Integrating Climatic and Fuels Information into National Fire Risk Decision Support Tools

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Abstract—*The Wildland Fire Assessment System (WFAS) is a component of the U.S. Department of Agriculture, Forest Service Decision Support Systems (DSS) that support fire potential modeling. Fire potential models for Mississippi and for Eastern fire environments have been developed as part of a National Aeronautic and Space Agency-funded study aimed at demonstrating the utility of NASA assets in fire potential decision support systems. Climate, fuels, topography and ignition are recognized as important components for modeling fire potential in Eastern forests and grasslands. We produced temporal and spatial water budget estimates using daily assessments of precipitation and evaporation (P-E) in a Geographic Information System. Precipitation values are derived from Doppler radar-based estimates of hourly rainfall accumulation, published on the Hydrologic Rainfall Analysis Project (HRAP) grid. Precipitation data are routinely available, but evaporation data are not. Regional estimates of evaporation have been produced to fill this void. Regression models that estimate daily evaporation in the Southern region of the United States were developed from readily available weather station observations. Evaporation estimates were combined with precipitation to compute the cumulative water budget. Improvement of these estimates when compared to Keetch-Byrum Drought Index (KBDI) was demonstrated using fire location data in Mississippi. Evapotranspiration (ET) from the NASA Land Information System (LIS), is currently being evaluated as a landscape moisture variable. We have implemented a hierarchical modeling methodology that combines information derived from ICESat (GLAS) data and MODIS Enhanced Vegetation Indices (EVI) to describe fuels structure. A graphical user interface (GUI) has been developed using Visual Basic (VB) that accesses an ESRI geospatial database that integrates water budget and fuels. The ignition component is derived from gravity models that assess the interaction of population density and forest areal size.*

Introduction

The Mississippi StateUniversity Departments of Forestry, Geosciences, and the GeoResources Institute have received National Aeronautical and Space Agency (NASA) funding to develop linear additive Geographic Information System (GIS) models designed to determine fire potential in Eastern forest regimes. Modeling concepts have been developed in cooperation with the USDA Forest Service Fire Sciences Laboratory (Missoula, MT), the Forest Inventory and Analysis (FIA) unit (Knoxville, TN), and the Mississippi Forestry Commission (MFC).

Much of the existing literature on fire potential modeling in the United States is oriented toward Western U.S. fire regimes. Fire is also of ecological and economic importance in the Southeastern United States. In Mississippi, fire frequency data obtained from the MFC indicates that on average, for a

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15-year period beginning in 1990, fire personnel were dispatched to more 4,000 fires per year. Decisions regarding fire response and suppression, personnel and equipment staging, prescribe burning for fuel reduction, and implementation of burn bans could benefit from spatial and temporal depictions of fire potential. GIS-based fire potential models can be a valuable aid for describing the temporal and spatial conditions that are favorable (or unfavorable) for fire ignition and spread.

Morgan and others (2001) compared several approaches for mapping fire regimes including two rule-based approaches, a vegetation succession modeling approach, and a statistical modeling approach for the Interior Columbia River Basin. Results of these comparisons show that fire frequency is related to four factors: climate, vegetation (fuels), anthropogenic influences (ignition), and topography (Morgan and others 2001). Topography is an important fire variable in the Western United States where changes in elevation and aspect are determinants of vegetation and climate. However, topography has less influence on fire potential in the Eastern United States where topography is characterized by much gentler slopes (Zhai and others 2003).

Results of modeling efforts designed to assess the importance of climate, fuels, and ignition are presented. The climate component is discussed in terms of the usefulness of water-budget indices and global climate processes in predicting fire potential. Topography is treated as a modifier of total precipitation in our models. The fuels variable is examined in more detail, particularly in light of damage to forests due to hurricane Katrina. The ignition component is presented as a comparison between road density and gravity models and their application in predicting fire potential. Finally, development of the data acquisition interface for fire potential modeling is described.

Discussion

The modeling flowchart (fig. 1) illustrates the conceptual approach used for modeling fire potential. Models are being developed and validated for Mississippi with the ultimate goal of expanding the modeling concepts regionally. GIS-based linear algebra approaches using raster (cell) data were developed to characterize fire potential in Mississippi. Climate, fuels, and ignition are the primary (weighted) variables, and topography is implemented as a modifier of precipitation. Different types of base data have been tested for usefulness for each variable. Initially, each variable's correlation to historic fire occurrence in Mississippi was tested. The results of these tests ultimately guide decisions about the importance of each variable and variable weights for the full model.

Climate

KBDI evaluation—The importance of climate for fire potential models in Mississippi is not clear. Figure 2 illustrates a 14-year history of the relationship between climate and fire frequency in Mississippi. Drought conditions generally occur in the late summer and fall in Mississippi and are associated with increased fire frequency, but the temporal period with highest fire frequency is associated with periods of luxury rainfall (spring). Indices like the Keetch-Byram Drought Index (KBDI) are often used (Texas Forest Service, WFAS, and others) to estimate fire potential. The usefulness of KBDI alone for determining fire potential in Mississippi has not been documented in

