severe weather in the peninsula as Georges passed over the Keys and entered the Gulf. The model does a good

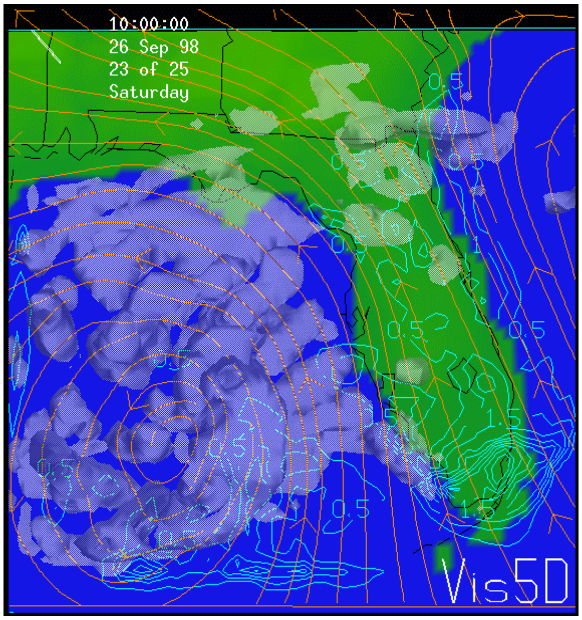

Figure 6. Output from MM5 showing the surface winds (streamlines) and cloud structure associated with Hurricane Georges. Contours represent total rainfall during the simulation (contour interval is 0.5 inches).

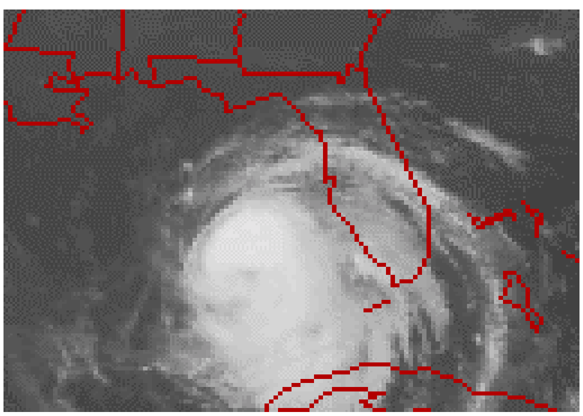

Figure 7. GOES satellite image of Hurricane Georges September 26, 1998.

job of depicting the two of the more intense rain bands; one stretching across the state near Ocala and the other near Naples. The high cirrus clouds layer is not shown in the model output, only the convective clouds.

PRESENT LIMITATIONS OF MM5

The above qualitative comparisons are very encouraging. However, detailed quantitative analysis of the output from MM5 will reveal a number of deficiencies in the model. One factor that limits the ability of MM5 to accurately forecast the weather is tied to the use of data from the Eta model for initialization and boundary conditions. We are assuming that the Eta model is providing an accurate forecast of the large scale atmospheric circulation in which the detailed circulations predicted by MM5 are embedded. At present MM5 uses a 16 km grid. This is still too coarse for resolving features such as thunderstorms and some of the dynamics associated with the sea breeze. Additionally the forecast area needs to be expanded and the length of forecast increased.

Many of these limitations are presently being addressed. A four dimensional data assimilation scheme is being implemented in MM5, which will allow observations and eventually satellite data to be incorporated into the model initialization process. This will lead to improved forecasts by providing MM5 with some real world data. The forecast period will also be increased from 24 hours to 48 hours. The issues of domain size and resolution are not as easily dealt with as they are dictated by the available computer resources. In the near future the Division of Forestry hopes to have the computing power so that the model resolution can be increased to 5km.

