J9.7 A FIRE SCENARIO BUILDER FOR COARSE-SCALE MODELING OF CURRENT AND FUTURE FIRE EFFECTS.

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ABSTRACT

Given the stochastic nature of fire ignition and spread, a modeling approach is needed to estimate the range of fire effects possible on current and future landscapes. We are developing a nationwide Fire Scenario Builder (FSB) that creates self-consistent, spatially explicit U.S. prescribed and wildland fire scenarios for use in modeling both current and projected fire effects, including fire emissions. The FSB creates stochastic fire location and size scenarios that are consistent with known weather, vegetation, and land management controls on fire ignition and spread.

At its core, the FSB is based on a coarse-scale classification and quantification of fire regimes and tunable land management strategies. Fire regime attributes are created from reconstructed fire history, historical fire records, and potential natural vegetation. The FSB also utilizes weather and climate information from global climate model output. The climate projections used in this effort are those from the NCAR Climate Systems Model which contains the CCM3 atmospheric model at T42 resolution, but the FSB methodology is not limited to a particular model or resolution. The FSB utilizes in parallel known statistical relationships between climate, vegetation, and fire to create fire-ignition probabilities and a probability distribution of estimated fire sizes. The FSB is still under development, but we present initial results from forecasts for 1996-2000 and 2046-2050 based on initial vegetation, lightning, and relative humidity relationships. Future work will utilize dynamical downscaling of the GCM output using the MM5 mesoscale model to increase spatial resolution and adapt the FSB to application at multiple spatial scales.

1. INTRODUCTION

We are interested in wildland fire's contribution to future air quality, and possible land management strategies that can help mitigate the effects of fire on future air quality. Wildland fire is well known to produce air-quality contaminants that can affect human and ecosystem health, such as particulate matter, ozone, and various carbon species. In order to develop strategies that can effectively mitigate fire's impact, a model of future fire emissions must be developed. Because of the long timescales involved in forest changes, such a model must be capable of projecting fire emissions many decades into the future.

Such a model is necessarily complicated by the fact that that wildland fire emissions are affected not only by human controlled land management and fire suppression strategies, but also by weather, vegetation and ecosystem variations, and long-term climate change. Of these latter influences, climate change is likely to cause the most significant changes in air quality impacts in the decades ahead. Global warming scenarios predict alterations in large-scale atmospheric circulation pattern changes that will affect the location of storm tracks, moisture transport, and large-scale temperature and precipitation patterns. These changes will cause a cascade of effects that can alter both emission production and transport, thereby affecting air quality. For example, changes in temperature can affect mixing-height depth, causing variation in ventilation of emissions, as well as affecting other aspects of planetary boundary layer meteorology such as reaction rates. Changes in temperature and precipitation patterns can also affect ecosystems, causing vegetation changes that affect both biogenic and anthropogenic emissions.

Wildland fire emissions are more sensitive to climatic change that many other types of emissions for several reasons. Wildland fire is largely event-driven; relatively few fires account for the majority of acres burned (and therefore emissions) in any given year (Strauss *et al*. 1989). The potential for a fire to occur is critically dependent on both short term weather (e.g. lightning storms) and longer-term trends (e.g., drought), both of which are directly impacted by climate change. Further, many studies have suggested that fire may be a key manner in which ecosystem transitions occur (e.g., Pyne *et al*. 1996; McKenzie *et al*. 1996, Lenihan *et al*. 1998).

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The FERA and AirFIRE Teams of the Pacific Northwest Research Station, US Forest Service, are developing a Fire Scenario Builder (FSB) that incorporates the effects of climate and vegetation changes as well as land-management strategies. The FSB takes in future climate predictions from global climate models, downscaled to regional scale, and expected vegetation changes, and produces probabilistic fire-emission forecasts consistent with this information using known fire regime information and statistical and dynamical linkages among climate, weather, and fire. The goal of the FSB is to be able to interface with high-resolution air quality modelling efforts and explicitly examine the sensitivity of air quality impacts from wildland fires to land and fire management strategies.