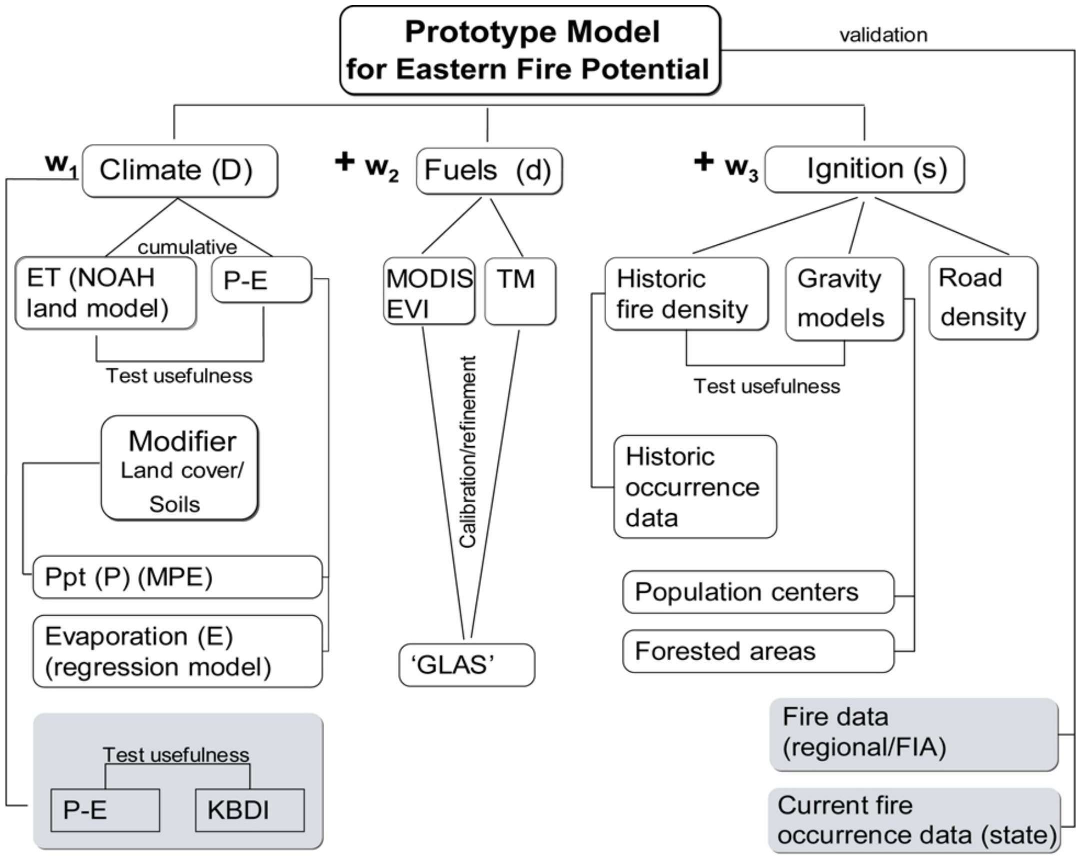

Figure 1—Modeling flowchart.

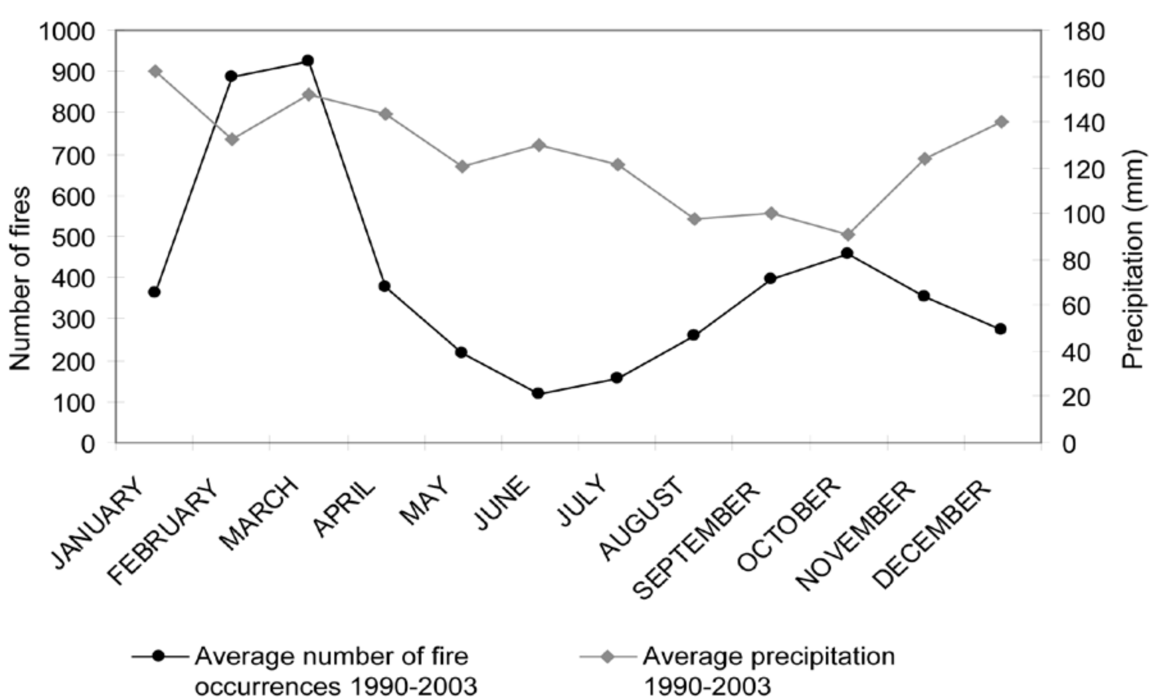

Figure 2—Relationship between climate and fire.

Table 1— KBDI as a measure of fire potential analysis results.

January – April 1989-2003					
X	**Y**	**Pearson's *r***	**R^2**	**Adjusted R^2**	***p*-value for *r***
KBDI	Fire total	.035	.001	.001	.166
May – August 1989-2003					
X	**Y**	**Pearson's *r***	**R^2**	**Adjusted R^2**	***p*-value for *r***
KBDI	Fire total	.220	.048	.048	.000
September – December 1989-2003					
X	**Y**	**Pearson's *r***	**R^2**	**Adjusted R^2**	***p*-value for *r***
KBDI	Fire total	.257	.066	.065	.000

