GLOBAL OBSERVATION OF FOREST AND LAND COVER DYNAMICS

Report on the International Workshop on Advances in Operational Weather Systems for Fire Danger Rating

Northern Forestry Centre

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Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) is a coordinated international effort to ensure a continuous program of space-based and in situ forest and other land cover observations to better understand global change, to support international assessments and environmental treaties and to contribute to natural resources management.

GOFC-GOLD encourages countries to increase their ability to measure and track forest and land cover dynamics by promoting and supporting participation on implementation teams and in Regional Networks. Through these forums, data users and providers share information to improve understanding of user requirements and product quality.

GOFC-GOLD is a Panel of the Global Terrestrial Observing System (GTOS), sponsored by FAO, UNESCO, WMO, ICSU and UNEP. The GOFC-GOLD Secretariat is hosted by Canada and supported by the Canadian Space Agency and Natural Resources Canada. Other contributing agencies include NASA, ESA, START and JRC. Further information can be obtained at http://www.fao.org/gtos/gofc-gold

Summary

Efforts to develop fire danger rating systems have been driven by a concern about large fires, particularly those burning out of control and endangering human lives and property. Fires burn vegetative fuels largely as a function of weather conditions. Meteorological data are critical to forecast the potential for fires to begin and their behaviour once started. A third area of meteorological data needed relates to predicting smoke trajectories and dispersion. The World Meteorological Organization (WMO), the Canadian Forest Service (CFS) and others, have addressed this issue over the years by developing tools to evaluate and predict the effects of weather and climate on fires and their potential. The CFS, WMO, and the panel for Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD), in collaboration with a number of other agencies (see Appendix 1) organized the International Workshop on Advances in Operational Weather Systems for Fire Danger Rating at Edmonton, Canada from 14 to 16 July 2008.

The workshop reviewed of the history and legacy of fire danger rating, which showed that nearly every country in the world with fire-prone vegetation utilizes some form of a fire danger rating system. Fire danger rating research and operational use of fire danger rating systems has a very rich history which is well chronicled from the early part or the twentieth century onwards in many agency publications, textbooks and journals.

International reports from 19 countries across seven continents indicated a general consensus that approaches to FDR and weather information play a critical role in fire management decisions and both personal and public safety. The many benefits of establishing a FDRS include access to information, which can be used in at least the following areas of decision making: prevention, preparedness and detection planning, initial attack dispatching, suppression planning, and escaped fire situation analysis. Among the international reports from 19 countries there were a number of common challenges and needs identified to improve fire danger rating:

- The need for on-going calibration and validation
- Incorporate local knowledge of quickly-changing synoptic conditions in the context of a national system
- Making use of new forecast products
- Improve consistency between state/provincial, national, regional, global systems

Opportunities were identified during the workshop to enhance operational FDR in areas including; weather observations and networks; data management; weather analyses; approaches to defining and evaluating fire danger levels; additional indices of fire danger; and smoke forecasting and monitoring. Recommendations for further work are provided.

The workshop concluded with a review of existing guidelines for weather-based FDR, which have been prepared at several levels including: operational provincial and national fire agencies, and international guide on best practices. A key source of information is the WMO, through its Commission on Agrometeorology (CAgM). Since 1978 the CAgM has supported several symposia and produced reference materials on methods, procedures and techniques on the meteorological aspects of fire management and supporting information systems.

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1. Introduction

Efforts to develop fire danger rating systems have been driven by a concern about large fires, particularly those burning out of control and endangering human lives and property. Fires influence on, and response to, the changing global climate and, on a smaller scale, fire's effects on regional and local air quality have become international issues. As countries have sought to improve public health and safety, wildland and agricultural burning have attracted increasing attention as sources of concern and have become the target of regulatory attention.

Fires burn vegetative fuels largely as a function of weather conditions. Meteorological data are critical to forecast the potential for fires to begin and their behaviour once started. A third area of meteorological data needed relates to predicting smoke trajectories and dispersion. The World Meteorological Organization (WMO), the Canadian Forest Service (CFS) and others, have addressed this issue over the years by developing tools to evaluate and predict the effects of weather and climate on fires and their potential. One of the key WMO focus areas addressed from 2008-2011 is agrometeorological aspects of sustainable agricultural development. A key performance target is the production of operational guidelines for fire weather agrometeorology.

It is with this background that the CFS, WMO, and the panel for Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD), and in collaboration with a number of other agencies (see Appendix 1) organized the International Workshop on Advances in Operational Weather Systems for Fire Danger Rating in Edmonton, Canada from 14 to 16 July 2008.

1.1 Objectives of the Workshop

The workshop reviewed operational methods used in fire danger rating (FDR) systems from around the globe and discussed new developments in system design and potential enhancements. Workshop objectives included:

1. Review FDR approaches and role of weather information in fire management including concepts and terminology, purposes/requirements, limitations, etc.
2. Report on operational and prototype weather-based FDR systems from around the globe, including North America, Europe, Russia, Southeast and East Asia, Australasia, Latin America, Africa, etc.
3. Identify opportunities for FDR system enhancement in the areas of:
    - Weather observations and networks with a focus on access and adequacy of in situ data, use of remote sensing, etc.
    - Data management including collection, storage and retrieval, spatial processing and display, and dissemination.
    - Weather analyses including fire weather normals, and short and medium term weather forecasts.
    - Approaches to defining and evaluating fire danger levels with a focus on calibration and validation.
    - Additional indices of fire danger including factors such as live vegetation, curing, soil moisture, human behaviour, etc.
    - Smoke forecasting and monitoring that address emissions, dispersion, etc.
4. Assess the status of operational guidelines for weather-based FDR including:
    - Discussions with provincial and national fire information centres

- Review of the WMO Guide on Agricultural Meteorological Practices

The 3-day workshop was followed by a 2-day meeting of the WMO Commission for Agricultural Meteorology Expert Team on Agrometeorology for Sustainable Development (ET 1.3).

1.2 Expected Outcomes of the Workshop

The target audience of the workshop included meteorologists, fire scientists, practitioners and managers of wildland fire prevention and mitigation, environmental monitoring organizations and the earth observation community. Workshop participants (82) representing 32 countries are listed in Appendix 2.

Senior experts in several fields were invited to prepare state-of-the-art presentations to address the above objectives (Appendix 4). The programme (Appendix 3) was designed in such a way as to engage all the participants in discussions on each of these presentations and to develop appropriate strategies to enhance operational fire weather systems and their application in fire management.

Recommendations from the Workshop were considered at the ensuing meeting of the Commission for Agricultural Meteorology of WMO for transferring appropriate implementation strategies and related services. As well, the workshop contributed to the 10-year work plan of the Group on Earth Observations (GEO) towards development of the Global Earth Observation System of Systems (GEOSS).

1.3 Overview of Report

Following this introduction the report consists of five sections. Section two includes an introduction and overview of fire danger rating science and practice. Section three describes operational and prototype fire danger rating systems from around the world. Fire danger rating system enhancements in six topic areas are addressed in section four, while operational fire weather guidelines are addressed in section five. The report generally follows the workshop agenda provided in Appendix 3.

2. History and Legacy of Fire Danger Rating in Wildland Fire Management

Martin Alexander of the Canadian Forest Service gave a keynote address on the *History and Legacy of Fire Danger Rating in Wildland Fire Management.* (Presentation 2).

Nearly every country in the world with fire-prone vegetation utilizes some form of a fire danger rating system. Fire danger is regarded as a general term used to express an assessment of fixed and variable factors of the fire environment (i.e., fuels, weather and topography), including lightning and human-caused ignition risk that determine the (i) ignition probability, (ii) spread rate, (iii) control difficulty and (iv) impact(s) of wildland fires. Fire danger rating is in turn the process of systematically evaluating and integrating the individual and combined factors influencing fire danger in the form of fire danger indexes. A fire danger index is a quantitative indicator of one or more facets of fire danger expressed in a relative sense or as an absolute measure. The use of a fire danger rating system enables operational decisions to be based on quantified indices rather than relying strictly on experience and judgment and is therefore less subjective. Nowadays fire danger ratings are used in a whole host of fire management applications ranging from prevention planning to initial attack dispatching to prescribed fire planning and execution.

Fire danger rating research and operational use of fire danger rating systems has a very rich history which is well chronicled in many agency publications, textbooks and journals (e.g., Journal of Forestry, Fire Control Notes, Forestry Chronicle, Australian Forestry, International Journal of Wildland Fire). Although a comprehensive synthesis doesn't presently exist, this is something that perhaps the World Meteorological Organization should consider commissioning. Harry T. Gisborne, the first full-time fire researcher for the U.S. Forest Service, is generally credited with developing the first fire danger rating system in about 1928. Work in Canada by the government's forest service, lead by James G. Wright who was later joined by Herbert W. Beall, followed shortly thereafter. Australian bushfire research pioneers Alan McArthur and Harry Luke began to make their mark starting in the mid 50s. One of the distinct trends in the evolution and development of fire danger rating systems has been the desire for increasing applicability and commonality. Early on the focus was at the local level and this gradually expanded to unique regional versions (e.g., in 1954 there were nine distinct systems being used in the U.S.). Recognition of the need for a nation-wide system began in the late 50s and was realized in the U.S. and Canada in the early 1970s. Presently, there appears to be a desire for a single global level system.

In developing a fire danger rating system, the first issue is to formulate objectives defining what the fire danger rating system should be designed to do. Once that is determined, decisions can be made on the six basic issues of developing an operating system: (i) what to measure; (ii) when to measure; (iii) where to measure; (iv) how to measure; (v) how to integrate measurements; and finally (vi) how to apply the danger ratings. In this regard, Taylor and Alexander (2006. Int. J. Wildland Fire 15: 121-135) have identified four key scientific, technological and human elements that need to be considered in developing any fire danger rating system based on experiences with the Canadian Forest Fire Danger Rating System. These include:

1. Development of a modular system of fire danger indicators, or models of fire occurrence and behaviour in important fire environments through a sustained program of scientific research and based on relationships between fire weather, fuels, topography, and ignition sources.
2. Reliable technical infrastructures to gather, process, disseminate, and archive fire weather data and forecasts and fire danger predictions within operational agencies.
3. Guidelines, decision aids, and training for fire managers in the application of fire danger indicators appropriate to the needs and capabilities of operational agencies based on research and operational experience.
4. Fostering communication, sharing resources, and setting common standards for information resources and training through cooperation between fire management agencies and research agencies.

3. International Reports on Fire Danger Rating Approaches and Role of Weather Information

Operational and prototype fire danger rating systems are used around the world. Reports are provided below on weather-based FDR systems in North America, Europe, Eurasia, Southeast and East Asia, Australasia, Latin America, and Africa.

