Fire Weather Technology for Fire Agrometeorology Operations

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Abstract

Even as the magnitude of wildfire problems increases globally, United Nations agencies are acting to mitigate the risk of wildfire disasters to members. Fire management organizations worldwide may vary considerably in operational scope, depending on the number and type of resources an organization manages. In any case, good fire weather information is vital. This paper describes an approach for introducing fire weather/fire danger-rating technology into fire agrometeorology operations, based on the collective experience of the United States, Canada, and Australia. A prototype fire weather forecasting system is presented, which has produced fire weather products for various parts of the world on a trial basis.

Introduction

The interaction between wildfire and demographic trends worldwide poses potentially serious consequences to human and ecosystem health, biodiversity, and global biogeochemical cycles. Smoke from large wildfires can impact not only local inhabitants, but also distant downstream populations across international boundaries. The Food and Agriculture Organization (FAO) and other United Nations (UN) agencies recognized the need for international collaboration to manage wildland fire globally, whether it occurs naturally or as a land management application (*Framework for the Development of the International Wildland Fire Accord, 22 June 2004*). FAO facilitates international agreements which countries use to assist each other in wildfire emergencies, and also supports countries in the development of fire management and preparedness programs.

Fire management organizations may vary considerably in size and level of sophistication, but they all require good weather and climate information commensurate with their needs. Even before any fire occurs, fire managers monitor the weather, because it determines the ignitability of vegetation. Fire management needs for weather and climate information are very similar to agricultural management requirements. This paper suggests how agrometeorology operations may be modified to service fire management needs.

Regional Fire Networks

By direction of the UN International Strategy for Disaster Reduction and the Inter-Agency Task Force for Disaster Reduction, the Global Fire Monitoring Center (GFMC) at Freiburg University, Germany, has been facilitating the establishment of regional wildland fire networks since 2002, with the ultimate goal of confederating a global wildland fire network (Figure 1). The networks organize members to share resources and expertise for wildland fire management. Some of the regional networks formed on their own initiative, and were solicited to join the global wildland fire network. Others were encouraged to organize with the assistance of the GFMC. Table 1 lists the nations that populate the various regions, although not all regions necessarily have formal agreements that bind the members.

