Attachment D

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NCAR

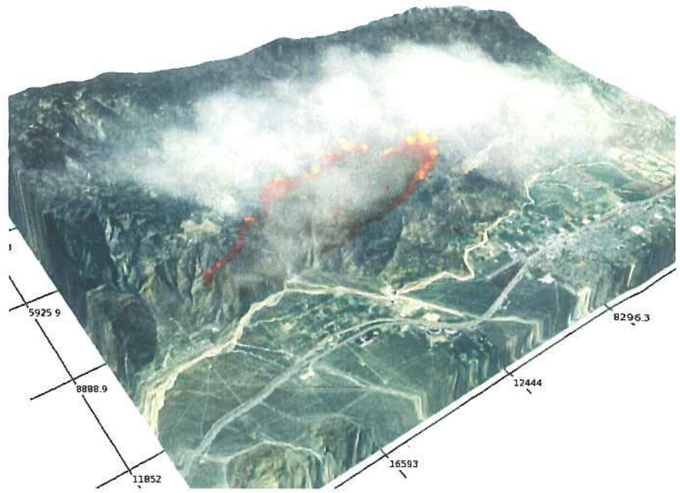
Coupled Weather-Fire Modeling
Decision Support for Wildland Fire Management

Problem Statement
Wildland fires are exceedingly complex phenomena. Despite rigorous training, abundant resources, and weather forecasts, even seasoned responders may be tragically unprepared for complex, unpredictable, and explosive fire behavior. Human intelligence cannot integrate all the interacting factors to anticipate when weather will combine with topography and fuels to dramatically amplify fire behavior.

Background
Large wildland fires are dynamic phenomena that encounter a wide range of fuels, terrain, and environments often during one event and produce extreme behaviors such as fire whirls, blow-ups, 100-m long bursts of flame shooting ahead of the fireline, fire winds 10 times stronger than ambient wind speeds, deep pyrocumulus, and firestorms – all resulting from the interactions between a fire and its environment.

For nearly two decades, the National Center for Atmospheric Research (NCAR) has worked with federal, university, and international partners to develop models such as the Coupled Atmosphere-Wildland Fire Environment (CAWFE) model and more recently, the Weather Research & Forecasting (WRF) model that couples numerical weather prediction with wildland fire models to predict fire behavior and its feedback on the local atmosphere.

The Waldo Canyon fire burns near Colorado Springs.



Model simulation of the 2006 Esperanza fire in Cabazon, CA shows the fire line and smoke plume.

This effort builds on longstanding NCAR research in areas ranging from atmospheric science, weather prediction, coupled models, data assimilation, land surface modeling, plume dispersion, atmospheric turbulence, system engineering, testing and verification, GIS, and decision support system development.

Technological Advances
It is widely accepted that wind, slope, and wildland fuel properties cause variations in wildfire behavior. Current operational tools encapsulate this understanding in relationships to make simple projections of fire spread rate and intensity as a function of these properties. In contrast, our coupled weather-wildland fire models have evolved recognizing that coupling between a fire and the atmosphere is the basis for many fundamentals of wildland fire behavior. Thus, they include this interplay as well as other important factors such as diurnal wind changes, temperature inversions, and gust fronts from clouds, enabling them to explain and predict numerous fire phenomena, rapid changes in fire behavior such as blowups, and extreme fire behavior such as firenadoes.

The NCAR systems combine numerical weather prediction models that incorporate the effects of complex terrain on airflow (and thus on fires) with a fire behavior model to simulate the intertwined influences of weather, fuel, and terrain on wildfire growth, plume development, and smoke transport.

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These models (CAWFE and WRF) are three-dimensional time dependent, nonhydrostatic atmospheric models that can be used in mountainous terrain, can model atmospheric motions over a region while focusing in with high resolution on one small valley with two-way interacting nested domains, and include large-scale atmospheric motions such as fronts that affect fire behavior by initialization of the atmospheric environment using larger-scale models. Our atmospheric models include formation of pyrocumulus clouds, hail, and rain over fires and track smoke dispersion.

CAWFE's fire module calculates the fire spread rate in different fuel, wind, and slope conditions, post-frontal heat release into the atmosphere, and the transition of ground fires into crown fires. The spread rate of the fire line (the interface between burning and unignited fuel) and burning rates are calculated using semi-empirical equations that depend on local wind and fuel characteristics. Surface fires can dry and ignite the canopy overhead. Heat and moisture from the fire feed back into the atmospheric state, affecting the simulated weather near the fire. Propagation of the fire line itself is accomplished by subdividing each atmospheric model cell into smaller fuel grid cells. When a fuel cell is ignited by contact with a neighboring burning cell, four tracers that outline the burning region are ignited and track the moving fire line. Simulating the terrain-induced airflow effects, the fire's forces on the air that alter winds, and the role of winds directing the fire spread allows the model to generate erratic and intense fire features often observed in actual fires and creates the uniqueness of each fire event. WRF-Fire, the fire package within WRF, is adapted from CAWFE.

Experiments have simulated fires in many atmospheric conditions with a variety of fuel types and in different types of terrain. The coupled models have been tested and verified on cases including the Big Elk Fire, CO, Esperanza Fire, CA, Simi Fire, CA, Troy Fire, CA, Spade Fire, MT, Hayman Fire, CO, High Park Fire, CO, and others.

In addition to modeling, NCAR researchers and collaborators have used infrared imagers to study dangerous phenomena within wildfires for more than a decade. The knowledge from field campaigns and computer modeling is sharpening our understanding of the erratic behavior of wildfires and its interaction with land, atmosphere, wildlife, and people.

Decision Support

This unique and advanced technology provides a solid foundation and scientific and engineering framework for a decision support system that could be used to plan prescribed fires, to identify the confluence of weather, fuel, and terrain conditions in which blowups occur, for tactical or strategic decision support to suppress wildfires, and to support emergency response such as reverse 911 calling for notification and evacuation. Additional research and development funds are required to adapt the technology for operational use. These funds would be used to build an engineering framework around a coupled weather-fire model that includes automated data ingest of real-time weather and up-to-date fuels information, a customized user interface to configure the location, domain size, grid resolution, fire ignition time and location, and updated fire perimeters at each reset time. The integrated decision support system could then be used pseudo-operationally to support fire operations and refined based on user feedback.

Model simulation of the 2012 High Park Fire, CO.

Primary Goal

The goal of developing the coupled weather and fire behavior modeling capability is to gain knowledge of the complex interactions and feedbacks between the atmosphere and fire behavior and to develop a tool that will support operational decision-making by fire managers and emergency response personnel. In addition to improving the ability to predict fire behavior, this technology could enhance training, allowing stakeholders to explore a variety of cases, developing better awareness among responders of why large fire events unfold as they do and where environmental conditions create a perfect storm for explosive fire growth.

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