3.1 North America

Assessing the Fire Danger in Alberta: Application of the Canadian FDR System

Assessing the Fire Danger in Alberta: Application of the Canadian FDR System, presented by Nick Nimchuck (Presentation 18) provided insight into the development of the Alberta fire danger and weather network, the advent of the pre-suppression concept and application of the fire weather and danger data in fire operations and management, and technologies in data collection.

There are two methods of Fuel Moisture Evaluation; the time consuming and impractical direct method determines moisture content through drying and weighing a fuel sample, and the indirect method. The indirect method measures the factors that most influence fuel moisture content, and estimates their influence on the fuels.

The Canadian Forest Fire Danger Rating System (CFFDRS) was developed by the Canadian Forest Service as an indirect system to determine the fuel moisture content of dead fuels (forest duff layers). The Drought Code (DC) is a seasonal moisture code essential in over-winter precipitation monitoring.

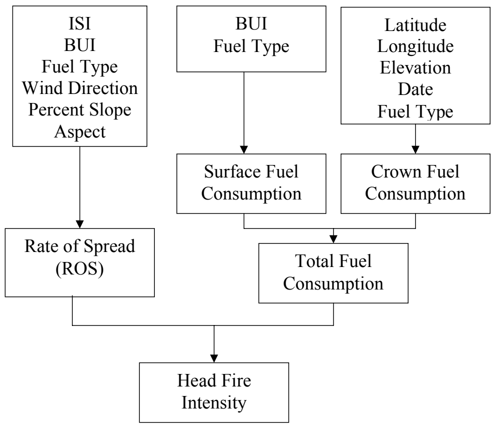
A case study of the Darwin Lake Project (Alberta) was presented as an example of determining values to build a fire danger rating system.

An effective FDR system must meet the following requirements: practicality, use simple inputs and daily weather observations with diurnal adjustments.

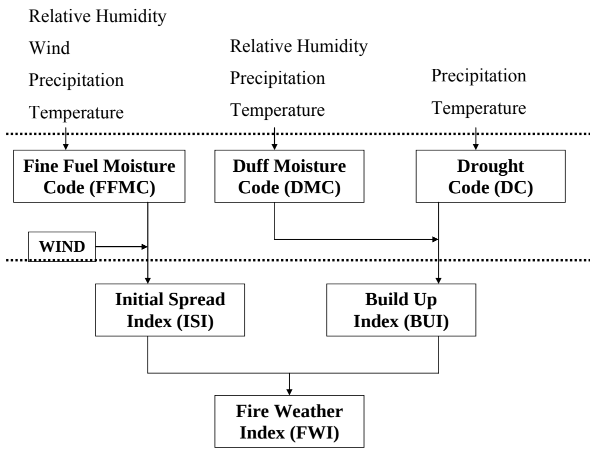
Remote Automatic Weather Stations (RAWS) provide data telemetry via satellite phone systems. Globalstar telemetry is used to track fire danger in Alberta and other provinces. Obstacles to actively monitoring fire danger conditions presented by geological factors such as inaccessibility to lookout towers may be overcome by means of helicopters and other technological advancements since the use of FDRS. Forecast fire danger indices provide guidance to pre-position resources, inputs for fire growth modeling with hourly and sub-hourly data, and heightens awareness of safety on the fire-line.

A Fire Behaviour Prediction System (FBP) links the FDR to specific fuels. Headfire Intensity (HFI), which largely indicates the difficulty of control, is the primary output of the FBP system. The FBP system predicts fire behaviour based on weather, the FWI components, topography, and fuel type. The same ISI value will produce a different rate of fire spread in different fuel types.

Head Fire Intensity:



Fire Weather Index System (FWI):



US National FDR: Past, Present and Future

Matt Jolly of the USDA Forest Service gave an introduction to the US National Fire Danger Rating System, decision-making processes and break points, and an indication of future directions of NFDRS in the United States, in his presentation *US National FDR: Past, Present and Future* (Presentation 17).

The First National System was developed in 1972. It was updated in 1978 and modified in 1988. The point-based system is based on approximately 2200 Remote Automated Weather Stations (RAWS) nationwide. All managers have control over their own stations.

Indices are calculated and applied to a broad Danger Rating area. Point values are interpolated to create spatial maps and distributed on the Wildland Fire Assessment System.

Uses of Fire Danger:

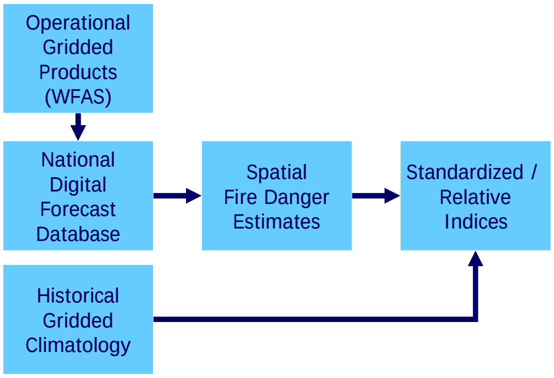
- Fire Danger Signs
- Public Land Closures and Burning Restrictions
- Logging operations limited
- Dispatch and Staffing levels
- Pre-positioning resources
- Situational awareness for firefighter safety
- Wildland Fire Use Decisions

Decision Points:

- Climatological Breakpoints
  - Compare current values to historical values
- Fire Business Thresholds
  - Compare historical fire danger values to fire occurrence
- Local managers decide the number and value of decision points using FireFamily Plus

FireFamily Plus Analysis Tools examine historical fire danger climatology to determine breakout points. They also calculate the CFFWI Indices such as variable season start-up initialization, and imports generic weather and fire occurrence data to collect indices.

The Gridded Fire Danger Rating System:



National Weather Service operational gridded forecasts are updated at least twice a day to provide three to six hour forecasts. The program is of a moderate resolution at 2.5 km; downscaled from 5 km. Forecasts for Alaska are currently in an experimental stage.

The North American Regional Reanalysis collects three hourly data to determine Fire Danger Climatology. It operates at a 32 km resolution in North America to collect data that includes all variables to calculate the US NFDRS. The standard NFDRS forecast is based on a climatological daily mean and standard deviation.

Future Enhancements include:

- Revisiting the current NFDRS structure and simplifying the system
- Creating a radiation-driven deal fuel moisture model
- Creating a new live fuel moisture model
- Initializing forecasts with gridded surface weather observations

3.2 South America

Operational FDR in Argentina

Carlos Di Bella of El Instituto Nacional de Tecnología Agropecuaria (INTA)/ Red Latinoamericana de Teledeteccion Incendios Forestales (RedLaTIF) presented *Operational FDR in Argentina* (Presentation 3).

Initially focused on fire issues, RedLaTIF is the Latin-American regional network of the GOFC-GOLD Fire Program, and is now also open to other topics.

Initial goals of RedLaTIF included;

- The compilation of a list of Latin-American experts working on remote sensing and forest fires. There are currently 75 members on the list of experts from the Latin-American region.
- Fostering the participation of Latin-American scientists in the global networks related to the GOFC/GOLD-Fire program; and
- Generating a thematic network for participation in fire-related projects within the Latin-American region.

SERENA is the Latin-American network focused on studying and monitoring natural resources. Created as part of the RedLaTIF network, SERENA is totally funded by the Science and Technology for Development (CYTED) program, with more than 13 Latin-American participant countries.

A principal goal of SERENA is to design and develop a continental processing system, using remote sensing and ancillary information, for:

- Fire detection
- Burned area quantification
- Fire risk estimation
- Local validation

There is a need for local validation, and for combining information from satellite remote sensing to the products of FDR. The goal is to develop a product for Latin-America that is uniform, accurate, and in real time.

National Fire Management Planning in Argentina

Also from Argentina was Fernando Epele of the Chubut Prov. Fire Management Service, who presented *Plan Nacional de Manejo del Fuego* (Presentation 4), a collaborative presentation with and on behalf of Maria C. Dentoni.

The Plan Nacional de Manejo del Fuego of Argentina focuses on coordinating suppression activities among fire management organizations, standardizing procedures, developing national training programs, and promoting new technologies in the area of fire danger detection, management and suppression.

Based on the Canadian Forest Fire Danger Rating System (CFFDRS), development of an FDR system in Argentina began in 2000. The same system is used throughout the country, and has been adapted to regional conditions. It is currently in the first phase of adjustments and implementation of an FWI. One of the many benefits of this process has been the observation of fire behaviour and the collection of data. Future developments include:

- Adjustment of codes and indexes in different ecosystems
- Development of models for interpretation in scrublands
- Development of danger maps
- Extension of the system to the rest of the country
- FBP development

Operational FDR in Peru

Maria Isabel Manta Nolasc presented *Operational FDR in Peru*, (Presentation 12) a collaborative work with Constantino Alarcón Velazco. The presentation provided an overview of forest fires in Peru, the theoretical basis of Fire Danger Rating, roles of weather networks, data and systems, the outlook of operational fire danger rating systems, applications in fire management, and collaborations and future developments.

Peru consists of three clearly defined natural regions: the Coast, the Andean mountains and the Forest. Wildlands and protected natural forest represents 42% of the total surface of the country, due to the Andes which crosses from South to North. The narrow Coastal region stretches for 900 km, with a wide range of altitudes throughout. This typography creates difficulties in combating forest fires.

The climatic characteristics of the country are the result of: a) The Andes, b) The cold Peruvian Ocean Current and El Niño ocean current, c) The Atmospheric Pressure Systems, d) The inter-tropical convergence zone, e) The jet stream, and f) The Frontal Systems. Thus, average temperature ranges from 12 to 26.9 ºC.

Annual precipitation is variable in relation to El Niño, but is generally low, and occurs seasonally along the Coast and Andes regions. These two regions are arid to semi-arid. The climate and soil produce extraordinary biodiversity. However, the conversion of the natural ecosystems into mining areas and land for agriculture has resulted in the destruction of 12 million ha of tropical forests. Slash and burn are common practices in the forest, as they are legal activities granted by the Agricultural Ministry. Fires are increasingly elevating in size due to climate change on top of eight dry months a year, El Niño, and population growth.

Annual burned area has increased drastically, from 30.7 ha in the decade of the 70s to 452.2 ha in the 80s and 11,762.2 ha in the 90s. The forest region however, as sustained an average affected area of 250,000 ha for the three decades. Large fires have taken place in Peru at Piura (1998, 1999), Lambayeque (2000), Satipo and Junin (2005). Forest Region: 250,000 ha of natural forest are burned yearly through slash and burn for agricultural and cattle purposes. Fire season is July thru October.

All forest fires in Peru are directly due to human error. Burning of land is a necessity for agricultural and cattle raising purposes. The rest of the instances are a result of negligence.