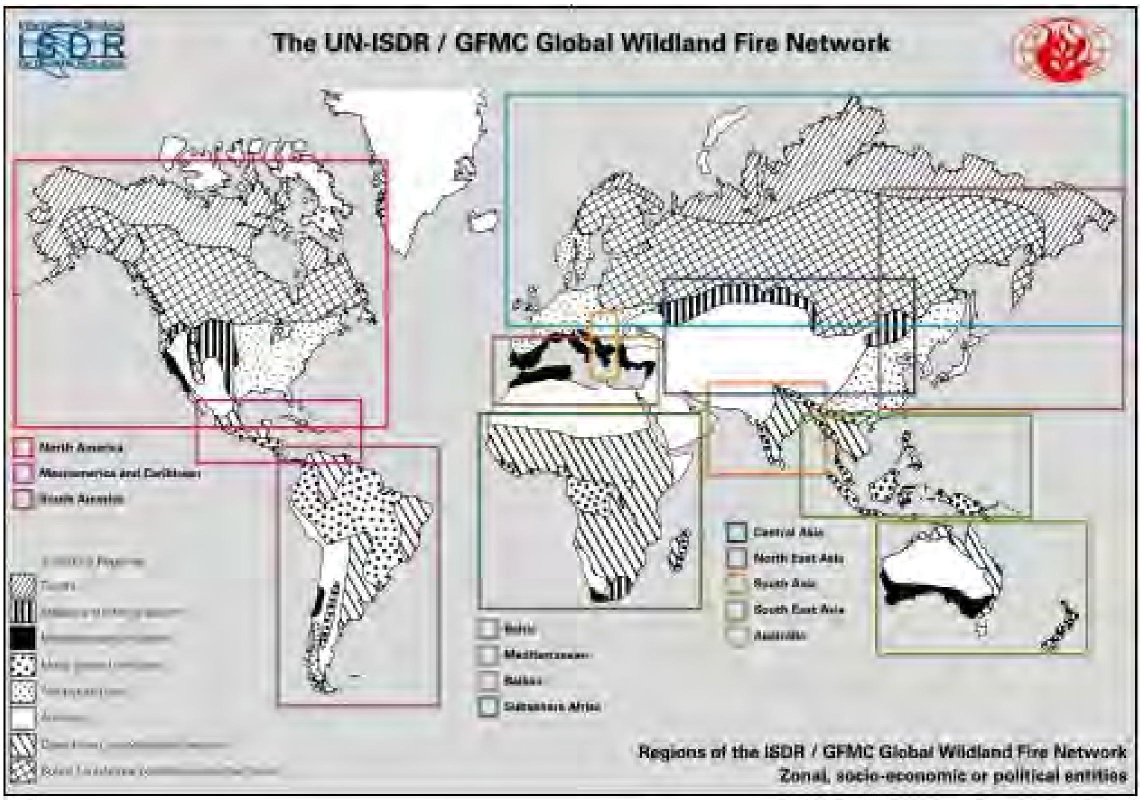

Figure 1. Regions within the UN-ISDR/GFMC Global Wildland Fire Network, from http://www.fire.uni-freiburg.de/GlobalNetworks/FAO-COFO-GFMC-March-2005.jpg.

Note the substantial variation in size of the regions. Some countries are members of multiple regions. The largest regions may include a vast range of climatic conditions and ecosystems, which define the biological and geophysical nature of the fire management problem. However, the regionalization described by the Global Wildland Fire Network provides an initial framework for organizing fire agrometeorology services, where those services are desired but either do not exist or are unacceptably deficient. In any case, a fire weather support function must be tailored to customer needs for information, which may also vary considerably from region to region.

Table 1. Regional memberships in the Global Wildland Fire Network, as suggested by the Global Fire Monitoring Center. Not all memberships are formalized.

Region	Countries Included in GFMC Grouping
Southeast Asia	Indonesia, Malaysia, Philippines, Thailand, Cambodia, Lao, Myanmar, Singapore, Vietnam
North East Asia	China, Japan, Korea, Russian Federation
Sub-Sahara	Benin, Central African Republic, Cote d'Ivoire, Ethiopia, Ghana, Kenya, Lesotho, Madagascar, Mozambique, Namibia, Senegal, South Africa, Sudan, Zambia, Zimbabwe
Central Asia	China, Kazakhstan, Mongolia, Russian Federation
Baltics	Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Norway, Poland, Russian Federation, Sweden, Belarus, United Kingdom
Southeast Europe	Albania, Bulgaria, Croatia, Macedonia (Former Yugoslav Republic)
Mediterranean	Albania, Algeria, Croatia, Cyprus, Greece, France, Israel, Italy, Portugal, Spain
North America	Canada, Mexico, United States
Mesoamerica	Mexico, Costa Rica, Guatemala, Belize, El Salvador, Honduras, Nicaragua, Panama, Cuba
South America	Argentina, Brazil, Colombia, Chile, Ecuador, Paraguay, Peru, Uruguay, Venezuela
Australasia	Australia, New Zealand, Fiji

Weather Information Requirements for Fire Management

The weather information requirements for fire management essentially depend on the level of sophistication of the fire management organization. The United States has developed one of the most sophisticated fire weather information systems in the world; because the supported fire management organizations have varied and complex data needs that span a broad range of temporal and spatial scales. Federal fire management planning functions consider the spatial variability of wildfire potential on continental and seasonal scales, usually well before the start of fire season. During fire season, fire management focuses more on regional and local scales and diurnal to daily trends. When a wildfire occurs, planning drills down to the immediate environs of the fire and its potential reach in a 2- to 3-day period, including the impact zone of smoke effects. Recently, fire weather prediction tools have routinely included mesoscale meteorological models that require supercomputing to support air quality and fire behavior prediction.