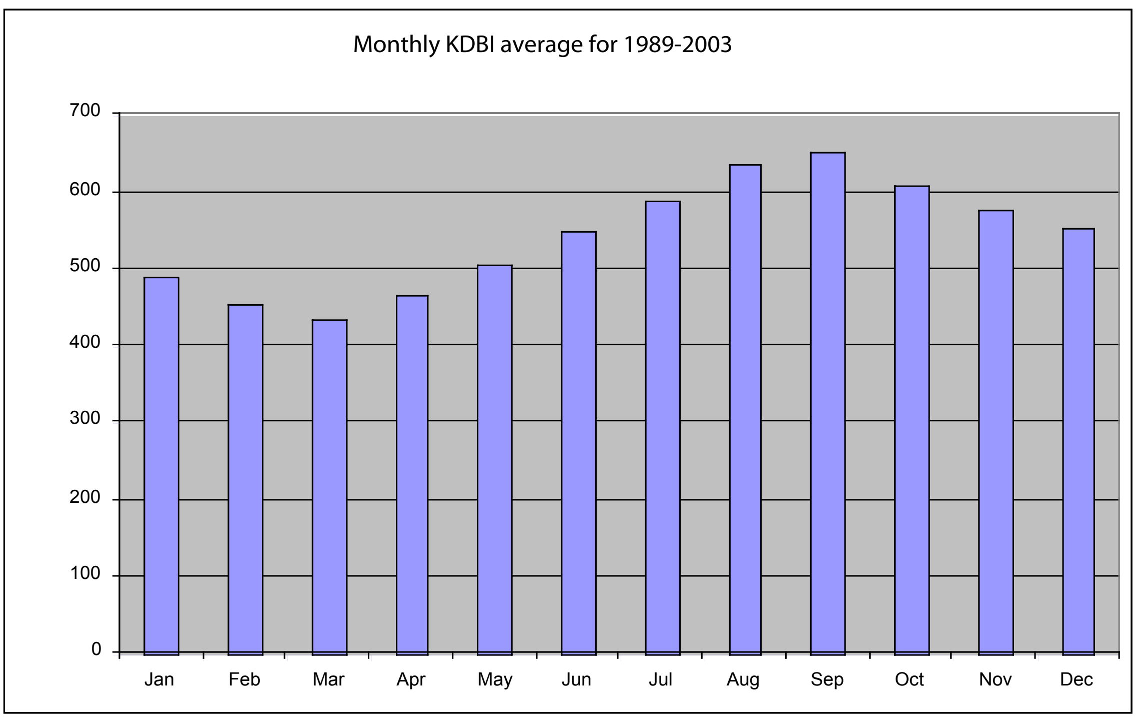

Figure 3—Monthly KBDI averages for 1989 through 2003.

the literature. We tested the usefulness of KBDI alone as a measure of fire potential. KBDI was a poor predictor of forest fire potential in southern Mississippi. Results are presented in table 1 and figure 3. Pearson's r = 0.220 (May through August) and r = 0.257 (September through December) are significant, but regression results indicate poor model fit and little of the variance in fire frequency or fire size is explained by KBDI (r-square = 0.048 and r-square = 0.066 respectively). Based on these results, other measures of climate were considered.

Comparison of multisensor precipitation estimate (MPE) and weather station estimates—KBDI is calculated from data obtained from weather stations' data. We tested whether increased sample density of MPE is superior to weather station-based precipitation. Interpolated Doppler (NEXRAD) radar estimates of daily precipitation recorded at 4 km intervals on the Hydrologic Rainfall Analysis Project (HRAP) point grid were tested against precipitation estimates interpolated at more widely distributed weather stations. Estimated precipitation at high spatial densities (HRAP grid) offers increased spatial precision necessary for recording the relatively small convective weather events that are characteristic of summer weather conditions.

Continuous surface raster grids of precipitation estimates derived from weather station data were compared with precipitation estimates from MPE data (Gilreath 2006). For each day, MPE and weather station data were interpolated to a continuous raster surface grid. All days in a month were added for a summary of the district's cumulative monthly precipitation. To compare monthly cumulative precipitation between different months the MPE and weather station data value ranges were normalized using a z-score transformation. The normalized MPE and weather station grids were then standardized to five fire potential classes via histogram slicing using Jenk's Natural Breaks. A value of 5 represented highest fire potential and 1 represented lowest fire potential. The standardized fire potential values for both the MPE and weather station surface grids were extracted at each known fire location using a 'zonal' function in a GIS. The extracted fire potential estimates for summer 2003 and summer 2004 are compared in bar graphs in figures 4 and 5. In general, monthly mean fire potential at known fire

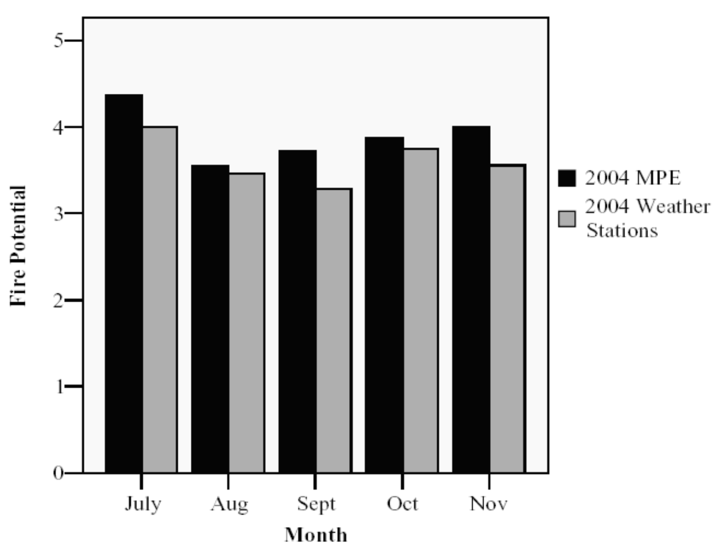

Figure 4—Comparison of the 2004 monthly fire potential estimates of the MPE and weather station layers