USES OF FFMIS

Having all of these tools and the information they provide is meaningless if they do not provide any benefits to the users of this system. Through the use of an Oracle Database and the GIS capabilities of ARC/INFO all of the information generated by the fire science components of the FFMIS can be merged into an application to support the management of Florida's open-burning program as well as wildfire suppression activities. This system is designed around a client-server computer network linking the central UNIX server in Tallahassee to remote client PCs at each district office via the Internet. The central server maintains a database for open-burning authorizations, wildfire incidence reports, as well as the daily fire weather forecast and fire behavior data from the previously discussed components. Each remote client PC runs a software application consisting of two decision support modules. The first module supports open-burning authorizations and incorporates GIS, spot weather forecasting and smoke dispersion modeling to assess the potential impact of a proposed burn prior to issuing a permit. The second module compiles and disseminates information for timely and efficient allocation of available resources for wildfire suppression.

Open-Burning Authorizations

The existing DOF open-burning authorization system uses dedicated computer terminals connected to a mainframe computer in Tallahassee, Florida to provide the Duty Officers (DO) in each district with the ability to enter and view information for open-burning authorizations stored in a central database. Currently, smoke-sensitive areas are designated in the database as sections from the Public Land Survey (Section, Township and Range) where a smoke-sensitive feature, such as a hospital or airport, exists. The sections are flagged in the database to prohibit any burning authorizations from being issued for that entire section. There are several drawbacks to this approach: the exact location of the smoke-sensitive feature within the section is not known, the effects of smoke from adjacent non-flagged sections are not considered, and the weather conditions (wind direction and dispersion index) are not considered. Additionally, the DO has little indication of the level and spatial distribution of burning activity across their district on a given day.

To address some of these drawbacks a new open burning authorization system is being developed by the Florida Division of Forestry. Two main databases are used to support this application. The first is an Oracle database that provides the application with data for current weather conditions and fire behavior parameters, such as dispersion and drought indices. In addition this database provides a repository for all information related to open-burning authorizations. The second database is a GIS database residing locally in each district and consisting of multiple thematic map layers. These layers are used in displaying clear and accurate maps of each district. The data used to construct these layers has been obtained from a variety of sources (US Census Bureau, Florida Department of Transportation, Florida Department of Environmental Protection, Florida Department of Community Affairs, US Natural Resource Conservation Service, digital satellite imagery, aerial photography and Global Positioning System (GPS) surveys).

The open-burning application is designed to follow a sequence of operations, beginning with a telephone call requesting an open-burning authorization and ending with either an approval or denial. The application was developed using Microsoft Visual C++ Professional, and makes extensive use of the Object Linking and Embedding (OLE) capabilities of this programming language.

In addition, two custom OLE controls (also called Active-X controls) are used to provide specific capabilities within the application. The first is MapObjects Lite by Environmental Systems Research Institute, Inc. MapObjects provides tools for displaying and querying ARC/INFO coverages. These tools allow embedding advanced GIS mapping and analysis capabilities within the context of another software application. The second custom control used is OracleObjects by Oracle Corporation. OracleObjects tools provide Visual C++ with robust capabilities for accessing data in local or remote Oracle databases.

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The user-interface consists of an electronic form (Figure 8) that is used by the DO to issue open-burning authorizations to the public. Prior to issuing an authorization, the DO enters information, such as section/township/range, type of burn, fuel type, acreage, date and time, into the electronic form. Next, a map showing GIS data layers, such as roads, lakes, streams, landmarks, conservation lands, cities and section lines, s displayed on the screen and is automatically adjusted and scaled to the location identified. The DO identifies the precise location of the burn by clicking on the map with the mouse. Subsequently, the application queries the weather forecast information for that specific location and retrieves relevant data, such as wind speed and direction, and mixing height. Weather forecasts are updated twice a day in hourly increments at midnight and noon.

The data from the form is input into both the Oracle database and transferred into the smoke dispersion model VSMOKE GIS (Harms, Lavdas and Saveland

