GIS BASED FIRE MANAGEMENT IN FLORIDA*

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ABSTRACT

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 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 (Oracle Corporation, Redwood Shores, CA), a comprehensive GIS database developed using ARC/INFO GIS software (Environmental Systems Research Institute, Inc., Redlands, CA), and a meso-scale weather model that was developed by the National Center for Atmospheric Research called Meso-Scale Model number 5 (MM5).

This system was cooperatively developed by 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. Considerable support has also been provided by Environmental Systems Research Institute, Inc. (ESRI) and Oracle Corporation.

1.0 FIRE WEATHER FORECASTING WITH MESOSCALE MODEL #5

The Mesoscale Model #5 (MM5) has been shown to do well at representing the observed diurnal evolution of the coastal environment in a non-forecast, "research" mode with a doubly nested set of domains at 36 km, 12 km and 4 km (Herbster, 1996) and, more recently, in an operational environment with a single domain of 15 km (Herbster and Watson 1998).

The model resolution for this project was chosen to be 16 km, as this coincides with other spatial aspects of the database. The domain covers the entire state of Florida, extending into southern Georgia and Alabama.

A real time archive of model data generated by the National Center for Environmental Prediction (NCEP) has been established, and the modeling system has been configured to run with either the Rapid Update Cycle (RUC), Eta or meso-Eta models. In general, the Eta model is used to provide the initial and time dependent boundary conditions to the MM5. Anticipated changes in the Eta later this year should make support of the meso-Eta obsolete.

The MM5 is initialized with the initial period from the large scale model with the highest temporal resolution boundary conditions that are available being utilized (generally six hour). At this time no data assimilation is being conducted, though this is a possible enhancement that is being planned for future development.

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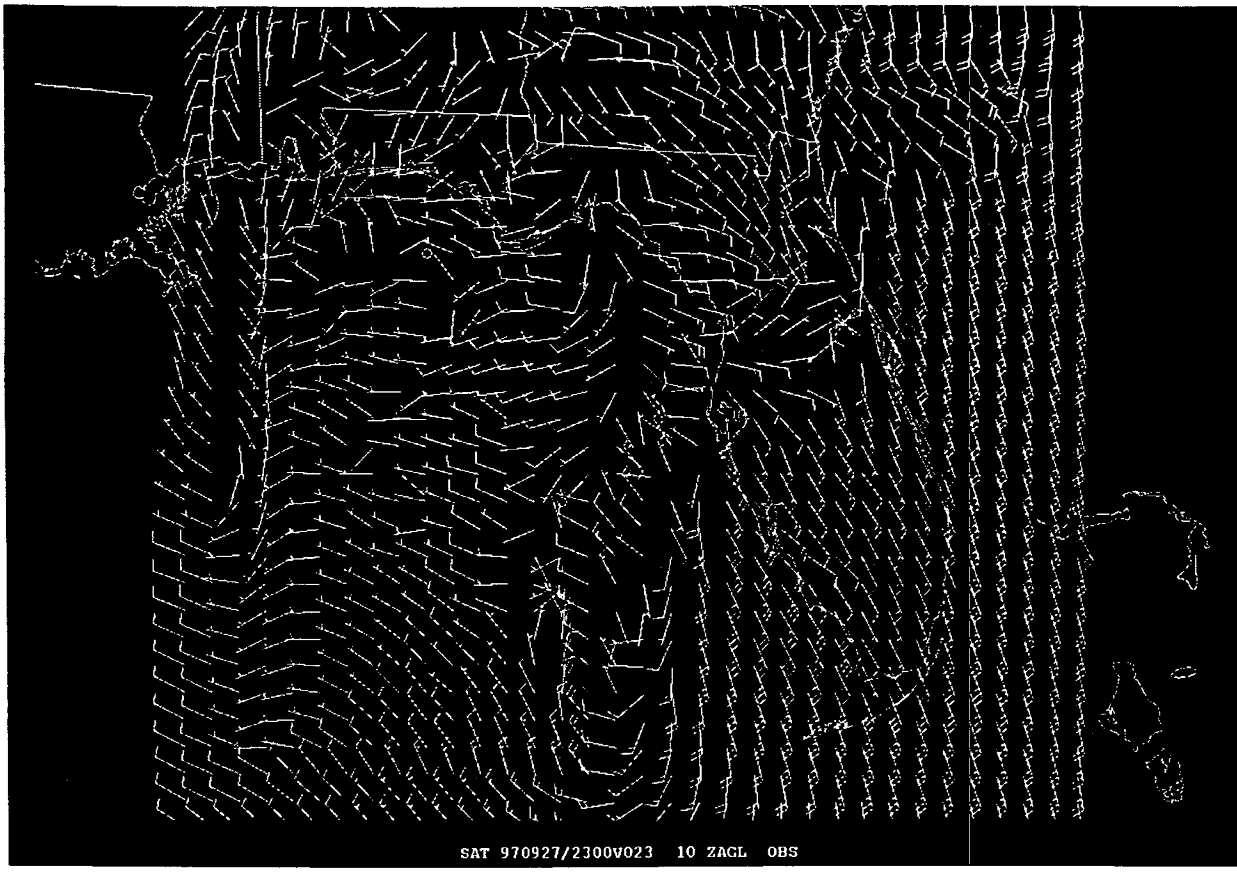