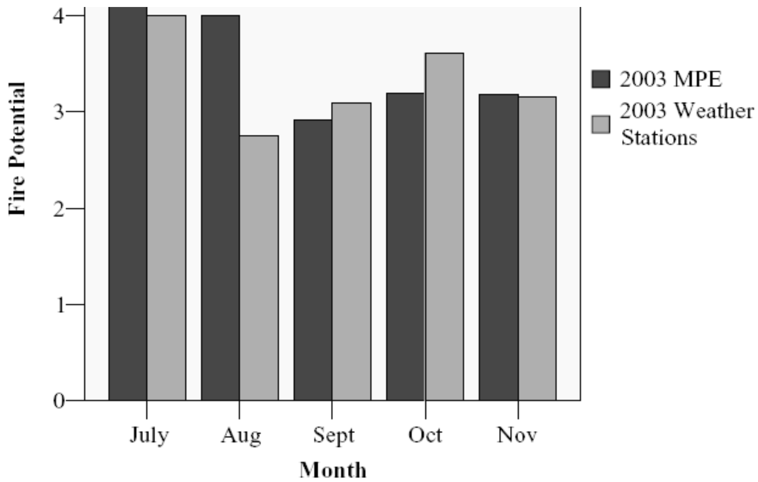

Figure 5—Comparison of the 2003 monthly mean fire potential estimates of the MPE and weather station layers.

locations is higher when precipitation is derived from MPE although exceptions are noted for September and October 2003.

P-E estimate—Precipitation (P) is a critical fuel moisture component, but high temperatures in Mississippi are associated with high rates of evaporation (E). Including evaporation in water budget calculations is important when determining available moisture in the environment. Pan evaporation was compared to regression-based predictions of evaporation developed in association with the Mississippi State Climatologist (Charles Wax). Pan evaporation stations that provide evaporation data exist but are sparsely distributed across the Southeastern United States. Therefore, regression models for inland and coastal locations have been developed that characterize the lower and higher humidity environments of the landscape respectively. Regression models were constructed using minimum daily relative humidity, maximum daily temperature, and total daily solar radiation data acquired at several pan evaporation locations. Evaporation predictions can now be made at any weather station that records daily minimum relative humidity and maximum temperature. These regression models enable interpolations of evaporation at a much denser point pattern than previously available at pan evaporation locations.

Daily water budget estimates were calculated by accumulating (summing) each day's precipitation minus evaporation (P-E) estimates and comparing these to long-term daily averages. Therefore, the water budget variable is an index that is calculated by measuring the daily departure of P-E from the historic P-E averages. While not a direct measure of fuel moisture, this index is representative of landscape moisture conditions critical for assessing fuel moisture in the various 'hour' fuels that exist in Mississippi and the Southeastern United States. The spatial depiction of cumulative wet or dry landscape conditions, used in conjunction with vegetation, ignition, soil, and topography, provide both a spatial and temporal view of patterns of fire potential.

Climate (P-E) modifier—A constructed variable similar to the soil textural pyramid is being developed by combining slope, vegetation, and soil texture. Slope was derived from the USGS National Elevation Data (NED)

30m Digital Elevation Model (DEM) data. Vegetation is characterized using summer 16-day MOderate Resolution Imaging Spectrometer (MODIS) Normalized Difference Vegetation Index (NDVI) data. Soil permeability from the State Soil Geographic (STATSGO) database was used as a surrogate for soil texture. This variable was designed to estimate the amount of runoff expected under various states of vegetation, slope, and soil texture and will act as a modifier of daily precipitation estimates.

Teleconnections—potential for fire potential predictions—In addition to traditional climate variables we examined the effects of global climate processes on regional weather of the Southeastern United States to better understand the impacts of climate variability on forest fires in Mississippi. Results of these analyses have the potential to support prediction of fire size and frequency in the region. Teleconection indices that were analyzed included: El Niño - Southern Oscillation (ENSO), Pacific-Decadal Oscillation (PDO), Atlantic Multidecadal Oscillation (AMO), North Atlantic Oscillation (NAO), and Pacific-North America Oscillation (PNA).

The literature documents that the El Niño – La Niña climate cycle has an effect on fuel load buildup and fire potential in the Western United States. During wet El Niño years, vegetation tend to thrive and expand. Big fire years in the West tend to occur when wet El Niño years are followed by dry La Niña conditions (Kitzberger and others 2001; Simard and others 1985).

Unfortunately, assessing fire potential is not as simple as identifying the phase of ENSO. Norman and Taylor (2003) also found that fires are more widespread during warm, dry years that followed cool, wet years. However, the effect of ENSO appears to be mediated by the PDO, such that fires are more widespread when the PDO is in a warm or normal phase (Norman and Taylor 2003). Further, it seems that the AMO may be the most dominant teleconnection index with respect to forest fire probability in the Western United States (Sibold and Veblen 2006). Nevertheless, no single climate variable appears sufficient for assessing and/or predicting fire risk. Rather, a combination of negative ENSO (La Niña), negative PDO, and positive AMO seems to be the most reliable method for predicting wildfires in the Western United States (Sibold and Veblen 2006).

Monthly fire data for each month during the study period (July1990 to June 2006; 192 months) were aggregated into three categories: total fire events, average acres per fire event, and total acres burned. These categories are treated as dependent variables for this study. Squared bivariate correlation coefficients (r2) were then calculated for the relationships between each teleconnection index and each fire variable for each month of the year. It is possible that variations in the teleconnection indices may not affect Mississippi fires until a few months later, and/or the effects may last several months. Therefore, fire variables were also correlated with teleconnection index values from each of the 6 previous months in order to identify any lagging relationships.