U.S. National Fire-Danger Rating System

On a national scale, the U.S. fire weather information requirements are driven principally by the National Fire-Danger Rating System (NFDRS) introduced by the USDA Forest Service in the 1970s (Deeming, et al., 1972, 1977). The basis for the NFDRS is a semi-empirical physical model that relates wildland fire characteristics to vegetation, topography, and weather (Rothermel, 1972). The system describes three attributes of a fire that comprise essential information for its management: ignitability, rate of spread, and energy release rate. Fire managers use this information to mitigate high fire risk and plan an appropriate response in the event of fire occurrence. Figure 2 illustrates the relationship of the fire characteristics to the variables that describe the fire environment, including weather.

Weather Relationship to Fire Potential

Figure 2 is a flowchart that shows how the NFDRS obtains fire characteristics (bottom tier of boxes identified as "Output") from the fire environment variables, mostly surface weather data (top tier of boxes, "Input"). Note that non-weather factors such as fuel type, topographic slope, and latitude are also required. Two types of weather data include an hourly observation of

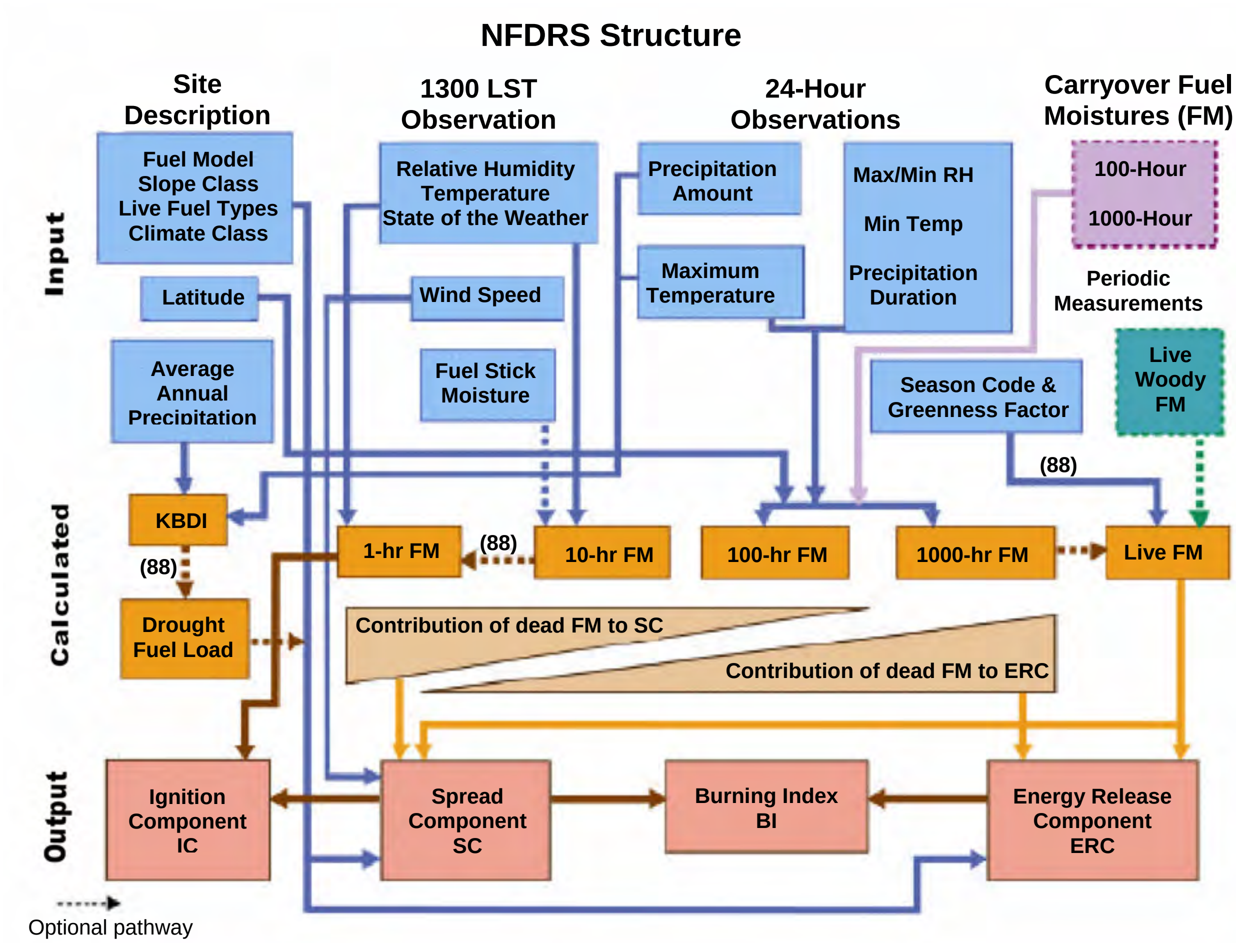

Figure 2. The U.S. National Fire-Danger Rating System (NFDRS) relates weather, fuel, and topographic characteristics to potential fire characteristics (Schlobohm and Brain, 2002).

weather conditions at 1300 Local Standard Time, nominally the time of day when fire potential is greatest. The second type of weather data is a 24-hour summary of weather variables, namely precipitation amount, maximum and minimum temperature and relative humidity, and precipitation duration (length of precipitation period). The system uses the data to estimate dead fuel moisture content in various fuel size categories. High moisture contents tend to inhibit the ignition and spread potential of fires. The heat release rate is also affected, because when moisture is present, it acts as an energy sink until it is vaporized.

U.S. Application of Fire-Danger Rating in Fire Management