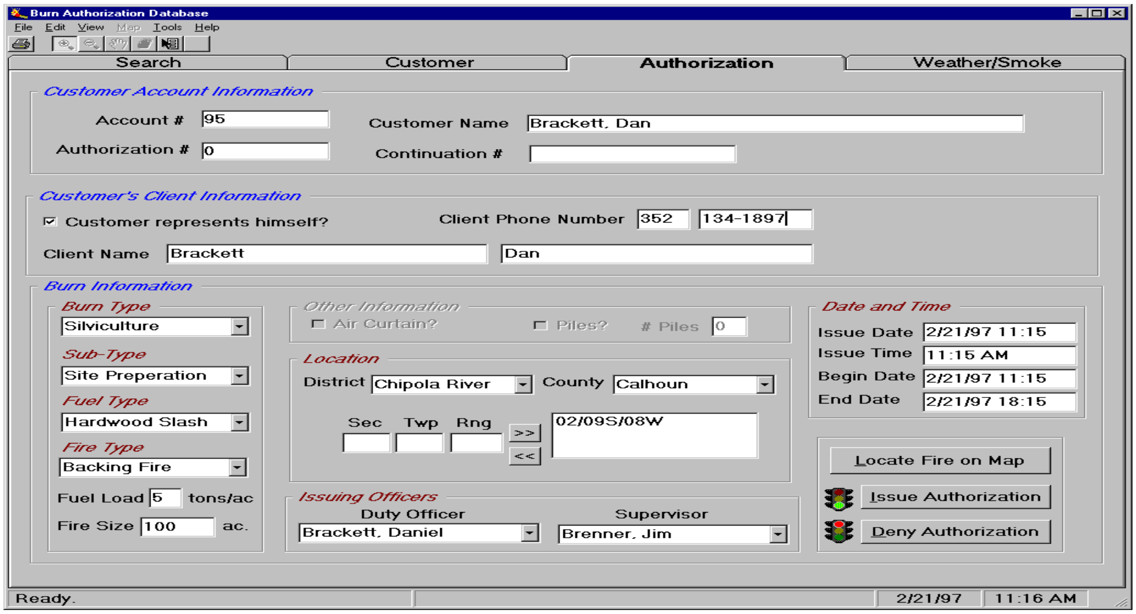

Figure 8. Example of form used for open-burning authorization.

1995). The Oracle database then performs a query to determine is the projected smoke plume will impact any smoke sensitive areas by using MapObjects. A set of three isopleths denoting different concentrations of smoke particles in the air is displayed on the Duty Officers screen (Figure 9). At this point the application will assist in differentiating between the Smoke Sensitive areas. Each area has a specific set of busi-