Best results for analyzed lagging relationships between teleconnection indices and fire events organized monthly are shown in figure 6. More specific correlations are outlined below:

- Niño 3.4: Late summer (August, September) is the only time of year that consistently displays strong statistical relationships ($\alpha = 0.05$) between fire variables and Niño 3.4. August fire variables display the strongest relationships with Niño 3.4 values.
- NAO: The relationships between fire variables and the NAO appear to be driven by NAO values in early spring and fall. NAO values during February and March display notable correlations with the average fire

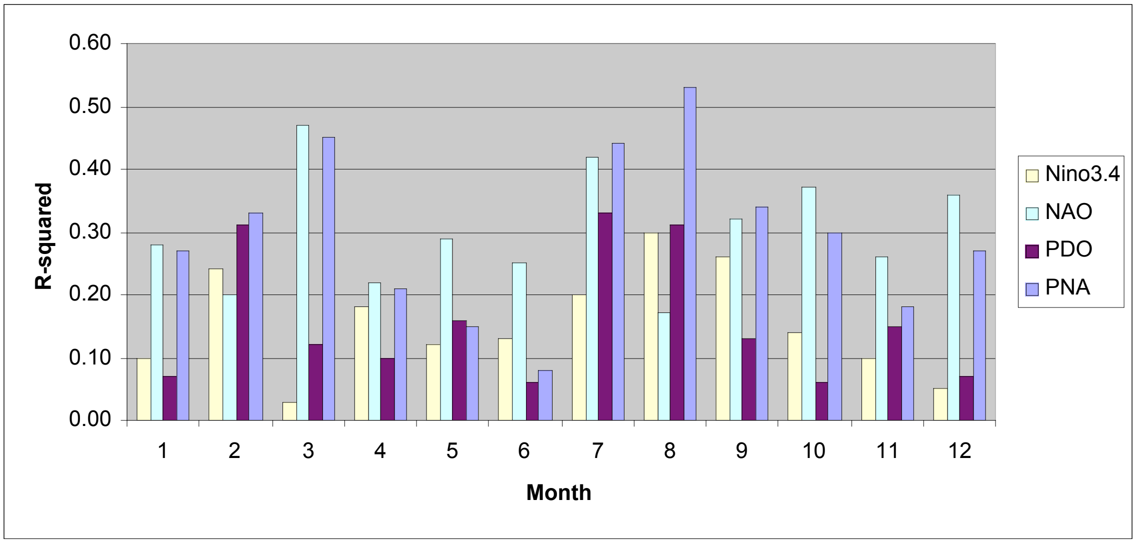

Figure 6—Best results for analyzed lagging relationships between teleconnection indices and fire events organized monthly.

size during the months of March, June, and July. In addition, April NAO values appear to affect the number of fires in September and October. Finally, NAO values during September and October display consistent correlations with fire variables in October, November, and December.

- PDO: The number of fire events in February show consistent correlations with PDO values during the months of December, January, and February, but the average fire size shows essentially no relationship to antecedent PDO values. All three fire variables for the month of August display impressive correlations with August PDO values. Of course, such a relationship provides little in the way of predictive ability. Nevertheless, despite no statistically significant relationships ($\alpha = 0.05$), PDO values during the previous 5 months appear to have some effects on fires in August, and PDO values in the previous February (6-month lag) have strong relationships with fire variables in August. Similarly, March PDO values display strong correlations with fire events in July.
- PNA: PNA values during the month of July illustrate the most impressive relationships with fire variables, as at least two of the three fire variables in each of the months July through October display statistically significant correlations with July PNA values. In addition, fire totals in January show some correlation with PNA values in the previous September, February fires are related to PNA values in January and February, and March fires appear to be affected by previous November PNA values.

Our analyses point out some correlations between indices and and soil moisture. For example, all of the ENSO-fire relationships are negative (that is, positive Niño 3.4 anomalies lead to decreased fire potential). This is most likely due to the annual minimum in precipitation that typically occurs in late summer. During these dry conditions, antecedent soil moisture becomes a primary factor controlling the fire occurrence and extent. Since positive Niño 3.4 anomalies (El Niño) usually result in increased precipitation across the Southeast, soil moisture remains high. There is also a negative relationship between PDO and fire events in Mississippi. Again, positive PDO periods are accompanied by increased precipitation across the Southeastern United States., so soil moisture is likely to remain above normal. Finally, most months display a negative PNA-fire relationship, but positive PNA values during and around the month of September seem to result in increased fires throughout the fall and winter. Usually, positive PNA leads to lower temperatures across the Southeast, which should yield fewer fires. However, fewer fires in August may mean more residual fuels available for fires in fall and winter, which could explain the reversal in sign of the correlation.

Fuels

Typically, fuel load is a relatively static or slowly changing variable; however, sudden changes in moisture conditions and substantial vegetation damage can contribute to rapid changes in fire potential. Development of GIS layers that enable rapid characterization of changes in forest fuel conditions is important for determining how fire potential can change due to natural disasters such as hurricanes. For that reason, in response to damage caused by Katrina, we developed GIS fuel-based models that assessed fire potential in areas of Mississippi that were most severely impacted by the hurricane.

Long time-series of Landsat imagery, pre- and post-Katrina satellite imagery, and aerial imagery were integrated into the fuel-based model. Pre- and post-Katrina fire potential was compared for six counties in southern Mississippi using information on forest age classes, forest type and damage categories. Information on forest age classes and types were derived from Landsat satellite data (Collins and others 2005). Hurricane damage information was derived from AWIFS imagery in form of binary damage mask, while aerial imagery interpretation of forest stand conditions was used to classify the damage categories and assess the accuracy of the satellite damage mask.

Pre-Katrina fire potential was derived a-priori from fire occurrence data. Forest type/age groups of similar fire frequency characteristics were determined by summarizing 20 months of pre-Katrina fire occurrence data. Number of fires, average fire size, and percentage of area burned in each class were evaluated and used as criteria for the assignment of fire potential for each group. This resulted in the several unique age/type group combinations that were assigned fire potential ranks ranging from 0 (no fire potential) to 5 (very high fire potential). Post-Katrina fire potential was determined by assigning the same ranks as pre-Katrina fire potential for undamaged areas and assigning an increased fire potential rank to areas classified as damaged by the satellite damage mask. A unique number was assigned to each unique combination of forest type, age, and damage layers to ensure that all combinations were assigned with appropriate fire potential rank. This is an important consideration in GIS modeling that enables the analyst to assess the exact conditions at a given cell location that give rise to a fire potential rank value.