Evaluations of forest fire risk indexes were performed from 2000 to 2004. Particular interest was paid to those indexes that were applied at a national level, as well as those recommended by the WMO and other institutions. The theoretical base of Canadian Forest Fire Danger Rating System (CFFDRS), particularly the Fire Weather Index (FWI) was selected. Application of the FWI at a national level began in 2008 and is to be completed by 2011. Calibration and implementation of the FWI operatively in high-priority areas of the country such as Tumbes Pirua, Lambayeque, Junin, Cuzco and Apurimac will occur.

The National Service of Meteorology and Hydrology (SENAMHI) supports forest fire prevention efforts through the automated collection of observations and data. Its four subsystems can be categorized as observation, communication, processing, and diffusion subsystems.

In order to calibrate and implement the FWI operationally in high priority areas of the country, it is necessary to:

- Carry out programs of training, particularly for the SENAMHI personnel, in order to calculate and analyze the values of FWI;
- Elaborate on guides and procedures for the administrative regions;
- Promote the implementation of the Incident Command System at local, regional, and national levels; and
- Investigate the behaviour of the FWI depending on the meteorological variables, under the expected future climactic conditions.

Use of the FWI would allow:

- Issuing meteorological early warnings of forest fires for the whole country;
- Defining burnings calendar;
- Helping to implement programs of prescribed burning; and
- Collaboration on forest fire control.

Collaborations at the National and Regional levels include: Universidad Nacional Agraria La Molina (UNALM), Meteorology and Hydrology NS (SENAMHI), and National Institute of Civil Defense. Collaborations at the International Level is sought for strategic partners for the implementation and training of the administrators of Wildfire management in Peru.

Further developments include operation of a South American Meteorological Early Warning System.

3.3 Europe

Fire Danger Rating in the European Forest Fire Information System

Andrea Camia of the EC Joint Research Center presented *FDR in the European Forest Fire Information System (EFFIS) of the European Commission* (Presentation 7). He gave an overview of the JRC, EFFIS, Fire Danger Rating in Europe and in EFFIS, fire conditions and fire seasons in the European Union, the adoption of FWI and ongoing work, weather data and forecasts, operational fire danger rating in the EFFIS system, and new products and further improvements.

As a service of the European Commission, the Joint Research Center (JRC) functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national. The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies.

There is a relatively young tradition in FDR in the EU, and many different approaches are used. The fire danger rating module of EFFIS has been established as a unified platform for implementing selected national indices at the EU scale. The main motivation was having a common system to support preparedness and cooperation among EU countries. Today, the Canadian FWI has been adopted, with ongoing research and development underway. Tools from several sources, such as MeteoFrance and Deutscher Wetterdienst are used together to forecast Fire Danger.

The EC initiative started in 1998, and had a legal framework supported by Member States. JRC is a network of EC services (DG ENC, DG JRC) and Member State fire agencies. Scientific and technical infrastructure provides EU level information to support forest fire protection. A web based platform with different modules (effis.jrc.it) make the network easily accessible and readily available.

Two new products for forecasting FWI daily anomalies and FWI absolute ranking were introduced in 2008, both based on long term (50 years) computations of daily FWI values (ERA40 dataset).

Wildfire Weather Analysis in Croatia

Wildfire Weather Analysis in Croatia Using Numerical Modeling and CFFWIS Products (Presentation 5), was presented by Marko Vucetic. It outlined operational Fire Danger Rating in Croatia, climate change and wildfire danger, and a case study: fire weather analyses and numerical simulations using ALADIN/HR and MM5 models.

Some background information is necessary to understand the needs and obstacles in wildfire management in Croatia. A Central-European and Mediterranean country, Croatia consists of several distinct regions with diverse climates: the Pannonian Flat with continental climates; the Dinaric Alps with mountainous climates, and the Adriatic Coast of Mediterranean climates. The Adriatic Coast region is most vulnerable to wild fires, due to high temperatures, droughts, flammable vegetation, and an increase in population during the summer tourist season. The predominant vegetation in this area is pine trees and Mediterranean macchi (shurbland).

The greatest economic loss as a result of natural disasters is from drought. Seven percent of the total losses are due to fire damage that occurs most often on the Adriatic coast and islands. The highest number of forest fires and the largest burnt area occurred in the years when summers were particularly dry and warm, consisting of dry spells that lasted longer than 30 days.

Operational Fire Danger Rating in Croatia

Since 1981, a forest fire protection program using the Canadian Forest Fire Weather Index System (CFFWIS) has been run along the coastal region by the Meteorological and Hydrological Service as part of the Government Program of Open-Air Fire Prevention. The newer Canadian Forest Fire Behavior Predicted System (FBP System) has yet to be calibrated before being implemented.

The Canadian method is applied to the fire weather indices once a day, from June to September. Indices for a particular date are based on real-time meteorological data from 20 synoptic stations using the SYNOP report. The indices predicted for the following day are based on the products of the ALADIN/HR limited area numerical weather prediction model.

Both actual and predicted fire weather indices are sent automatically to the Fire Department of the National Protection and Rescue Directorate each day during the fire prevention season.

Actual fire weather indices are also publicly available on the web site of the Meteorological and Hydrological Service.

Seasonal Severity Rating (SSR) is the index used for assessment of forest fires. The mean SSR for the period 1971-2000 is remarkable greater than for the previous normal from 1961-1990, which indicates the wildfire risk increased in the last decade of 20th century. An SSR > 8 occurred in 10 fire seasons during the last 35 years compared to 9 fire seasons in the preceding 100 years.

To establish the regional impact of climate change on the potentially greater danger of forest fires in the Adriatic area, the linear trend of long-term time series of monthly severity rating (MSR) has been analyzed for two stations: Crikvenica (northern Adriatic, 1891-2005) and Hvar (mid-Adriatic, 1867-2005). Linear trend analyses of MSR indicate the possibility of the earlier onset of the fire season and spreading of high fire risk from the middle Adriatic to the northern Adriatic, particularly in July and August.

A case study of the fire on the island of Kornat that resulted in the biggest human loss in the history of fire-fighting in Croatia revealed two meteorological indicators – low-level jet and approaching of a cold front – point at the specific behaviour of a forest fire. Thus, a well predicted time of a passing cold front and numerical modeling simulation of vertical flow profile just before and after its passing could help to assess the fire risk and extreme behaviour of a forest fire.

Conclusions and Recommendations

Since 1981 the Meteorological and Hydrological Service of Croatia has been applying the old version of the Canadian Forest Fire Danger Rating System (FWI System) because the newer Canadian Forest Fire Behavior Predicted System (FBP System) still needs to be calibrated before being used (the problem is calibration)

Impact of climate change in forest fire danger in Croatia indicates the tendency of earlier onset of the fire season and spreading of high fire risk from the middle to the northern Adriatic.

Two meteorological indicators – low-level jet and approaching of a cold front – point at the specific behaviour of a forest fire. Thus, well predicted time of passing cold front and numerical modelling simulation of vertical flow profile just before and after its passing could help to assess the fire risk and extreme behaviour of a forest fire.

Developing a FDR System for the United Kingdom

Karl Kitchen of the UK Meteorological Service presented *Developing a FDR System for the United Kingdom* (Presentation 8), which provided an overview of wildfires in the United Kingdom, requirements and the legislative framework, application of the Canadian FWI, using numerical weather prediction forecasts, fuel models, and future work.

All fires in the UK are anthropogenic, as a result of BBQs, arson, and 'out of control' controlled burns. Lightning plays in insignificant role in the cause of fire.

A wide range of models were compared before the Canadian FWI was chosen. Reasons why the Canadian FWI was preferred inlcude:

- A sound scientific base of evidence
- Noticeably emphasises the high risk periods
- Identifies risk caused by prolonged drought
- Identifies risk due to combinations of high winds/low humidity/warm temperatures when drought is absent or not severe
- Validates well against known periods of fire risk
- Has been used successfully elsewhere in the world

The FWI has not been implemented to assist land managers or fire services. Access to the countryside can be restricted when fire danger levels are high.

A FWI of 42 is currently applied (with a 6 year return period), as an FWI of 30 (Extreme) occurs frequently, and therefore not considered exceptional. "Exceptional" FWI was identified using 30 years of data. Severity is assessed through frequency related to the Fine Fuel Moisture Code (FFMC).

The daily restrictions process is fully automated. There is currently no manual assessment of ground conditions.

Numerical Weather Predictions

Observations are only used for historical studies. All data from Numerical Weather Predictions (NWP) are for operational forecasts of more than five days. The current grid is 10 km^2 but a 4 km^2 grid is being tested. However there are significant issues with NWP model bias.

NWP / observational differences include:

- FWI values derived from NWP are very different
- Up to fourfold lower with NWP data
- Pattern extremely consistent (r^2 0.73)
- Consistent difference over 4 years of analysis
- Combined influence of different met variable biases

Models are currently being developed for different fuel types, specifically heather and peat. Fires from the heather shrub experiments were found to be self-sustaining when fuel moisture is less than 65%. Empirical models can predict fire behaviour from vegetation height and structure, wind speed, and fuel moisture. However a fuel moisture model is needed and empirical models are proving difficult to progress. From the peat model experiments with Edinburgh University, boreal peat was found to ignite at moisture levels below 135%. Modelling Smouldering Fire Ratings from weather data is a potential. The next step to these findings would be to continue the soil measurement campaign, begin laboratory work on peat drying rates, finally incorporating these findings into a peat soil moisture model and developing a peat fire severity model.

Operational FDR in Spain

Antonio Mestre of the State Meteorological Agency in Spain presented *Operational Fire Danger Rating System in Spain* (Presentation 16), a collaborative work by Mestre, M. Allue, C. Peral, R. Santamaría and M. Lazcan.

Forest fires in Spain are a critical issue. 48% of forest fires are intentionally set, 24% due to negligence and other causes, 7% from natural causes, 4% are re-ignitions, and 17% are from unknown sources.

The Meteorological State Agency of Spain has been in close cooperation with the Regional and National Forestry Services and Civil Protection Authorities since 1990, providing meteorological support for forest fires prevention activities. These activities are currently being undertaken in the framework of the State Committee of Operative Coordination (CECO) for forest fires. The CECO integrates several Institutions at state level: National Civil Protection, General Direction of Forestry Policy, AEMET, Ministry of Defence, Military Unit for Emergences and the Unit of Crisis of the Precedence of Government.

In Spain, fire prevention and fire fighting activities are the responsibility of the Regional Forestry Services of the autonomous communities. The role of State Institutions in this matter is subsidiary to that of the Regional Institutions. AEMET provides meteorological support and specific fire-weather services at both regional and national levels during the Forest Fires Campaign. The CECO annually establishes the date of the beginning and the duration of the Campaign at the national level, which implies the production of fire weather risk maps for the whole country during this period. Nevertheless, the production of weather-fire services at the regional level is mainly based on specific agreements between AEMET and the Forestry Regional Services.