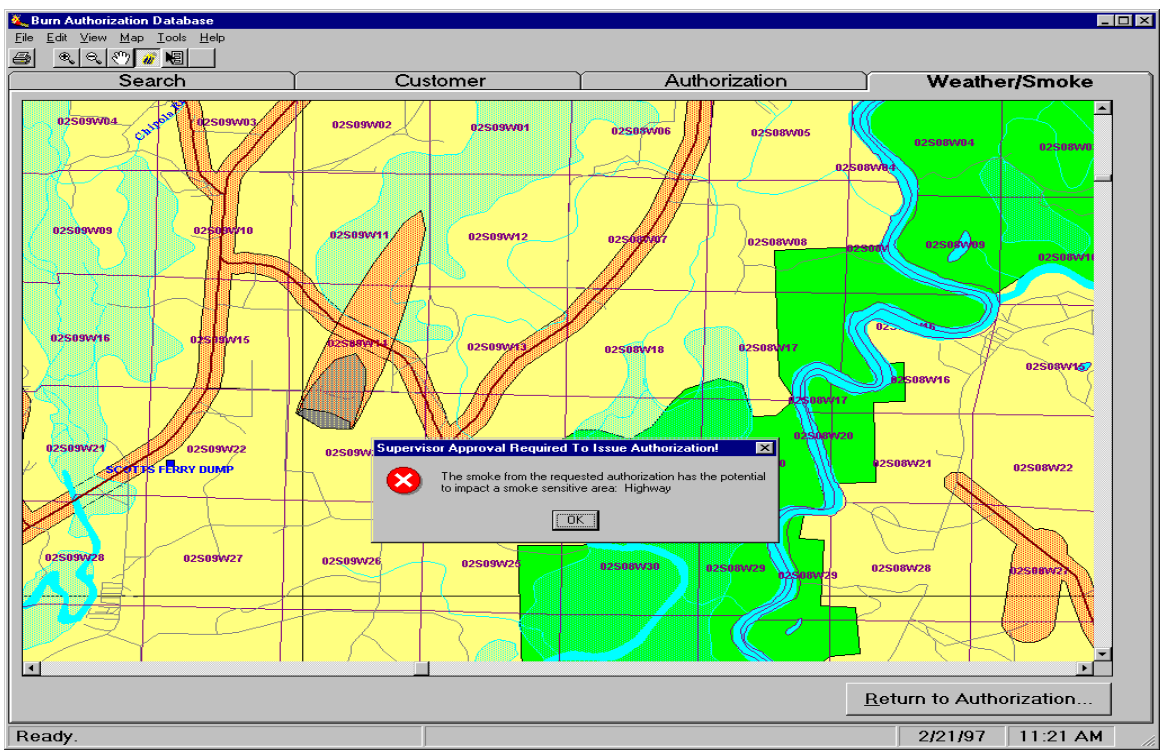

Figure 9. Example of predicted smoke plume location relative to smoke sensitive areas and other geographic features.

ness rules that must be followed. For example, the smoke concentration on a road can not (by law) restrict visibility to below one thousand feet. At the same time, any reduction of visibility at an airport is not permitted. In this way the DOF can define particulate concentrations for the Smoke Sensitive Areas that will implement the Division's business rules. Each smoke plume on the map is linked to the corresponding authorization in the database allowing the DO to retrieve an authorization by clicking on the plume itself. All smoke plumes for a given day are stored in a shared file so that each DO can simultaneously view all authorizations for that day. Smoke plume files are archived for future reference and validation purposes. This is extremely important for handling possible liability issues.

Wildfire

Like the Open-burning Authorization module, the Computer-Assisted Dispatch user-interface depends also on an electronic form to access and query the Oracle database and interact with the GIS map. Upon receiving notification of a wildfire, the DO selects "Wildfire" from the Authorization module to load the appropriate form. The DO would then collect relevant information about the fire, including the general location, the type of fire and person reporting. Next, the DO identifies the location of the fire on the map by clicking on the location with the mouse. Distance and azimuth information provided by one or more fire towers can be used to aid in pinpointing the fire location (Figure 10). Latitude-Longitude coordinates from a GPS equipped spotting plane can also be used for the same purpose. All existing authorized burn plumes can be displayed on the map, allowing the DO to quickly determine whether the reported wildfire is an authorized fire. If this is the case, the DO can click on the plume to retrieve the authorization for that fire to find out when it was scheduled to be completed, or perhaps contact the individual responsible to confirm that the fire is under control.

In the event that the reported fire is not an authorized one, the system will query the GIS database to retrieve information on the conditions at the fire site, such as