The analysis resulted in spatial depictions (fig. 7) and statistical summaries of pre- and post-Katrina fire potential. Overall accuracy of the remotely sensed damage assessment was 72 percent. Based on the modeling results, validated with actual 2006 fire data, the fire potential in the region increased after the hurricane. The post-Katrina landscape is characterized by reduction in the contiguity of areas classified as very low fire potential, and increases in the amount and contiguity of areas classified as very high fire potential (fig. 7). Due to the hurricane, areas of very low potential decreased from 19 to 3 percent, while areas of very high potential increased from 3 to 13 percent.

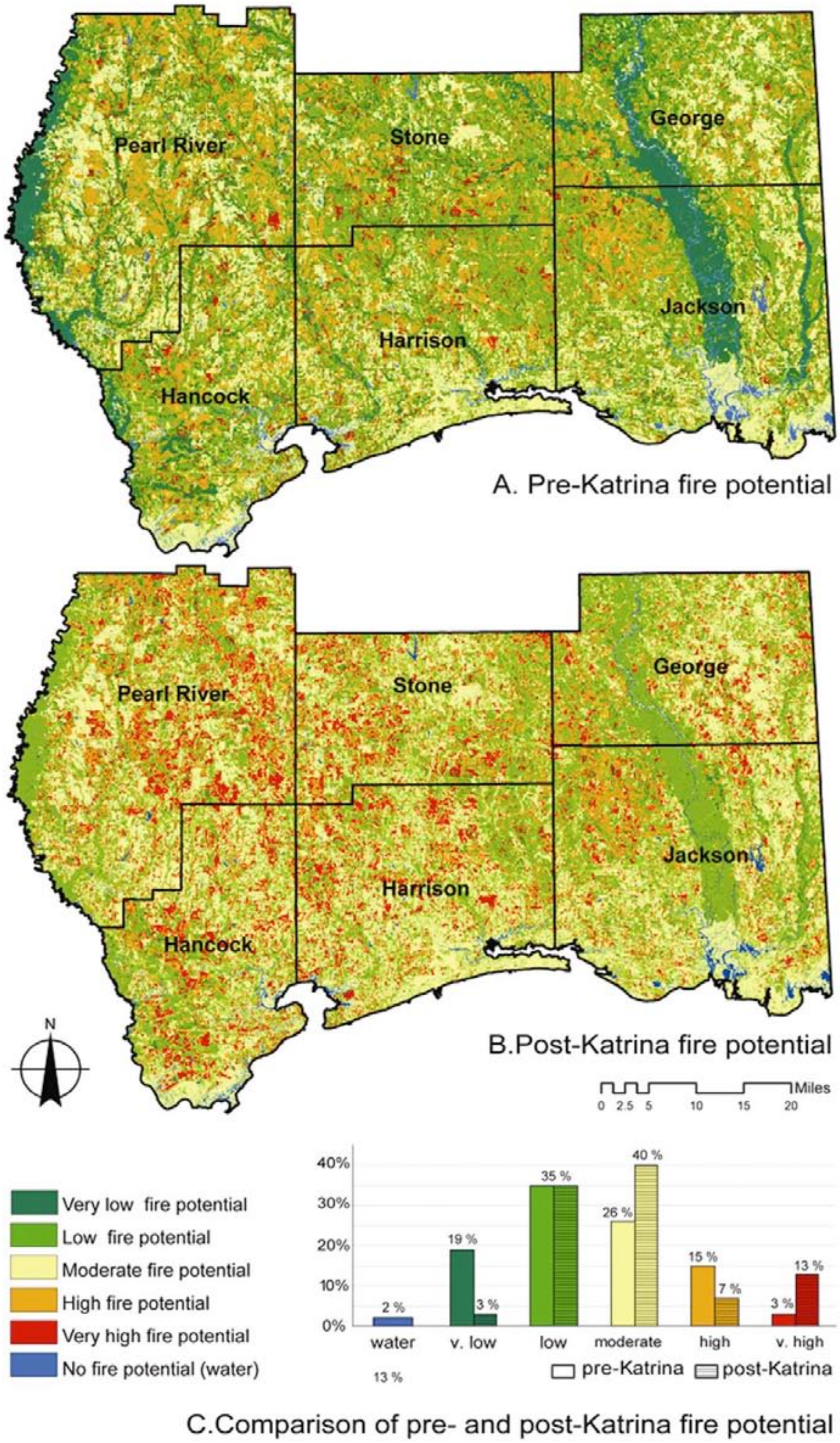

Figure 7—Pre- and post-Katrina fire potential comparison for six southern Mississippi counties.

Overall, the proportion of the landscape that was classified as very high fire potential after Katrina is greatest in the western counties (Hancock and Pearl River), somewhat lower in the central counties (Harrison and Stone), and lowest in the eastern counties (Jackson and George). This west-to-east fire potential gradient corresponds closely with the strongest wind seeds and highest amount of rainfall that occurred in Hancock, Harrison, Stone, and Pearl River counties.

The modeling results were validated with actual fire occurrence data. The greatest increase in post-Katrina fire potential was observed in the very low potential class (mixed and broadleaf stands), which may indicate that areas traditionally considered fire resistant change dramatically in terms of fire potential following hurricanes. Overall modeling results point out that increased numbers of fire suppression personnel may be needed for coming fire seasons in the impacted region.

Ideally, the fuels variable should characterize the amount of 1-hour, 10-hour, and other fuels (Anderson 1982). We are currently testing the usefulness of space-borne waveform Light Detection and Ranging (LiDAR) data for measuring vertical structure and fuel loads. Similar to the Fire Potential Index (FPI) described by (Burgan and others 1998), we use NDVI derived from Advanced Very High Resolution Radiometer (AVHRR) and MODIS data for regional fuels analyses. We have tested regression approaches for describing the sub-pixel components relevant to fuel loads using Landsat Thematic Mapper (TM) data (Berryman 2004), 'QuickBird' high resolution multispectral imagery, and airborne pulse LiDAR data.