Along the Campaign, specific meteorological predictions for fire prevention and fighting purposes are issued for the whole country. These forecasts are made by the predictors of the Regional Meteorological Centres of AEMET and are integrated in a specific fire-weather bulletin.

This bulletin contains the predicted values for D+1 of the different meteorological parameters which are relevant to characterize fire danger conditions and fire-spreading (2m-temperature, wind, relative humidity and probability of thunderstorms). It also includes the predicted values of the probability of ignition as well as the final risk value class (classified in four categories) using the Spanish forest fire index which is an adaptation of the NFDRS ignition component.

These forecasts are produced for a total of around 100 zones which cover the whole territory of Spain. The predicted values of the fire-weather index for the different sub-regions are integrated into a national fire danger map that is sent every day during the fire season, to the National Civil Protection Authorities and National Forestry Services.

	Wind Speed (km/h)			
Ignition Probability (%)	0-7	8-19	20-35	>35
0-20	0	0	1	1
30-40	0	1	1	2
50-60	1	2	2	3
70-100	2	2	3	3

The New Fire Danger Rating System

A new Fire Danger Rating System based on FWI is now being developed in the framework of an agreement between AEMET and the Spanish National Forestry Service. The goal of this new System is to improve and extend the meteorological support for wildfires prevention activities. In this context, a web-page specifically devoted to fire-weather conditions has been developed in collaboration with the NFS of Spain. The Fire Danger maps will be included in the page as well as other different graphic products containing basic meteorological and climatological information of interest in fire prevention and fire suppression activities, in particular:

- Soil moisture values in both superficial and deep soil layers and anomalies of these values in comparison with the mean climate values from an operational water balance
- Real time information from radar and lightning detection network
- Fine dead fuel humidity (assessment and predicted values up to H+36)
    - Forecasts of relative humidity and 10-m Wind up to H+72 (HIRLAM)
    - Maps of daily extreme temperature forecasts and probabilistic forecasts of daily precipitation exceeding a set of predefined thresholds (up to D+6)
    - Analysis and predicted values for different instability indexes
- Analysis and prediction of parameters of the Behave Simulation Programme (rate of propagation, heat releasing per unit of area, flame length)
- Indexes of fire consolidation (including dynamic and static risk-components)
- Specific products to provide meteorological support to the aircrafts which combat against the fires

The New Fire Danger Rating System: Fire-Weather Webpage

The new FDR system, currently in an advanced stage of development, is based on the automated production of gridded analysis and short-term predictions of FWI. FWI analyses are being produced through the use of the data from the Automatic Weather Station Network of AEMET. A bilinear interpolation scheme is employed to produce the gridded values for the different meteorological variables that integrate the FWI.

To improve the FWI analysis some activities will be undertaken in the near future, in particular the incorporation of real-time data from the high density weather station networks managed by the Hydrological Services and the use of a more sophisticated interpolation scheme based on a multi-regression technique that incorporates topographic features.

Short-term gridded forecasts of FWI are directly produced from the numerical outputs of the high resolution HIRLAM model. This model runs every 6-hours with a maximum time range of H+36. The HIRLAM spatial resolution is 0,05º. Both FWI analyzed and predicted gridded values are transformed into FWI mean area values for a set of predefined zones covering the whole country. FWI values have been calibrated using daily data of forest fire occurrences and total burned area. This calibration has been made for every Spanish province. From the results of the calibration study, the threshold values for the five risk classes established (low, moderate, high, very high and extreme) have been obtained for each province. This approach will make it possible to routinely issue maps of observed and predicted FWI-based wildfire risk classes for the predefined zones.

Future Developments

- Extension of the FWI forecasts into the medium-range. Production of both deterministic and probabilistic products using ECMWF outputs.
- Monthly and Seasonal outlooks.
- Development of a Fire-weather analogue system.

3.4 Eurasia

Assessment of a Forest-Fire Danger Index for Russia using NOAA Information (presentation 13) was presented by Ivan Csiszar on behalf of Anatoly I. Sukhinin, Douglas J. McRae, and Eugene I. Ponomarev. Also discussed are fire danger rating in Mongolia and Kazakstan.

Forest-Fire Danger Index for Russia using NOAA Information

Russia encompasses large remote forested regions. Remote sensing using satellite data can provide reasonable estimates of fire danger across Russia – no dense network of local weather stations are required to calculate fire danger. An algorithm has been developed that can assess current fire danger. Ambient weather conditions are derived from remote sensing data obtained from NOAA satellites (AVHRR and TOVS). Variables used in these calculations include surface temperature dew point, and precipitation.

Pre-processing Data

Satellite data is derived from NOAA/AVHRR, an imager product, and NOAA/TOVS, a vertical sounding system that collects data on characteristics for the near-surface atmospheric layer.

Preprocessing of data occurs in three stages: 1) acquisition and recording of the satellite signal, 2) radiometric data calibration and sectorization, and 3) geographical correction of imagery and cartographic projections.

Three AVHRR channels are involved in determining the Fire Danger Index. Channels 1 and 2 determine surface albedo, and channel 5 determines surface temperature. Correction of the index is based on precipitation information obtained from local weather stations.

NOAA-Satellite data is processed to determine Forest-Fire Danger Index. A modified version of Nesterov’s equation is used to estimate the fire danger index.

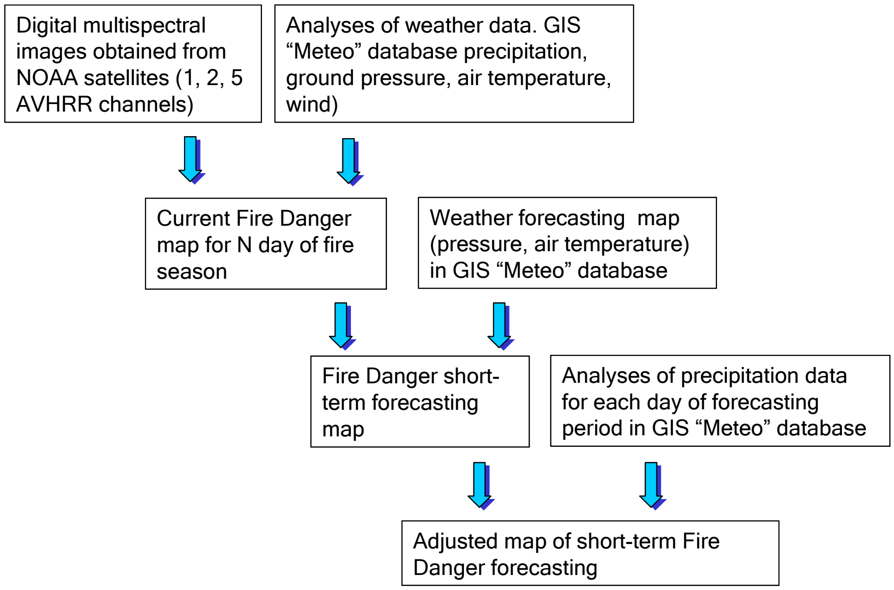
Processing

Pixel data is projected onto a given cartographic projection to generate fire danger index maps, which are updated daily. Radiometric parameters for the underlying surface from remote-sensing are used instead of actual meteorological parameters to estimate atmospheric near-surface layer parameters. NOAA-16/AVHRR channel 3 data are used for a correction factor for the vegetation index (AVHRR Channels 1 and 2 data) and provide a quantitative estimation of surface moisture. Cloud obscuration is mitigated using NOAA/TOVS instrument data, where microwave TOVS data allows for the restoration of atmospheric moisture and temperature parameters for overcast regions. Interpolation is done using a piecewise-linear approximation method. Linear extrapolation using the three nearest data points enables the restoration of a parameter value at any point using the TOVS data. There is a high correlation between NOAA measurements and temperature data recorded at the on-ground weather stations ($r = 0.7$, mean bias 4-6°C). Corrected TOVS data were used in the estimation of the fire-danger index.

GIS mapping

ARC/INFO 3.4.2 and ArcView 3.2 software packages are used for GIS mapping to produce maps of potential levels of fire behaviour and fuel consumption. Classes of fire danger are selected according to the range of actual fire-danger index values, based on those used by the Russian Fire Service. Further processing using GIS technology could combine the fire-danger maps produced here with forest fuel information.

Fire weather danger prediction is done based on the satellite data and GIS “Meteo” database.



Fire Danger Forecasts

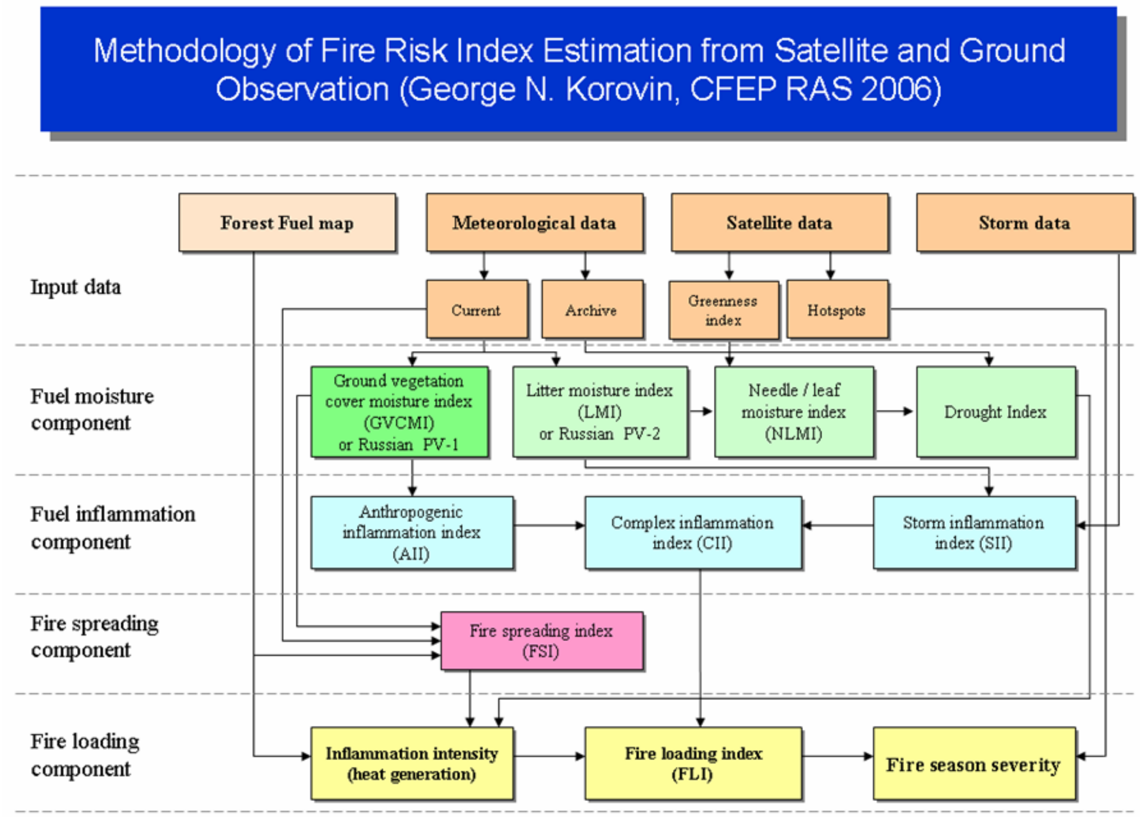
Forecasts are made to predict the occurrences and behavior of any future wildfires. Short-term meteorological forecasts provide short-term prognoses of air temperature and pressure over the periods of 12 to 168 hours. These forecasts are available as part of the world database GIS “Meteo”. Prediction maps show the upper limits of fire danger for Russia over the next 1 to 7 days. The prediction maps are updated on a daily basis, using actual precipitation recorded at on-ground weather stations. In the regions with registered precipitation, fire danger classes were lowered to 3 and 2 classes in accordance with the amount of recorded precipitation. The correction is applied daily throughout the forecasting period.