2. BACKGROUND

The impetus for this work stems from the current conditions of US National Forest land, much of which currently carries elevated fuel loadings due to 20th-century suppression. The US National Fire Plan and Healthy Forest Initiative call for increased treatment (through both prescribed fire and mechanical removal) of densely stocked forests in order to reduce the risk of catastrophic wildfire. Quantifying treatment levels and prioritizing areas for treatment require understanding the likelihood of future wildland fire under changing climate.

Additionally, the US Environmental Protection Agency has enacted long-term air quality planning requirements under the 1999 Regional Haze Rule provision of the Clean Air Act. The Regional Haze Rule requires the elimination of excess visibility impairment from regional haze from all wilderness areas by 2064. Wildland fire, to the extent it is due to the “non-natural” excess fuel loading caused by historical fire suppression, is considered an excess, anthropogenic source. This designation is critical because wildland fire has been shown to be a major source of regional haze during the fire season (Ames and Malm, 2001; Park et al. 2003).

Federal, state, and tribal agencies in the US are required to develop plans that will accomplish reducing regional haze levels to natural levels by 2064. Current efforts to model wildland fire’s contribution to regional haze in the future, for example, by the 13-state cooperative Western Regional Air Partnership (WRAP), have no explicit mechanism for modelling the effects of climatic variability and change on wildland fire extent and severity (e.g., WRAP, 2002). Since understanding fire in the future requires understanding the combination of both climate change and land management practices, the FSB is poised to be a strategic tool useful to researchers and regulatory agencies to estimate future fire activity and emissions.

3. COMPONENTS OF THE FSB

The FSB consists of three major parts (Figure 1): (1) a vegetation module designed to predict nominal fire-regime classifications and fuel loadings for the future climate; (2) a probability generator that generates probabilities of fire occurrence and fire size based on the future climate and known climate/fire, weather/fire, and fuel/fire relationships; and (3) a smart randomizer that uses the fire occurrence and size probabilities as well as selected fire suppression strategies to create specific scenarios of fire locations, sizes, and emissions. The FSB works on an x-y-t grid, where the x-y grid can be of various resolutions (initial work is at 36x36km over the continental U.S.), and the time step is daily.

The vegetation module takes the currently observed vegetation and alters it to reflect future climate by comparing predicted multi-year climatology with current, observed climatology. Projected land-use changes are also incorporated based on the land management strategy being used. Future fire regimes for each grid location are then assigned based on the projected vegetation cover type and that cover types historically observed fire return interval. Fuel loadings are assigned based on vegetation cover type, ecosystem geography, and projected climatology.

After future fire regimes and fuel loadings are determined, these need to be translated into probabilities of fire occurring and the potential size of the fire. The probability generator module does this by initially using the fire return interval to calculate a base probability of fire occurrence and then using observed fire history and seasonality for that fire regime class to distribute the probabilities climatologically throughout the year (e.g., enhanced fire occurrence during dry months, decreased fire occurrence during wet months). The probability generator module then compares high-resolution downscaled climate predictions to the observed climatology to adjust the fire occurrence and size probabilities based on the downscaled weather. This step is critical in assuring consistency between the downscaled high-resolution weather and the fire emission inventory, e.g. large fires are unlikely to occur during a heavy rainstorm.