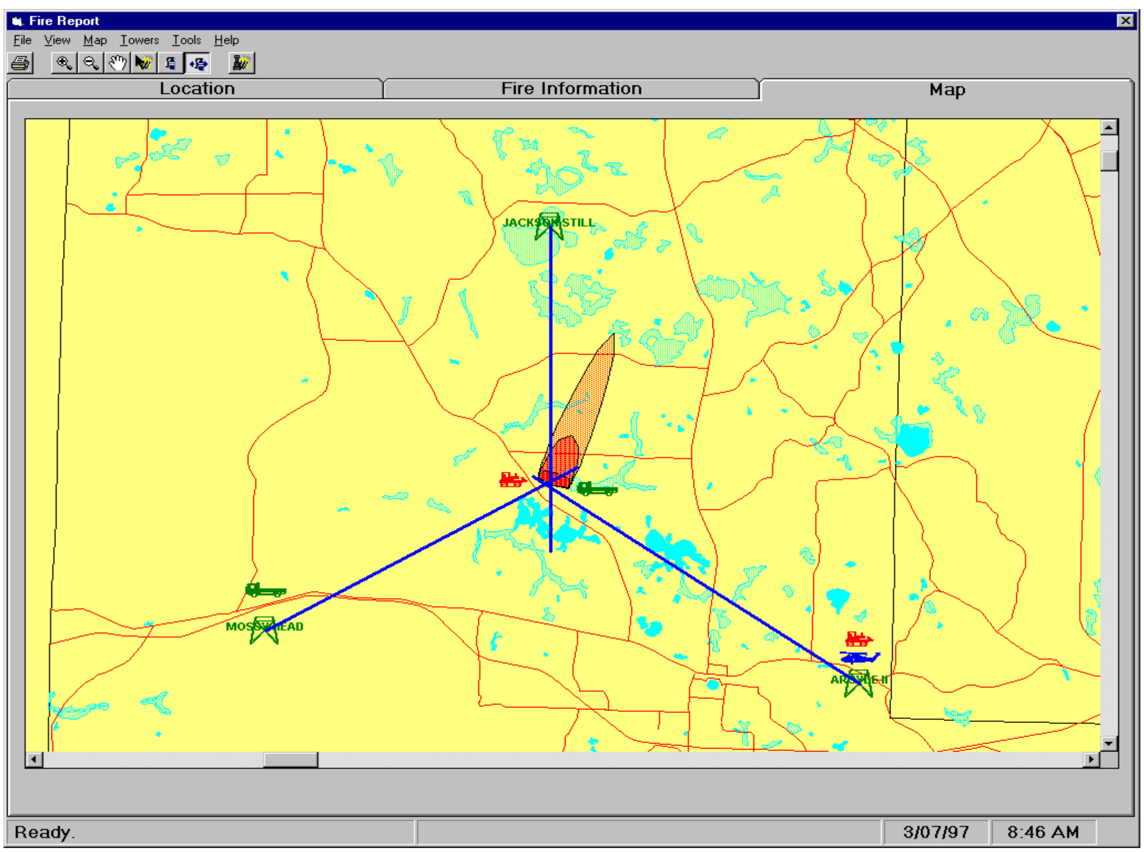

Figure 10. Wildfire Reporting interface showing fire tower spotting vectors, closest available suppression resources and predicted smoke plume.

soil type, vegetation type, fire danger rating and weather parameters. The size and direction of the resulting smoke plume is displayed on the map as in the Open-burning Authorization module. The application will alert the DO if the smoke from the fire is likely to reach smoke-sensitive areas. In addition, the system allows the DO to view current locations and status of all fire-suppression resources, such tractors, water trucks, aircraft and personnel in the District. The DO may relocate resources on the map when they are dispatched to a fire by using the mouse and dragging each one of them to a new location. Fire suppression resources may be tagged as "In Service" or "Out of Service" to indicate their availability for responding to a wildfire. The application allows the DO to dispatch the closest fire suppression resources based on fire type, magnitude, proximity to populated areas, rate of spread and site conditions.

SUMMARY

The ultimate objective of the Division of Forestry's new GIS-Based Fire Management systems is to provide quality service to the public and to minimize the harmful effects of smoke from open-burning, as well as minimize the loss of human life and property as a result of wildfires. This is especially important in Florida where urban-rural interfaces are highly dynamic, mainly due to increases in population. Application of these innovative decision-support systems will greatly enhance the ability of the Florida Division of Forestry to suppress wildfires and handle open-burning authorizations throughout the state.

The system described here will undergo extensive testing to identify areas where improvements or enhancements are needed. In addition, it must be determined if certain aspects of the system will be effective under field conditions. For example, it is unlikely that all persons requesting an open-burning authorization will know the fuel type and load for their respective sites. A simpler classification scheme such as low, medium, and high fuel quantity, or calculation of an approximate fuel load based on the last burning date for the site (if applicable) may be necessary. Testing is also essential to determine whether Duty Officers can quickly locate the site of a proposed open-burn based on only a few questions to the caller.

A number of enhancements to the system are already under consideration. Wildfire dispatching activities may be aided by the use of vehicle-mounted Global Positioning System (GPS) receivers to keep track of fire suppression resources in real-time. Utilizing new high-resolution satellite imagery could provide the system with timely and cost-effective updates on vegetation, fuel loads, and land use/cover information for the GIS database. The use of a high performance, server-based GIS database is also being investigated to facilitate central GIS data administration and, by storing map data in contiguous layers, to reduce the effects of district boundaries on GIS analyses.

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