Field work was recently begun designed to calibrate ICESAT GLAS data waveform LiDAR with fuel characteristics in a study area on the MSU 'Starr' Forest in Mississippi. Data were acquired over a variety of forest and some nonforest conditions. The ground data collection includes understory and overstory measurements for 60 field plots that are coincident with the elliptical footprint of the GLAS data. Figure 8 contrasts waveform differences

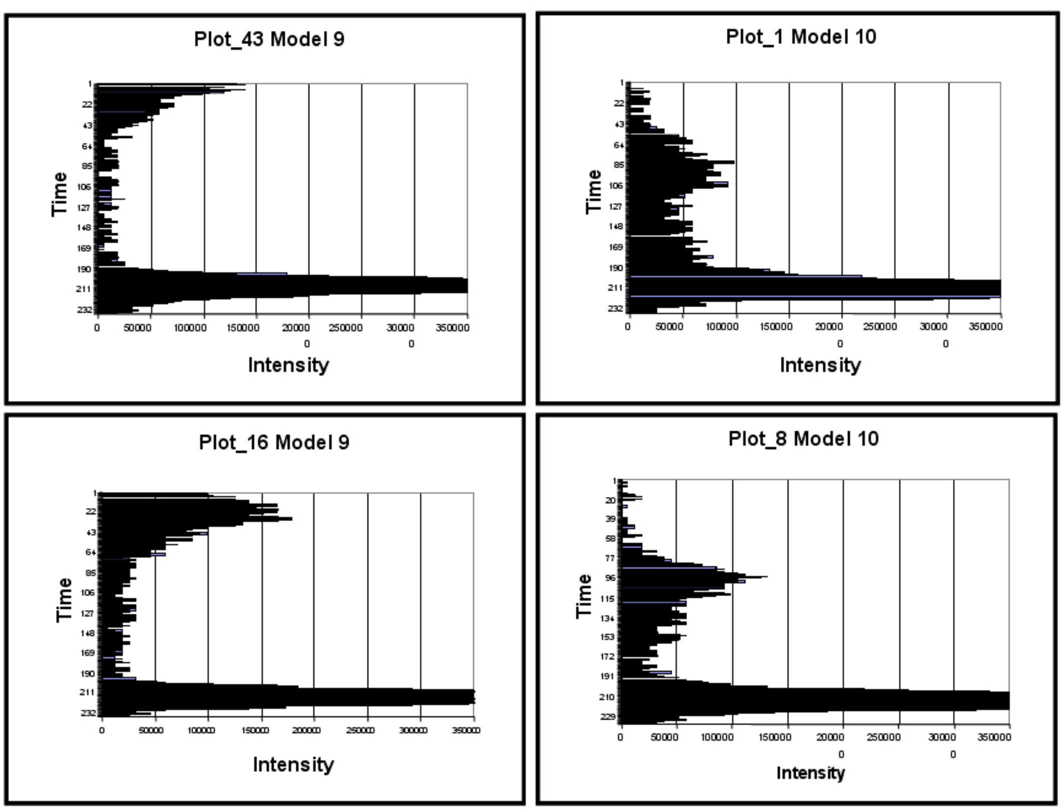

Figure 8—Contrasting waveforms for Anderson's fuel model 9 and 10.

between for Anderson's fuel model 9 (pine plantation with little understory and downed woody debris) and fuel model 10 (mature pine plantation with hardwood understory and downed woody debris). Note that the earliest waveform returns are from the canopy, the next waveform returns are from the midstory and understory, and the last (and highest intensity) returns are from the ground. Our goal is to characterize fuel models from LiDAR samples for a variety of conditions, then extrapolate those conditions to larger (regional) landscapes via coarse resolution MODIS data using a subpixel prediction algorithm under development.

Ignition

Anthropogenic factors play a major role in fire ignition in Mississippi. Humans affect wildfire ignition by altering the vegetative fuel load characteristics and by providing an ignition source (Petrakis and others 2005; Pye and others 2003). Pye and others (2003) demonstrated that proximity to roads and certain levels of road density are significantly correlated with increased fire risk. Gilreath (2006) showed that in Mississippi, road density calculated using the gaussian kernel for all primary, secondary and county roads is a good predictor of fire frequency. Findings indicate that areas of very high and very low road density are at very low fire potential. Conversely, areas of moderate road density are at significantly higher risk. Sadasivuni (2007) tested the application of gravity models that measure the interaction among cities and medium-age large contiguous pine forests for fire frequency relationships. Independent t-tests were used to test for significant differences among levels (ranks) of gravity models and road density models for all fires, winter fires and summer fires. Finally, t-tests for significant differences between levels (ranks) of gravity models versus road density models were made to test the hypothesis that no differences exist between the two methods for predicting fire frequency. Results of the tests for no differences between the two methods are shown in table 2. The gravity model proved to be better overall for estimating fire potential at the very low fire potential level for all seasons. It was also better at estimating fire potential in the medium level during the winter and for low and medium levels in the summer. For all other comparisons, there was no significant difference between road density and gravity models as predictors of fire potential.

Table 2—Results of t-tests for gravity models and road density models (*indicates statistically significant results).

Gravity and road density	Annual critical	Annual p-value	Winter critical	Winter p-value	Summer critical	Summer p-value
Very low gravity and very low road density	3.51*	0.0085	3.64*	0.0058	3.58*	0.007
Low gravity and low road density	1.6	0.11	1.56	0.13	2.0*	0.05
Medium gravity and medium road density	3.09*	0.003	2.82*	0.0064	2.78*	0.007
High gravity and high road density	0.62	0.534	0.67	0.5	0.29	0.77
Very high gravity and very high road density	0.44	0.664	0.08	0.58	0.42	0.68

Fire Potential Modeling Tool (FTMT)

Our geospatial database integrates water budget and fuels for wild fire potential modeling for the Eastern United States. A fire potential modeling tool (FPMT) has been developed to manage the geospatial database and to extract water budget (P-E) for the fire potential model. Development of an extension is underway for tools that will incorporate data from the Noah land model.