Information from the NFDRS has various uses in U.S. wildland fire management (Schlobohm and Brain, 2002). For example, the Energy Release Component or the Burning Index may be used to determine the staffing level of a local unit. If the indices indicate high fire danger over an extended area, coordinated staffing and/or resource sharing might be considered. The Spread Component may be used in presuppression planning to determine an appropriate suppression response. In this case, good wind information is essential, because the Spread Component increases nonlinearly with wind speed. Many fire organizations use the NFDRS to inform the public of fire danger in recreational areas. The indices for any given day determine an adjective fire danger level, e.g., low, moderate, high, very high, or extreme. The public is educated about expected behaviors on affected lands, given the danger level.

Canadian and Australian Fire-Danger Rating Systems

Although the NFDRS was designed to be a national system, it is not uniformly applied in the United States. The NFDRS is sometimes criticized because of its complexity. Some fire organizations in the northeast favor the somewhat less demanding Canadian Fire Weather Index component of the Canadian Fire-Danger Rating System (see the Web site at http://fire.cfs.nrcan.gc.ca/research/environment/cffdrs/fwi_e.htm). The structure of the Canadian system is similar to the NFDRS, but it doesn't share the same theoretical underpinnings and data requirements (Figure 3). Note the sequential processing starting with weather data, from which fuel moisture content is estimated, which in turn yields fire behavior indices. Australia's McArthur Forest Fire-Danger Rating System not only shows similarities to both U.S. and Canadian systems, it utilizes the U.S. Keetch-Byram Drought Index (Figure 4). It might be possible to meet user needs with a subset of components from existing fire-danger rating systems.

Weather Data Requirements for Fire Management Support

The examples of the U.S., Canadian, and Australian fire-danger rating systems provide, at a minimum, the means to determine where the high potential ignition areas are, given the appropriate weather information. In all three systems, this potential is dependent on the moisture content of fine fuels, which in turn depends on air temperature, relative humidity, and either precipitation amount or occurrence. Once a fire starts, its potential growth rate can be estimated with the addition of wind data. The weather data requirements for these tasks are very similar to the data requirements for agricultural applications (Motha and Sivakumar, 2001).