Validation

When analyzing data from 15 on-ground weather stations in the Krasnoyarsk Region during 1996-2000, a high correlation was found between our fire-danger index created using remote sensing data with the Russian Nesterov’s index (r » 0.9).

Russian Forest Fire Danger System (RFFDS)

The RFFDS, as part of Information System for Wildfires Remote Monitoring, is based on the complex meteorological index developed by V. Nesterov (FWI). The RFFDS characterizes a readiness of ignition of forest fuels as a conductor of ground forest fires. It incorporates evaluation of fuel susceptibility to fire as well as anthropogenic and natural drivers of fire ignition risk, fire spread rate, amount of released energy, fire danger, fire suppression difficulty, etc. for different forest conditions of Russia.



Predictive Early Warning Systems in Kazakhstan

The risk of fire occurrence is not driven by current weather conditions (temperature and humidity); rather, it is driven by biomass productivity of steppe ecosystems. Fuel buildup sustains large fires: a single burn can reach the size of nearly 1 million hectares.

Predictive Early Warning Systems in Mongolia

Integration of information and communication technology with the indigenous knowledge and wisdom and the best practices of the developed countries are considered key factors towards development and in-depth understanding, assessment and successful management to reduce disaster risks and vulnerability in Mongolia.

3.5 Asia and the Pacific

Forest Fire and Fire Danger Rating in China

Yonghe Wang presented *Forest Fire and Fire Danger Rating in China* (presentation 6) on behalf of Xueying Di, Zhan Shu, Guang Yang, of the Northeastern Forestry University, Harbin China.

Forest fires are a serious problem in China. For example, from January to April 24th, 2008, 10,230 forest fires occurred across the country, of which five large fires caused serious damage. During this period, 166 casualties were incurred in forest fires.

History of Forest Fire Management China

From the 19th century - 1950s:

- The Forest Law, 1914.
- The Forest Police Rule, 1943.

- "Songbei Province Interim Procedures", 1949.

1949 – 1976:

- 1949 - 1956: Set up and published forest fire protection regulations.
- 1957 - 1965: Established forest protection office in The Ministry of Forestry.
- 1966 - 1976: Stagnated due to the Cultural Revolution.

Modern Times:

- 1979 - Forest Law of Peoples' Republic of China
- 1987, a Historical Turning Point - the 1987 Great Xing'an Mountain Range forest fire.

Characteristics of Forest Fires in China

Forest Fires: 1950-2008

There are distinct differences in the occurrences of fires from year to year. The years which have more than 15,000 ignitions and more than 1,500,000 ha area burned are: 1951, 1955, 1956, 1961, 1962, 1972, 1976, 1977, 1979, 1987, with periods of 5-6 years and 10 years in-between.

May 6th, 1987 is noted as a milestone in forest fire protection. The event leading up to this date, was a massive fire in early May of that year. The fire resulted in 213 deaths, burned more than one million ha, and destroyed more than tens of thousands of homes and large amounts of equipment. As a result of this crisis, known as the "May 6th Forest Fire," the government of China began to place greater priority to forest fire prevention.

Comparison of fire data of 1950 -1987 and fire data of 1988 - 2007:

	1950-1987	1988-2008	Decline
Average of forest fire frequencies per year	15,932	7,754	51.33%
Average area burned (ha/yr)	947,238	93,402	90.14%
Average area burned (ha) per fire per year	59.5	12.0	79.74%
Average wounded per year	788	200	74.62%
Average deaths per year	110	54	50.91%

Fires were found to occur more frequently in the East and South, than the West and North. The presence of over 7.8 million ha of plantations in the South of China is one reason fires are more frequent in that region. Most of the fires are caused by agricultural activities. Factors that contribute to the large burned areas in the northeast and southwest forest regions are the frequent dry storms and windy conditions in the spring and autumn. Larch and white birch are populous in these regions, species that make fire management difficult, once a fire has ignited.

Causes of Fire

98% of fires are a result of human activity. Out of control mining fires contribute to 38% of the human caused fires. 57% are the result of fires started during memorial ceremonies, smoking, and children playing with fire.

Accumulation of fuel loads as a consequence of the development of intensive forest protection procedures also impact the frequency and intensity of fires. The fuel loads can reach 50 - 60 t/ha in some important forest regions, seriously threatening the forest.

Forest Fire Danger Rating

1950s – 1990s

The main activity in this period was importing and adapting forest fire forecast systems from foreign countries, specifically: the Synthetic Index Method from the former Soviet Union, the Moisture Method from Japan, and the Fire Danger Ruler from the USA.

Other activities include:

- Developing a Synthetic Index Method supplementing wind speed index
- Double Index Method
- 801 Fire Danger Ruler Method

1990s – 2005

This period saw the introduction of several procedures, such as the "Regionalization Level of Country's Forest Fire Danger" in 1992, and the "Weather Level of a Country's Forest Fire Danger" in 1994. Forest fire danger monitoring became more important through the use of forest fire danger rating and other regionalization methods.

Over 50 methods of fire danger rating throughout the nation have been either adapted or developed locally rather than a national standard. Nearly all of the methods have not been carefully calibrated. This result is forecasting that may not be reliable enough to be used by fire management agencies. There is also a lack of fundamental research on fuel moisture and fire behaviour in the nation.

Current Action and Future Activities

The central government has realized these problems, and in 2006 began to work out a national fire danger rating system incorporating advanced technologies. A national fire danger rating and emergency response center was set up in Beijing, with the personnel, hardware, and software resources necessary. It has been suggested to the National Forest Fire Prevention Headquarters to test the Canadian Forest Fire Danger Rating System as a FDR system China may adapt. ￥30 million Yuan (3.5 million US dollars) has been budgeted for research and development in the following areas:

- fuel models for fire danger rating and fire behaviour
- fire behaviour and fire suppression
- a national fire weather index system

This group works under joint collaboration with the National Forest Fire Prevention Headquarters and the Chinese Academy of Forestry working on these projects. Some personal communications have also been made with Canadian fire experts. Cooperation and support from foreign fire experts to projects of this group are welcome. Contact information for this group are online at www.nefu.edu.cn and alternatively at dixeying@126.com

Operational Fire Danger Rating (FDR) in Indonesia

Guswanto Abdul Gani of the Meteorological and Geophysical Agency (BMG) presented *Operational Fire Danger Rating (FDR) in Indonesia* (presentation 9), a collaborative presentation by Guswanto, Israr Albar of the Ministry of Forestry, and Orbita Roswintiart of the National Institute of Aeronautics and Space (LAPAN)

Indonesia has increased public-awareness activities, and stepped up detection activities as preventative actions taken to decrease occurrence of wildfires in Indonesia. Situation notification is relayed to relevant agencies and companies. Monitoring actions include providing daily indicators of fire hazards, critical for planning aerial surveillance and pre-suppression activities and enforcement. Mitigation efforts are effective, thanks to positioning resources where more fires are expected, determination of resource requirements based on potential severity of fire, and coordination of resources of relevant agencies and companies.

Current FDR operations

Spatial information has been provided by weather stations based BMG since February 2002, and satellite remote sensing-based LAPAN since 2005. Single weather station based-XLFWI calculations have been provided by Ministry of Forestry (MoF) since 2005 for 29 operation areas in 8 provinces. The MoF also plays a vital role in training local staff to operate FDRS.

Users of FDR include:

- MoF
- Ministry of Environment
- Disaster Management Agency
- ASEAN Secretariat
- CARE Indonesia

Operational features of FDR

The many advantages of Early Warning Information include:

- Improved monitoring information related to forest fire
- Increased understanding of underlying causes of fire
- Increased Law enforcement
- Increased investment by government and industry
- Increased capacity at local levels
- Stabilization of local government
- Increased community awareness and empowerment
- Improved information to support decision makers

FDR Development (1999-2002)

- Meteorological and Geophysical Agency (BMG)
- National Institute of Aeronautics and Space (LAPAN)
- Ministry of Forestry (MoF)
- Agency for Assessment and application of Technology (BPPT)
- Canadian Forest Service (CFS)

Pilot project areas:

- Riau Province
- West Kalimantan

Limitations

- Distribution of weather stations distribution are not fully supported for land/forest fire monitoring
- There is difficulty in keeping inputs for FDR consistent because of technical problems in areas such as weather data communication, data format, weather observation instrument, AWS sensors problem (MoF), etc.
- Adjustments for fuel type have not been developed
- The public is not yet familiar with FDR information
- The distribution of human resources would result in less support for law enforcement

Conclusion

Significant efforts are required to address the database interface requirements in order to sustain an effective Fire Danger Rating System. A consistent flow of weather data is necessary. FDR providers must work closely with fire management agencies to ensure useful outputs. The user agencies of FDR ought to utilize information provided, and should eventually augment meteorological data on a seasonal basis and high fire risk areas.

Operational FDR in Malaysia and Association of Southeast Asia Nations

Ahmad Zaki Mohamad Saad of of the Malaysian Meteorological Department presented *Operational FDR in Malaysia and Association of Southeast Asia Nation* (Presentation 10).

The Forest Fire and Haze Episode of 1997-98 has affected many aspects of life in Malaysia and Southeast Asia Nations. Health of the people, transportation, sport, education, and tourism are very serious sectors that have been impacted.