The database adopts the ESRI Geodatabase structure (fig. 9). Feature classes include radar sample points and weather station location. Two object classes store radar data and weather station data that are connected to the corresponding feature table based on measurement time in the time table. Time table is the third object class. Precipitation and evaporation are accumulated based on the period chosen as user's input. Individual accumulation data are stored as object tables, which are connected to the corresponding feature tables. To populate climatic data in the database, the automated procedures were developed in FPMT.

FPMT is an application designed to facilitate data management, spatial modeling, and map generation. Therefore, FPMT consists of three sub modules: data management, fire fuel modeling, and mapping modules. Current FPMT includes the data management module that includes data input, formatting, coordinate transformation, and accumulation procedures. Fire fuel modeling and mapping modules are under way, which include interpolation, fire fuel model, and creating map documents.

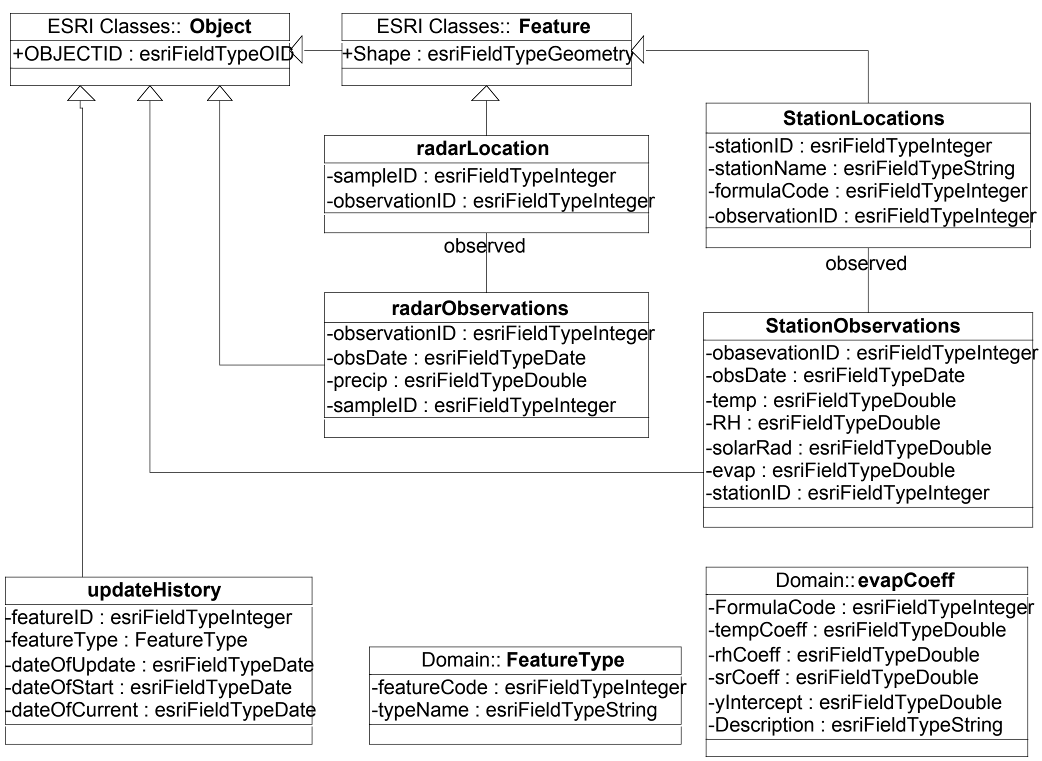

Figure 9—Geodatabase structure.

Conclusions and Plans

Each variable that has the potential of being included in the Mississippi fire potential models has been tested with historic fire occurrence data. Once the model variables and weights have been calibrated for Mississippi landscapes, we will extend the models to the southern region to test the usefulness of these modeling concepts over a larger landscape area.

We believe that measures of climate should include the effects of precipitation and evaporation (P-E) and that calculation of environmental moisture is cumulative and compared through time against the long-term P-E average. Although KBDI is a cumulative (soil) moisture index, our studies show that KBDI is a poor predictor of fire frequency and fire size for southern Mississippi. Precipitation and evaporation are important components for water budget calculations. Our goal was to interpolate precipitation and evaporation from the densest available source. Local measurements of precipitation and evaporation for our models result in descriptive products that are designed to estimate relative fire potential on the basis of comparisons of current climatic conditions with long-term averages. The ability to forecast future fire potential depends on understanding how global climatic processes influence fire occurrence (teleconnections). We are testing historic information derived from Pacific and Atlantic oscillation indices against historic fire occurrence in Mississippi, particularly concentrating on the temporal lag between index values and fire frequency and size.

This project demonstrated the utility of combing GIS raster modeling and remote sensing change analysis in assessing fire potential following hurricane Katrina. In this study actual change in fire threat was demonstrated empirically by validating fire potential predictions with actual fire occurrence data. This study demonstrates the capability of GIS-based analysis to provide rapid assessment of landscape conditions that favor fire ignition in coastal regions following destructive hurricane events. Such information is essential for emergency and wood recovery personnel to allocate their resources within areas of elevated fire hazard.

Understanding the anthropogenic factors that affect fire ignition is important in the Southeastern United States. We examined two methods of determining ignition from a spatial perspective. We found that city/fuels interaction (gravity) models are better than road density for characterizing fire potential in very low and low fire potential strata.

We have recently acquired 18 years of AVHRR NDVI bi-monthly composites for the United States. We calculated the 18-year average greenness for physiographic regions in Mississippi. We plan to test correlations between fire variables and NDVI (greenness) as a departure from the 18-year average.

We are designing a Web-based graphical interface for our fire potential modeling tools (FPMT) to display results. Initially, fire potential estimates will be summarized on a bi-monthly basis. The Data acquisition interface is user-friendly and can adapt to a variety of precipitation input data. We hope to have the fire models calibrated, functional and available on the Web in the near future.

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