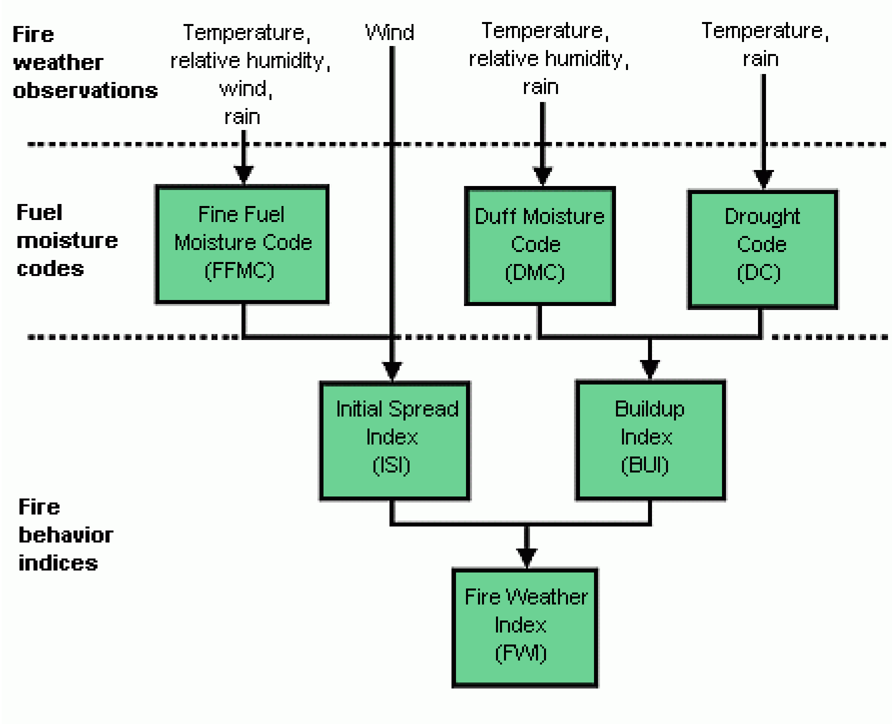

Figure 3. The Fire Weather Index component of the Canadian Fire-Danger Rating System is structurally similar to the U.S. NFDRS.

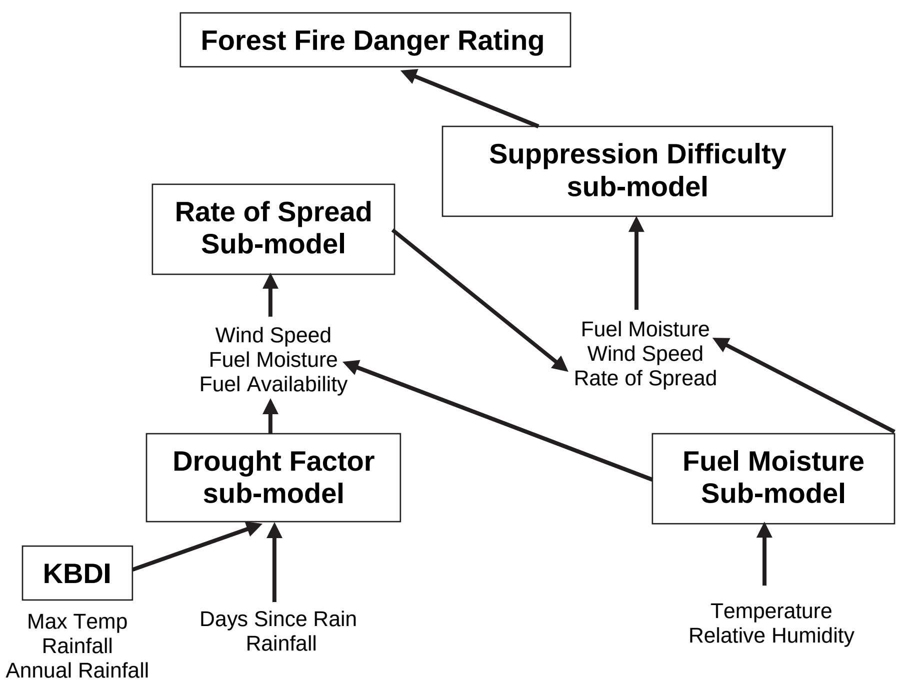

Figure 4. Flowchart of the data processing and sub-models of the Australian McArthur Forest Fire-Danger Rating System (San-Miguel-Ayanz, et al., 2003).
The flow proceeds from the bottom up, which is opposite from Figures 2 and 3.