National and Regional Actions and Responses

The Association of Southeast Asian Nations (ASEAN) approved the need for an early warning system in the Regional Haze Action Plan (RHAP) in 1998 to prevent forest fires and the resulting haze through improved management policies and enforcements. One of the proposed systems for implementation as part of the RHAP is a Fire Danger Rating System (FDRS). Collaborations between the Canadian International Development Agency (CIDA) and Southeast Asian Countries were initiated in Indonesia, with the Canadian Forest Service (CFS) as an executing agency

The Malaysian Meteorological Department (MMD) provides information on location of forest fires (hotspots), prevailing and predicted weather conditions and if required, cloud seeding operations. Malaysian Remote Sensing Department (MACRES) provides relevant remotely sensed data. The Department of Environment (DOE) provides information on air quality and haze. It is also responsible for implementation and enforcement of open burning bans.

The purpose of FDRS is to protect life and property, serve to monitor fire danger, fire behaviour prediction, preparedness planning and as a guide to the policy makers.

Outputs of an FDRS can be used by many agencies related to forest fires and the environment to take mitigating and preventative action including, but not limited to the fire department, DOE, the agricultural community, MMD, Forestry Development and logging companies.

Mitigation and preventative actions include:

- Planning and allocation of fire suppression resources, including mobilization of fire-combating machinery and manpower
- Decisive bans to open-burning in high risk areas
- Remedial action taken, such as carrying out cloud seeding operations in fire-prone areas
- Planning in agricultural plot preparations

MMD decided to initiate an FDRS because:

- There is a need;
- It is simple and easy to use;
- Weather variables are available;
- Climate information/data may be used extensively; and
- GIS (ArcView software) is available.

Spatial Fire Management System (SFMS) is an information and display system. Software integrates fire science models into a geographic information system (GIS Platform – ArcView). The modules are interdependent.

The weather data for Malaysia's FDRS is collected from all MMD main stations throughout the country. As of October 2003, MMD also generates similar FDRS products for the Southeast Asia region. These are based on weather data received from meteorological stations in the region made available on the GTS. Daily weather is retrieved along with weather station locations to generate a point shape file. The weather (and possibly Fire Weather Index) grids are then generated using this shape file.

At present, the National Fire Danger Rating System (FDRS) is running operationally through the Malaysian Meteorological Department (MMD), the outputs of which are displayed on the MMD website. In addition to the Malaysian FDRS, the MMD is responsible for running the Southeast Asia Fire Danger Rating System (SEA FDRS).

The Canadian Forest Service (CFS) was appointed by CIDA as the initial executing agency to implement this project in the SEA region. CFS has been running the SEA FDRS from Edmonton, Canada. In September 2003, the CFS requested that the MMD take over this responsibility, running SEA FDRS operationally from MMD Headquarters.

Monitoring Stations of the MMD:

- 36 Principal Meteorological Stations
- 154 Climate/Auxiliary/Rainfall Stations
- 22 Air Pollution Monitoring Station
- 10 Radar Station
- 8 Upper Air Station
- 6 Satellite Data Receiving Station
- 165 Agrometeorological Station
- 8 Seismological Station
- 3 Atmospheric Ozone Monitoring Station
- 69 Automatic Weather Station (AWS)

A team of six is involved in the operation of SEA FDRS. It runs at 0030 UTC when all the weather data of SEA region has been collected. Just before 0300 UTC, the products will be displayed on the MMD website. At 0630 UTC, when all the Malaysian data goes into the MMD database, Malaysian FDRS will be generated and before 0830 UTC, the product will be displayed on the web. The system has been running smoothly thus far, and has produced useful products.

Key Assumptions and Limitations

Limitations of the FWI System are that it only accounts for weather influences on fire potential, and is based on a single daily observation time. The daily standard FWI system values represent the mid afternoon peak of fire danger. It is also based on empirical data, and uses a single point observation. The numerical values are relative, with no units, and require that a minimum 20 per cent change in value be present for different fire behaviour to be recognized. The FWI System assumes level terrain.

Another assumption in the system is that the component weather elements follow a more or less average diurnal pattern. If the weather suddenly changes, (e.g: wind picks up, wind calms, precipitation starts after the readings are taken) the values generated from the 1200h LST reading may no longer reflect the current fire potential.

In this case, new weather observations may be taken, and new codes and indices calculated to better reflect the current fire potential.

The Malaysian FDRS has been running operationally since January 2003 and SEA FDRS since October 2003. Hourly/daily weather data is collected from MMD Principle Stations and other meteorological stations in the region. Products of the system are available on the MMD website at http://www.met.gov.my. Further development depends on cooperation with other related agencies including MACRES, BOMBA, DOE, UPM and the Forestry Department.

Malaysia's action plan consists of collaborations with various regional departments, including: MMD, MACRES, BOMBA, DOE, the Forestry Department and UPM etc.

Operational FDR in New Zealand and Predictions of Fire Season Severity

Jim Salinger of the National Institute of Water and Atmospheric Research presented *Operational FDR in New Zealand and Prediction of Fire Season Severity* (presentation 11), a collaborative presentation by Jim Salinger and Grant Pearce, of Scion Research.

Three thousand "rural" fires burn about 6,500 ha every year as a result of escaped fires from land clearing burns. The number of fires is growing at a rate of 200-300 per year. An increase in arson has also been observed.

Major fires occurred during 1945/46 in central North Island (40,000 ha total, including 13,000 ha pine plantation); in 1955 Balmoral (Canterbury) (3100 ha pine plantation); in 1983 Ohinewairua (CNI) (15 000 ha of tussock + beech); in 1999 Alexandra (9600 ha in two grass fires); in 2000 Blenheim (7000 ha in two grass fires); and in 2003/04 Canterbury (major fires at West Melton, Flock Hill, Dunsandel and Mt Somers).

Hot, dry and windy climate combine to create a heightened fire risk in New Zealand. Fires can occur at any time of year, but typically through October to April.

New Zealand FDRS

The Canadian Fire Weather Index (FWI) System was adopted in 1980, followed by subsequent adoptions of other Canadian components of FDR. A core component of NZ FDRS, the Canadian FWI describes "probability of a fire starting, spreading and doing damage". The principal use of NZ FDRS is for notifying the public of the relative ease of ignition, fuel availability, fire spread and difficulty of control. Numerical ratings of fuel moisture content and fire behaviour potential are produced based solely on weather inputs. The FDRS of New Zealand provide a basis for Fire Danger class criteria for Forest, Grassland, and Scrubland.

Fire Weather Monitoring Network

Observations of temperature, relative humidity, wind speed and direction, and 24-hour rainfall are calibrated daily (1200 NZST) at 160+ stations across the country. MetService/NIWA oversees 45 stations, the remaining 115 overseen by Rural Fire Authorities. The data is collected and archived by the National Rural Fire Authority, and used to calculate and map daily fire danger ratings.

Seasonal Climate Prediction

Day-by-day weather detail and individual events can be predicted for 1-2 weeks in advance. The forecasts are determined by the weather today. Climactic forecasts are predictable for 3-6 months, providing an average picture and distribution of events. In contrast to weather forecasting, today's weather is almost irrelevant; the ocean is most crucial in climate prediction. Specifically, sea temperatures in the tropical Pacific Ocean have a large influence on New Zealand.

Impacts of Future Climate include changes in the average number of days of Very High and Extreme (VH+E) Forest Fire Danger (%) occurring over the full calendar year.

Summary

Based on the Canadian System, New Zealand's Fire Danger Rating system uses solely weather inputs to provide numerical ratings to establish fire danger class criteria for Forest, Grassland and Scrubland. NZ FDR operates and serves the needs of New Zealand well, and is a valuable daily input to the management of forest and rural lands. Over 160 stations are employed to allow daily monitoring of fire weather. Further research in the development of management tools is ongoing.

3.6 Africa

Operational FDR in South Africa: Lowveld FDR

Operational FDR in South Africa: Lowveld FDR; Advanced Fire Information System (presentation 14) was presented by Christopher de Bruno Austin

The Lowveld Fire Danger Rating System was developed from the McArthur grassland Model. It was first used in the 1970s in Rhodesia and was further developed in South Africa from the late 1980s. Fire Danger Indexes and forecasted indexes are supplied by Working on Fire to contributing land owners covering 3 million ha. The South African Weather Service provides early warning to the rest of the country using the USA NFDRS.

Davies Vantage Pro Automatic Weather Station is used in conjunction with PC Link (Software) and 12 weather stations to monitor a total area of 3 million ha. The weather stations are placed along the Escarpment 40-50 km apart at 6500 ft, in the path of the progression of the prevailing weather system, enabling tracking of the movement of the system.

Weather is measured at 10h00 to ensure a more accurate indication of expected fire weather. Data is relayed through cell phones by South Africa Cell Phone (Mobile) Service Provider. Two downloads with information on temperature, RH, wind speed/direction, and barometric pressure are sent via mobile text, fax, and email per day, at 10h00 and 14h00. Weather stations are programmed to take the temperature every 5 minutes, and display the average every 30 minutes.

WINWIS and Davis Data is stored on PCs and backed up on external hard drives. An average fire season lasts 5 months, approximately 153 days. Network dispatch based stations data is transferred through PC Links. Remote based weather stations have modems for data transfer via cell phones. 20 years of data has been captured.

Windows Weather Information System (WINWIS) is used to calculate the real-time Fire Danger Index (14h00), forecast the FDI daily and weekly, and measure the accuracy of the forecast against real time data. This software only uses 5 components in generating a forecast.

A private weather forecasting service provider supplies a 5 day forecast which is supplied to clients through Working on Fire. The weather is sent to the client at 10h00 and 14h00 via mobile text, fax, and email. FDI can also be calculated manually using a Hand Held Weather Measuring Device (Kestrel)

An agreement with a service provider ensures annual services in activation, calibration, maintenance, and mothballing of weather stations. All weather stations are removed during the summer season to reduce damage.

The following Fire Management Activities make use of the colour coded FDI Chart describing Expected Fire Behaviour:

1. Initial Attack Responses
2. Fire Suppression Standbys
3. Readiness Alert
4. Prescribed Burning Activities
5. Fire Awareness Program

Operational FDR in South Africa: Advanced Fire Information System

Karen Steenkamp of the Council for Scientific and Industrial Research (CSIR), presented *Advanced Fire Information System* (presentation 15), which was collaborative presentation with Philip Frost of the Meraka Institute.

The Meraka Institute's Remote Sensing Research Unit's (RSRU) mission is to conduct basic and applied remote sensing research for the advancement of scientific knowledge about the environment. Its primary goals are to develop world-class remote sensing scientists within South Africa, collaborate with partners to produce remote sensing products used for environmental management, publish in international journals, and improve remote sensing training at TEI's.