Figure 1. 16 Km Grid - Surface Winds from MM5

Winds from the MM5 forecast are used to provide a source of time dependant guidance for the diurnally varying winds that are common to the bulk of this state over much of the year.

Figure 1 is an example of the 16 km resolution model output, valid at 2300 UTC, 27 September 1997, for this project. Note that the winds around the state show an interaction between the local sea breeze circulation and the large scale flow. This type of local/regional variability in the low level wind field is consistent with observations and is critical for estimating where a smoke plume may be advected. This type of detail is not possible with any of the nationally run forecast models and is the primary motivation for running a mesoscale model as part of this project.

Additional information regarding the details of this project, including the details and examples of the user interface, is available at the following URL: www.fl-dof.com.

2.0 FIRE WEATHER AND BEHAVIOR MODELING

2.1 OVERVIEW

The fire weather and behavior module of the Florida Fire Management Information System (FFMIS) provides core GIS functionality to support the State of Florida's wildland and prescribed fire management programs. This module is based upon the same GIS approaches used by the Canadian Wildland Fire Information System (Lee, Bryan 1995). FFMIS spatially displays the current and forecast state of surface weather, atmospheric stability, fire danger, fire weather and fire behavior potential. The following provides a description of the FFMIS fire science models, data management issues and GIS processing and map production.

2.2 FIRE SCIENCE MODEL DESCRIPTIONS

Surface Weather Modeling - The surface weather sub-system provides spatial displays of 1300 LST temperature, relative humidity, wind speed and wind direction. Displays of maximum and minimum temperature and relative humidity are also presented as are 24 hour precipitation amounts and the number of days since rain. The source of weather observation 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. These GIS layers provided by this sub-system are the principle inputs to the following models:

(a) Atmospheric Dispersion Index - The Atmospheric Dispersion Index (ADI) is an integer greater than or equal to one reflecting the efficiency of the atmosphere at carrying gaseous or particulate matter away from a source. The ADI is based on the Gaussian Plume statistical model (Lavdas, Lee 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 and an upper bound (mixing height) for the turbulent surface layer, in which turbulent mixing aids in pollutant dispersion.

(b) Fire Danger Rating - This module 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 hour, 100 hour and 1000 dead fuel moistures; Keetch-Byram Drought Index, Woody Greeness Factor, Ignition Component, Spread Component, Energy Release Component and Burning Index.

(c) Fire Weather Modeling - 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. The FWI system estimates forest floor moisture conditions using empirical models driven by the 1300 LST weather observations and forecasts.

(d) 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 sub-module is based on empirically developed equations from the Canadian Forest Fire Behavior Prediction (FBP) System (Forestry Canada Fire Danger Group, 1992).