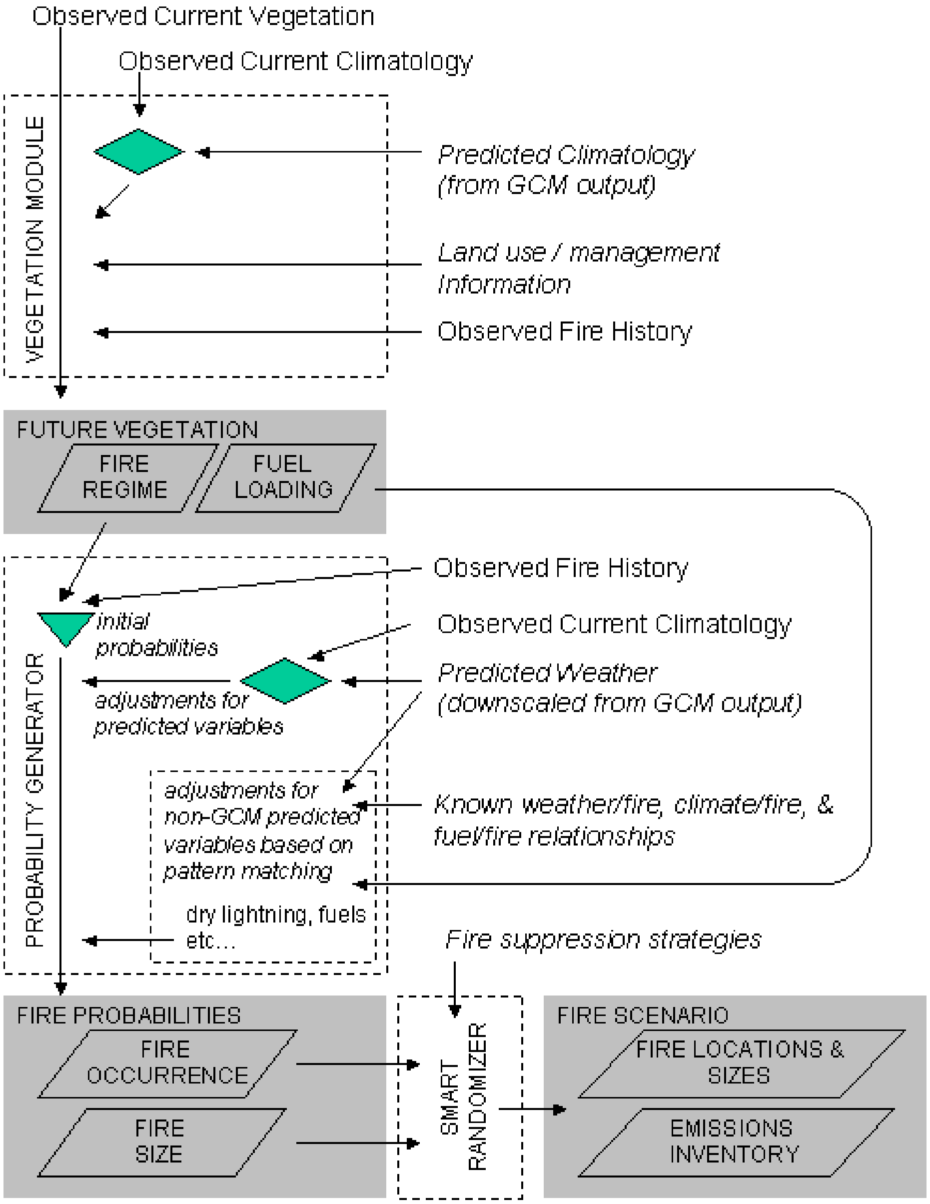

Figure 1: Fire Scenario Builder flowchart showing observed and predicted inputs, and output datasets (in gray).

To account for fire occurrence and size influences that are not well predicted by climate forecasts, such as dry lightning, etc., a further step is taken to adjust the FSB probabilities. This includes pattern matching predicted meteorology against empirical orthogonal function models (citation), then using known relationships between these influences and fire to adjust the FSB probabilities. Because these latter adjustments are less direct, due to the limited ability of climate models to predict them, they are done in parallel, using a simultaneous weighting scheme, and given less weight than the more direct weather adjustments above. Finally, the probabilities are adjusted based on fuel loading and land management strategies.

Once the daily probabilities are generated, the smart randomizer then randomly locates fire locations and fire sizes throughout the year. The smart randomizer adjusts the calculated probabilities to account for multiple-day fires, the decrease in fire probability due to an earlier burn, and fire suppression strategy. The net result is an emissions inventory of fire sizes, locations, and fuel loadings that can be input into emissions and dispersion models for air quality assessments.

4. SUMMARY

The Fire Scenario Builder allows the user to explicitly enter the land management and fire suppression strategies of interest and examine the ensuing fire scenario. In this way, the FSB should prove valuable in assessing management strategies. Additionally, the FSB is designed feed into high resolution air quality models that are now being applied to future climates, allowing for an enhanced ability to incorporate wildland fire into these applications. This is becoming particularly important due to regulations such as the US EPA Regional Haze Rule that require US federal, state, and tribal agencies to perform long-range air quality planning.

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