Advanced Fire Information System (AFIS)

The Council for Scientific and Industrial Research (CSIR) and Electricity Supply Commission (Eskom), South Africa's power supply company initiated the development of an Advanced Fire Information System (AFIS) in 2004. The main aims of AFIS are: i) detection (near real time fire detection); ii) assessment (burn area mapping), and; iii) prediction (Fire Danger Index). It serves as a research tool as well as an alert service for fire suppression, with a focus on Southern Africa. Multiple satellite sensors are employed to carry out these actions.

Eskom decided to collaborate in the development of the AFIS because as a dominant power supply company in South Africa, fire has a large impact on the service it can provide to clients. Eskom produces 95% of South Africa's, and 70% of Africa's electricity. Each year, Eskom experiences a substantial amount of down time on its transmission lines due to wildfires. Flames and the hot air from flames can cause flash-overs from line to line and from line to ground. Hot air reduces what is called the flash over potential. Flames are compared to air (even hot air) a good conductor. The flash over occurs in the form of a lightning bolt. A flash over will cause a 300 ms dip in electricity flow which can severely impact some machinery.

Continuous observation of Africa and Europe is managed via geostationary satellite, projecting images at 15 minute intervals at 4.8 km. Fire sizes of 5-10 ha can be observed.

AFIS products under development include an operational burned area mapping tool, Flashover Probability Index, a daily FDI product based on the Lowveld model and DB CRAS forecast data, and integration of 100 automated weather stations in South Africa into AFIS for 15 minute wind speed and direction updates. Dissemination of fire products via GEONETCAST's network of Eumetsat is also underway.

Operational burned area mapping:

- MODIS 500m burned area product (CSIR & Louis Giglio)
- Burned area products 2003-2007 over Eastern South Africa MODIS tile
- Each pixel provides Julian date of burn (i.e. at least 4 yr data record when each pixel burned)
- Operational burned area product ready in next 2 weeks

Development of a Flashover Prediction Model

A flashover prediction model has been developed to identify fires close to transmission lines with a high probability of causing a flashover. The model is based on a MODIS active fire product to detect fires close to power lines and numerical weather forecasts derived from the CRAS model. Wind speed, Wind direction, Air temperature and Relative humidity forecasts are used to predict flashover probability.

CIMSS Regional Assimilation System for MODIS Direct Broadcast Sites (DBCRAS)

CIMISS has configured a version of CRAS that assimilates products from the Moderate Resolution Imaging Spectrometer (MODIS). This version can be installed at MODIS direct broadcasting sites and assimilates MODIS products generated locally using IMAPP. DBCRAS domain using MODIS direct broadcast products from the antenna at the Space Science and Engineering Center, University of Wisconsin, Madison. The impact MODIS direct broadcast products can be seen as the Aqua and Terra satellites pass over the SSEC direct broadcast site.

GEONETCAST

CSIR disseminates products for areas such as daily active fires, daily FDI, and 16-day burned area. The FDI and burned area products will be available for Southern Africa in 2009.

3.7 Development of a Global Early Warning System for Wildland Fires

A Global Early Warning System for Wildland Fire (presentation 19) was presented by Tim Lynham, Natural Resources Canada and Ivan Csiszar, GOFC-GOLD, University of Maryland.

Recent wildfire disasters have caused global loss of lives, structures, and natural resources. There are many negative economic, social, and environmental impacts of uncontrolled wildland fire. Many of these impacts can be mitigated, and sometimes prevented, through early warning of wildfire disaster conditions. Early warning allows implementation of: fire prevention, fire detection, and resource mobilization before wildfire disasters occur.

A Global Early Warning System provides international coordination and sharing of: fire risk intelligence, suppression resources and expertise during times of wildland fire disaster. Fire Danger Rating and fire weather forecasting are the backbone of wildland fire early warning.

Global EWS for Wildland Fire, Basic Structure

- Global: international coordination of fire risk and activity information (current and future)
- Regional: coordination of regional fire information and resource-sharing
- National: Sets national standards (training, equipment); collects, processes fire and weather data, distributes to local level; direct national resource movements; fire permits, fire bans (centralized)
- Sub-National or Local: implements fire operations: prescribed fire planning, staff training, monitors fire/weather data, field level fire management decisions

Fire Danger Rating Products

Actual fire danger:

- Compilation of current national FDRs
- Continuous updating – approx. 6 hours

Forecast fire danger:

- 1 to 14 day forecast fire weather
- Global modeling of several national FDRs (FWI, McArthur, etc.)

Early Warning Products include 1 to 14 day forecasts of:

- Ignition, fire spread, drought (low, moderate, high, extreme)
- Fire threat (combined fire potential and current fire activity)
    - Smoke transport, C emissions, health warnings
- Fire management decision-aids
    - Prevention, detection, suppression planning
    - Decision criteria for resource-sharing agreements

Expected Impacts

The Global EWS for Wildland Fire will provide:

- Daily fire danger rating information to countries without operational fire danger rating systems;
- Forecast weather and global early warning information to all countries; and
- A common system with which to implement international resource-sharing agreements during times of wildfire disaster.

Future Developments

The next step is to secure funding. Most of the cost is related to in-kind funding for human resources. A three-year time frame is planned to implement system. If minimal funding, initially develop system for a specific global region (several potential areas).

3.8 Synthesis of International Reports on Operational FDR Approaches

The international reports from 18 countries across seven continents indicate a general consensus that approaches to Fire Danger Rating and weather information play a critical role in fire management decisions and both personal and public safety. The many benefits of establishing a Fire Danger Rating Systems (FDRS) include access to information which can be used in at least the following six areas of decision making:

1. Prevention Planning
    - Fire and fuel management modeling and planning
    - Early warnings of forest fires
    - Informing the public of impeding fire danger
    - Implementation of programs of prescribed burning
    - Collaboration in forest fire control
    - Regulating access and risk associated with public and industrial use of forest and rural areas by using:
        - Public land closures and burning restrictions
        - Restrictions on logging operations
    - Development of a burning calendar
2. Preparedness Planning
    - Level of readiness
    - Pre-positioning of suppression resources
    - Evaluation of fire behaviour potentials, to establish a situational awareness for firefighter safety, and guidelines for safe work practices

- Training for those in the field of fire analysis, suppressors, etc
- Prescribed Fire Planning and Execution, including smoke management

3. Detection Planning
   - Lookout staffing and aircraft scheduling and routing
4. Initial Attack Dispatching
   - Prioritizing of targets for air tankers and ground crews
5. Suppression Planning
   - On active wildfires (including short-range predictions of fire behaviour and growth)
6. Escaped fire situation analysis (including long-range projections of fire growth and behaviour)

The common features between the FDR systems reviewed include:

- There are few technological hurdles, most are human resources and capital
- There is a need for standardization of fire danger rating systems
- Common emphasis on simplicity
- Spatial fire danger displays predominate
- Newer systems backed up by validation and local adaptation
- Broad range of expertise: fire and forest management, meteorology, remote sensing
- Well established distinction between fire detection and fire potential

Among the international reports from 18 countries there were a number of differences noted including:

- Differences between countries in their stages of development in areas such as:
  - Weather network
  - System calibration and basic fire research
  - Links to fire management activities
- A broad range of applications, including for example land closures in UK and resource pre-positioning in US and Canada
- Development of new systems vs. adoption of existing system
- Differences in weather data management procedures
- Differences in level of communication between FDRS operations and users

The following common problems and needs were identified:

- The need for on-going calibration and validation
- Incorporating local knowledge of quickly-changing synoptic conditions in the context of a national system
- Find a balance between the availability of automated fire danger information and the need for expert assessment
- Making use of new forecast products
- How to use remote sensing data for meteorological inputs

- Consistency between state/provincial, national, regional, global systems
- Reliance on experimental data sources (eg. MODIS)

4. Enhancing Fire Danger Rating Systems

Following the review of operational FDR systems from around the world, the workshop identified and discussed FDR system enhancement in the following areas:

1. Weather observations and networks
2. Data management
3. Weather analyses
4. Approaches to defining and evaluating fire danger levels
5. Additional indices of fire danger
6. Smoke forecasting and monitoring

4.1 Weather Observations and Networks

Discussions were co-facilitated by Richard Carr (Natural Resources Canada, Canadian Forest Service) and Antonio Mestre (State Meteorological Agency, Spain). Topics of focus included: network definitions, why a network is needed, instrument standards, access and adequacy of in situ data, interdepartmental communication, and remote sensing.

Weather in the Canadian Wildland Fire Information System

Richard Carr presented the background material described under “Breakout group focus”, then proceeded with Presentation 20, *Weather in the Canadian Wildland Fire Information System*. His paper focuses on weather data acquisition and processing in the Canadian Wildland Fire Information System (CWFIS), which provides daily information on Canadian fire danger, behaviour, and locations.

Forest Fires in Canada

35% of wildland fires in Canada are caused by lighting (higher proportion in the west); 65% are caused by people; 87% of the area burned is from lightning-caused fires, with most fire activity occurring in the boreal forest.

Canadian forest fire science began in the 1920s, the same period permanent manned lookouts were first in put in place. The Canadian Forest Fire Weather Index (CFFWI) system was developed and established in 1970s. Fire weather stations were first dedicated in Alberta 1940-1950, in Ontario 1963, Saskatchewan and the Yukon Territory 1985. By 1990, the Fire Behaviour Prediction (FBP) system was implemented, allowing for new fire dangers to be anticipated.

Canadian Wildland Fire Information System (CWFIS)

Daily maps and reports of forest fire conditions across Canada can be found on the Canadian Wildland Fire Information System (CWFIS), at http://cwfis.cfs.nrcan.gc.ca. The CWFIS also provides fire behaviour maps year-round and hotspot maps throughout the forest fire season, generally between May and September to aid public safety and awareness. CWFIS contributes to the development of data processing and fire weather forecasting techniques.

Weather Stations

Data from weather stations throughout the country are employed to generate products, and monitor fire danger conditions. The weather stations are owned by the Federal Government (800), Fire Management Agencies (800), and the USA National Weather Service (75). Placements of these weather stations require consideration of public safety, geography, boundary conditions and data sharing, amongst many other factors.

Weather Data Acquisition

Weather data used in the CWFIS is generally retrieved from internet archives using web harvesting software. Data from stations run by national meteorological agencies must be decoded, being in the raw report formats. The CWFIS decoding software, which has been developed in-house, uses symbolic letters and code tables appearing in WMO Publication 306 Part A. These decoders are currently being translated from Perl to C. Data from stations operated by provincial or territorial fire management agencies is in plain text format so decoding is unnecessary, although some processing is necessary to convert the data to the standard CWFIS input format.

Weather Observations Used

Hourly synoptic and rawinsonde reports are used to determine conditions in the upper air, temperature, humidity, wind speed and direction, pressure, precipitation, snow depth, horizontal visibility, and cloud cover.