2.3 DATA MANAGEMENT

The FFMIS uses geographical, meteorological, climatological, and informative data in its calculations and products available to clients. Station parameters, weather observations and forecasts, and FFMIS index values (ADI, NFDRS, FWI, and FBP) are stored in an Oracle database, which consists of ten tables. The FFMIS index tables grow at a slower rate, since the ADI is calculated once every six hours, and the NFDRS, FWI, and FBP once each day. Some information is too cumbersome for database storage, such as radiosonde reports and vegetation classes, so this information is archived in ASCII text files or ARC/INFO GRID format.

The Oracle database transactions are served by SQL (Standard Query Language) , and the driver programs for data collection and index calculation consist of FORTRAN, PERL, C++, and AML.

2.4 GIS PROCESSING AND MAP PRODUCTION

Once the ADI and NFDRS calculations are complete, the FWI and FBP calculations and all ARC/INFO map production is activated by a CRONTASK call to the Spatial Fire Management System (SFMS). SFMS is a fire management tool which generates maps of fire weather and fire behavior for

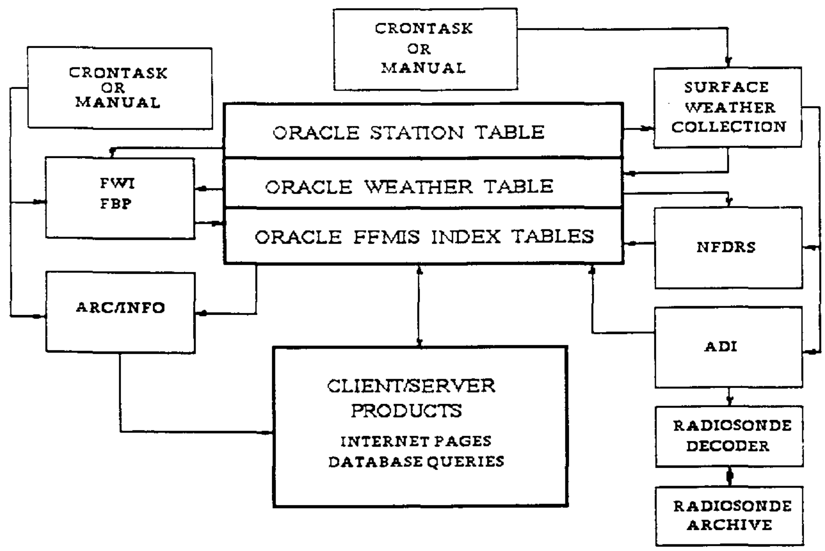

Figure 2. FFMIS Process Flowchart

specific regions. Originally the system implemented the Canadian Fire Danger Rating System (Stocks, *et al* 1989) but has been extended to incorporate the American National Fire Danger Rating System. It is a collection of integrated software modules, written in ARC/INFO's Arc Macro Language (AML). Typically, SFMS is operated in batch mode, running daily to provide a picture of the current day's fire situation. In addition, SFMS has a menu driven graphical user interface from which the user can generate ad-hoc maps from current, historical or even forecast data.

2.4.1 Processing Methods

SFMS runs entirely under ARC/INFO's GRID module, generating thematic grids representing the many components of each of the Canadian and American fire danger rating systems. All outputs are in GRID format from which maps can be generated using ARCPLOT commands. Creating these grids involves two different methods of processing, depending on type of data being modeled and the type of input data available. The first method is the interpolation of a grid surface from a set of sample data points. Grids representing fire weather are created in this manner. The second method is a cell by cell processing using GRID's DOCELL construct. Grids representing fire behavior are created using this process.

2.4.2 Interpolation Processing

Interpolation from sample points is performed on data that lends itself to this type of processing. Since weather data is usually only available for specific points in a geographic region it is necessary to obtain values for the grid cells between these points. SFMS uses GRID's IDW (inverse distance weighting) function to perform the interpolation of the grid surface. For each cell being analyzed, data from the twelve nearest points is used to interpolate a value for that particular grid cell. The point data is weighted by dividing the value by the square of the distance.