A Fire Weather Forecasting System Prototype

The Experimental Climate Prediction Center (ECPC) at Scripps Institution of Oceanography features a fire weather/fire-danger prediction system co-developed with the USDA Forest Service Forest Fire Laboratory in Riverside, California. ECPC routinely generates regional and global fire weather forecasts for the United States on a daily basis (Roads, et al., 2001). It has also generated fire weather forecasts for other regions of the world, including Africa, South America, the Middle East, and Europe, on a trial basis.

ECPC determined that its weather models are relatively useful at predicting the Fosberg Fire Weather Index (FFWI), which is different from the Canadian Fire Weather Index. The FFWI is a modification of the NFDRS Burning Index (BI). Unlike the BI, however, the FFWI does not require fuel information, because it assumes the fuel characteristics of fine dead vegetation. The BI is calculated from a combination of the NFDRS Spread and Energy Release Components (Figure 2), and is a theoretical indicator of expected flame length.

The efficient distribution of the ECPC forecast products is not a trivial task. In the course of a day, numerous maps for different regions and different weather and fire-danger variables are generated. ECPC serves these highly perishable products with ease and efficiency through the Internet. Figure 6 shows a sample menu of items offered by ECPC on the Web.

There are many products offered by the ECPC on the Web, which are generated by variants of a spectral weather model originally developed by the U.S. National Weather Service. For each of the three weather models, there are forecast maps of over 10 variables, provisionally offered in 6-hourly, weekly mean, monthly mean, and seasonal mean timeframes. However, only a subset of these products is available at the present time, commensurate with user demand.

Summary and Conclusions

A global need exists for fire weather information to support fire management activities. These activities may differ in the level of sophistication from one organization to another, but they all depend on the best weather information available, commensurate with their needs. Various United Nations agencies, including the FAO and the Inter-Agency Task Force for Disaster Reduction, have instituted programs to facilitate a coordinated approach to fire management for the mutual benefit of all participants. Under the direction of the Interagency Task Force (IATF), the Global Fire Monitoring Center at Freiburg University has identified regional fire weather networks. These may be considered initially as regional fire weather networks for the purpose of starting up fire agrometeorology services, where none exist or current services are marginal at best.

In consideration of existing fire weather technologies, this paper has presented a limited view of three examples, the U.S., Canadian and Australian fire-danger rating systems. Nevertheless, these systems exemplify fire management technology at the highest level of sophistication, given their histories and degree of operational maturity. If fire-danger technology is desired where it doesn't exist, a startup fire weather service might begin with a subset of the U.S., Canadian or

Australian fire-danger rating system. The Canadian system has been successfully adapted in other parts of the world (e.g., de Groot, et al., 2005).

The fire weather forecasting system prototype at the Experimental Climate Prediction Center demonstrates the possibilities of instituting a versatile fire weather forecasting system that can be tailored to a variety of regional needs, given adequate resources. The modeling methodology that ECPC is testing makes it possible to generate fire weather/fire danger forecasts for virtually anywhere in the world, although ECPC is not an operational forecast center. Its primary function is research and development of weather models. Generation of fire weather/fire danger forecast products requires a full-time commitment, the dimensions of which would depend on customer requirements. Weather forecast centers with sufficient advanced computing resources are logical candidates to provide fire weather/fire danger forecasts. The Australian Bureau of Meteorology recently submitted a proposal to the World Weather Research Programme of the World Meteorological Organization inviting the opportunity to host a fire weather forecast demonstration project. The Bureau's experience in fire weather forecasting and support of a sophisticated fire management community easily qualifies them for the task.

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