2.4.2.1 System Inputs

To perform the interpolation, SFMS requires a point data set for the actual values, and an ARC/INFO point coverage to provide the spatial information. Using the ARC/INFO RELATE environment, a relationship is established between the point data set and the point coverage. SFMS can access the point data set in a number of forms. The data can be contained in an INFO file, an Oracle database table or a DBASE dbf format file.

2.4.2.2 System Operation

There are four basic steps performed in the creation of the final grid surface. First the connection between the point coverage and the point data set is established. If the data set resides in an external database management system such as Oracle, a connection is made to the DBMS via ARC/INFO's Database Integrator. Next. SFMS ensures that data is available for the particular date of analysis. If so, the IDW function is invoked to create the output grid. As an additional step, the grid can be converted to an integer grid rather than a floating point grid to conserve disk space.

2.4.3 Individual Grid Cell Processing

The second processing method used by SFMS is cell by cell calculations using ARC/INFO's GRID modules DOCELL construct. This type of processing is performed where the input data is readily available on a per cell basis or where interpolation is a poor method for obtaining values for individual cells. The fire behavior components are calculated in this manner since the input fuel type and previously gridded fire weather inputs exist in grid format.

2.4.3.1 System Inputs

As mentioned previously, all inputs to the FBP system are in grid format. These include grids representing the fuel type, elevation, latitude, slope and aspect as well as the fire weather inputs created by the interpolation process.

2.4.3.2 System Operation

SFMS begins by ensuring all required input grids exist and are accessible. In the event that any of the fire weather grids do not exist, SFMS will invoke the interpolation process to create these grids prior to performing the FBP calculations. The calculations are performed for each cell in the analysis region using the GRID modules DOCELL block. The output grids can than be optionally converted to integer grids to conserve disk space.

3.0 OPEN-BURNING AUTHORIZATIONS

3.1 OVERVIEW

The data provided by the Fire Weather Forecast and the Fire Weather and Behavior Modeling components are combined with sophisticated GIS analysis and database capabilities in these modules to provide DOF duty officers with up-to-date information for decision-support. The duty officers are responsible for issuing Open-Burning Authorizations to the public, as well as for coordinating suppression response in the event of a wildfire. They currently use computers to assist with issuing authorizations, however, several shortcomings have been identified in the system.

3.2 CURRENT APPROACH

The existing DOF Open-burning Authorization System uses dedicated computer terminals connected to a mainframe computer in Tallahassee, Florida to provide 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 the entire section. There are several drawbacks to this approach: a) the exact location of the smoke-sensitive feature within the section is not known: b) the effects of smoke from an adjacent, non-flagged section are not considered; and c) the weather conditions, such as wind direction and dispersion index, are not taken into consideration. Additionally, the DO has little indication of the level and spatial distribution of burning activity across a district on a given day.

3.3 GIS-BASED OPEN-BURNING AUTHORIZATIONS

3.3.1 Processing Methods

To address some of these drawbacks a new open burning authorization system is being developed by the Florida Division of Forestry. This system is designed around a distributed, replicated Oracle database at all fifteen dispatch centers and at the State Office in Tallahassee. These systems are linked via T-1 Internet connections. The fire weather and behavior forecast information that originates at the State Office is replicated to all of the field office servers/clients, while the authorization data from each field office is replicated to all of the fifteen client/servers (including the State Office in Tallahassee). We refer to each of the machines at all sixteen locations as both client and server because they function as clients on the Internet, receiving data from across the state, while functioning as servers locally to the personal computers (PC's) where the application resides. The fire behavior/danger information that is displayed spatially via the Internet can be viewed at each of the client PC's with any browser. The open-burning authorization application incorporates GIS, spot weather forecasting and smoke dispersion modeling to determine the potential effects of a proposed burn before a permit is issued.

3.3.2 Data Collection

Two main databases are used to support this application. The first is an Oracle database on all sixteen client/servers which provides the application with data for current weather conditions, as well as fire behavior parameters, such as dispersion and drought indices. In addition, the database provides a repository for all information related to open-burning authorizations. The second 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 a DOF District. The individual GIS data layers have been obtained from a variety of sources including, the US Census Bureau, Florida Department of Transportation, Florida Department of Environmental Protection, Florida Department of Community Affairs, US Natural Resource Conservation Service (formerly the Soil Conservation Service), digital satellite imagery, aerial photography and Global Positioning System (GPS) surveys.

3.3.3 Application Framework

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.

The Open-burning Authorization user-interface consists of an electronic form that is used by the DO to issue Open-burning Authorizations to the public. The form allows the DO to query the database using a customer name, account number address or telephone number and then retrieve account information, including a list of all previously issued authorizations. After confirming account information, a new authorization may be issued or a prior authorization may be continued.

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, is 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, wind direction and mixing height. Weather forecast data are updated twice a day in hourly increments at midnight and noon.

The data, along with information on fire type and size, are input into both the Oracle database and transferred into the smoke dispersion model VSMOKE GIS (Harms, Lavdas and Saveland 1995). The Oracle database performs a query for intersects with the smoke sensitive areas, and then the actual intersection is calculated in the application using MapObjects. A set of three isopleths denoting different concentrations of smoke particles in the air is displayed on the Duty Officers screen (See Figure 3). At this point the application will assist in differentiating between the Smoke Sensitive areas. Each area has a specific set of business 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 setup particulate concentrations for the Smoke Sensitive Areas that will implement the Division's business rules. The local office has the ability of adding or designating points as smoke sensitive. This is used in the event that

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.

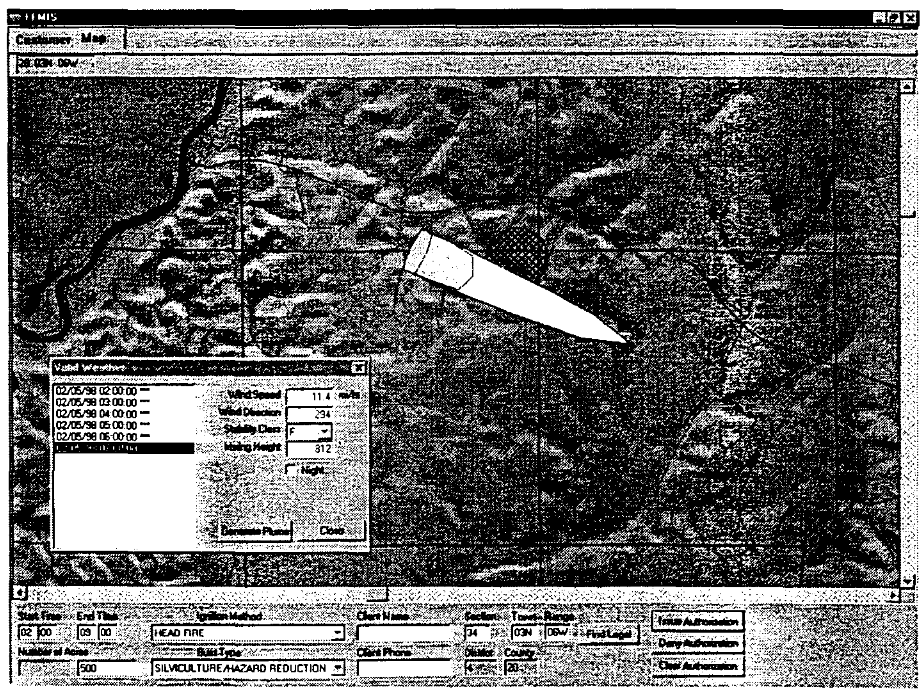

Figure 3. Smoke Plume Projected by VSMOKE GIS

4.0 CONCLUSIONS

The ultimate objective of the Division of Forestry's new GIS-Based Fire Management Information system is to provide quality service to the public and to minimize the harmful effects of smoke from open-burning. 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 open-burning authorizations throughout the state.

A number of enhancements to these 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.

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