These weather observations are used for:
- FWI and FBP
- Smoke dispersion products
- Drought monitoring
- Seasonal forecasting
- Insect, disease, and growth studies

Quality Assurance and Quality Control:
- Global maxima and minima
- Project initialization files have regional equivalents
- Temperature compared against latitude and seasonal estimate of maximum possible
- Auto stations ignored with sensors with known problems

Interpolation:
- Do stations provide data at correct time for index?
- Temporal
  - Linear
  - Station may have diurnal trend data
- Does station represent region of concern and fire behaviour?
- Spatial (IDW, kriging, spline [Anusplin], ...)
  - Temperature and relative humidity elevation correction are fairly easy to do in homogenous vegetation/terrain

Canadian Interagency Forest Fire Center (CIFFC) and Forest and Fire Meteorology Working Group (FFMWG)

The Canadian Interagency Forest Fire Center (CIFFC) coordinates the exchange of fire suppression resources between provinces, and between Canada and other countries.

- Forest and Fire Meteorology Community of Practice (FFMCoP):
- CIFFC's advisory committee on operational forest/fire meteorology
- Coordinate meteorological activities between members, CIFFC, and external agencies
- Representatives from provinces and territories, Parks Canada, CFS

- Improvements in observing practices, instrumentation, forecasting methods, software, data exchange
- Annual meetings feature agencies sharing developments; guest speakers

Projects coordinated include:

- Revised Weather Guide for the CFFDRS
- Wind adjustment vs forest instrument site clearing size
- Wind speed sampling frequency (2m vs 10m)

Concerns and Innovations

Concerns:

- How much automation is enough? Cost of manned?
- How can nations ensure data availability?
- Can we afford an operational system yet still perform necessary research?

Innovations:

- METAR/synoptic/upper air decoders follow WMO publication 306 Part A
- T/RH adjustment with elevation
- Precipitation based on rate derived from current weather description for regions without precipitation reports

Application to Global regions:

- CFFWIS has been adopted by many nations/regions
- CFS is currently running systems for Mexico, northern Europe /Russia
- Past experience adapting system to SE Asia
- Global and regional concerns (smoke, climate change, loss of resources, human safety)

FDRS for West Africa: The GOFC GOLD/WARN Initiative

Cheikh Mbow, Université Cheikh Anta Diop, Senegal, presented *FDRS for West Africa: The GOFC GOLD/WARN initiative* (presentation 21). Issues presented include: fires resulting from human, specifically agricultural activity; a need for a local scaled FDRS, and; language barriers that prevent a common understanding of concepts.

In response to a UN request and Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities in Disaster, a proposal for a Global Fire Danger Product was accepted for presentation at the third Early Warning Conference at Bonn, April 2006. This product will require the joint efforts of the WMO, BoMRC, BCRC, CFS, GOFC-GOLD, ECMWF, WWRP, U of Md) to provide a system where none exists, and complementing existing systems.

A sub-Saharan Africa prototype was presented November 2007 at the GOFC-GOLD Workshop on Requirements for Early Warning System in Africa, held at the University of Ghana.

Fire Early Warning System (EWS)

The three components of Fire-Early Warning Systems (EWS) are:

1. fire danger rating system,
2. fire risk assessment, and
3. fuels assessment.

The prototype will operate at the sub-Saharan Africa and West Africa regional levels as a contribution to the production of operational guidelines for fire weather agrometeorology by 2009.

A key activity to improve fire management is making better fire management decisions because using better information or fire intelligence. An exchange of fire information is required for better fire management decision-making. Mechanisms (metric) to make fire management decisions at various scales and levels should be in place.

Objectives for EWS at the Accra Workshop were to provide an assessment of the African requirements for such systems. A state of the art review of operational fire weather and early warning concepts was an outcome of the workshop.

Data Needs:

- Actives fires (free data available, ATSR, MODIS)
- Burnt area not yet available (MODIS products expected)
- Fire potential, fire risk, fire proneness, fire readiness: small knowledge available
    - Important for prevention, fire management, planning for fire management

Parameters to consider in risk determination are both directly (FMC, fuel, resilience) and indirectly (lightning, human, meteo, slope, emissions, properties, wood, recreation) estimated.

Considerations in establishing an EWS:

- What are the major causes of fires?
- Why/how do people use fire? eg, Cooking, heat, pastoralism, land clearing?
- Do fires often get out of control? How large do they become?
- Is uncontrolled fire a problem? Why? What does it threaten?
- How can you reduce human fire problems?

Human activities that account for severe forest fires are a result of using fire in clearing or preparation of land for agricultural and pastoral uses, and resource extraction. Consequences of these actions range from long term loss of soil fertility, erosion, and deletion of natural resources, to diminishing biodiversity with the loss of ecosystems.

Factors influencing fire intensity are:

1. Fuel – physical and chemical properties, fuel load, fuel cover, composition, humidity
2. Climate – temperature, air humidity, wind speed, atmospheric stability
3. Topography – aspect, slope, altitude, topography units

Other important parameters include: Fire weather, fire seasons, fire severity and types, fuel flammability (fuel type, fuel model), fire regimes.

Upon analysis of land cover maps provided by the JRC, and FAO eco-regions of Africa, productive areas of agriculture and pastoral lands were found to be most affected by fire. There is an ever increasing risk of fire risk with climate change. Rising temperatures in the Sahel, and declining rainfall means drier fuel, and heightened fire danger in these areas. Fire risk is again dependant on vegetation types.

Summary

Necessities recognized in conclusion to the Accra workshop are the needs to:

- conduct a fire risk assessment for West Africa, as part of the Fire-EWS for West Africa;
- conduct a fuels assessment for West Africa;
- review the current decision-support tools, and potential decision-support tools supporting other fire management activities (i.e., prevention, detection, pre-suppression planning);
- fund raise; and

- develop a communications plan so early warning information gets to the local community level.

Technical Requirements:

- Establish regional algorithms for fire danger rating for West Africa
- Development of the prototype Fire-EWS for Africa (with 3 modules: a fire danger rating system, a fire risk assessment, and a fuels assessment)
- Complete an operational coarse resolution fire danger rating system (FDRS) for Africa by CFS
- Fuel types assessment for West Africa
- Locate a host for the operational regional system
- Technical capacity building (GIS, calculation and use of fire danger information training should be given to selected technicians in country's key institutions; appropriate translation of concepts)

Suggested points of discussion included:

- Common understanding of fire danger, fire risk, fire vulnerability, fire readiness, fire proneness;
- Complexity of savannah mosaics: the fuel types characterization (based on land cover such as JRC, AFRICOVER)
- Meteorological networks (low density, functionality, data consistency, data quality, archiving)
- Capacity building within WARN (Thematic group on fire should be the 'victim')
- Development of the prototype in a given area or country as a test to be replicated within WARN workshops to other areas or countries of W-A.
- Scale of FDRS products: natural resources management at high local scale, while maps are produced at regional scales

Remotely-Sensed Fire Danger Rating System to Support Forest/Land Fire Management in Indonesia

Orbita Roswintiarti's presentation on *Remotely-Sensed Fire Danger Rating System to Support Forest/Land Fire Management in Indonesia* (presentation 22) brought fourth advantages of remote sensing (large area coverage, cost effective) while acknowledging limitations such as indirect measurements, clouds, and a complex processing system. Adapted interpretations of FWI codes and indexes were also explored.

Weather stations which are sparsely distributed make the use of satellite remote sensing data the best alternative for monitoring weather and fire danger. Local governments need FDR information at a local scale.

WMO Weather Stations:

- Indonesia -127
- Brunei - 2
- Malaysia - 27
- Singapore - 4
- Philippines - 59
- Myanmar - 23
- Thailand - 64
- Viet Nam - 21
- Laos - 4

Required inputs to the FWI System are: air temperature, relative humidity, 24-hour precipitation, 10-m wind speed, and the FWI calculations for the previous day. These outputs are ideally measured at 12:00 LST.

Qmorph – NOAA:

- Spatial coverage: 60.0°N-60.0°S (by 8 km and 0.25°)
- Temporal coverage: Dec 2002 – recent (every 30 minutes)
- Rainfall estimates are produced from the microwave observation of DMSP-13 (SSMI), DMSP-14 (SSMI), DMSP-15 (SSMI), NOAA-15 (AMSU-B), NOAA-16 (AMSU-B), NOAA-17 (AMSU-B), TRMM (TMI), AQUA (AMSR-E)

Tropical Rainfall Measuring Mission (TRMM) – NASA and JAXA:

- Spatial coverage: 50.0°N-50.0°S (by 0.25°)
- Temporal coverage: Jan 1998 – recent (every 3 hour and monthly)
- The estimates are produced in four stages;
  1. the microwave estimates precipitation are calibrated and combined,
  2. infrared precipitation estimates are created using the calibrated microwave precipitation,
  3. the microwave and IR estimates are combined, and
  4. re-scaling to monthly data is applied.

LAPAN website: http://www.rs.lapan.go.id/SIMBA

ASEAN Secretariat Haze-on-Line: http://www.haze-online.or.id/

GOFC-GOLD website: http://gofc-fire.umd.edu/projects/index.asp

Summary

Satellite remote sensing data has many advantages. It provides a comprehensive and multi-temporal coverage of large areas in real-time and at frequent intervals, and mapping at regular spatial resolutions. It is also cost-effective. However it has limitations; clouds may block land observation, data processing is more complex, and meteorological parameters are not directly estimated.

Fire Weather Program for the Province of Ontario

Mick Rice presented the *Fire Weather Program for the Province of Ontario* (presentation 23).

History of Forestry Stations:

- 1963 – 1pm Manual Observations began
- Early 80's – First portable Auto Stations (FTS)
- 1989 – Auto Stations with Telemetry (Solar)
- Early 90's – 10 Stations added in Far North
- Mid 90's – Expansion through Boreal Forest
- Minor Expansion of Network since 2002
- Early 2008 – 144 Stations (T, RH, Wind, Precipitation) plus 11 rainfall-only stations

Network upgrade plans underway includes the installation and testing of 5 GOES satellite dishes and hardware in 2008. The current GlobalStar network is not reliable enough for regular hourly observations. By the end of 2012, GOES upgrades are planned for 57 Automatic Weather Stations. Reliable land lines and data loggers are to be added to the remainder of the network.

Fire weather forecasts are only as good as the skill of the forecasters. The accuracy of the model outputs and the tools available can vastly improve predictions. Current model data and Forecast Productive Assistant (FPA), developed by Environment Canada, are available; however a good

Prog Tephi program is essential. A contouring program that can animate selected fields such as temperature, relative humidity, wind and precipitation that Daily Fire Operating Support System (DFOSS) data can be imported into, is needed for Nowcasting.

Synthesis of Weather Observations and Networks

The presentations were used as a basis for discussion within the topic of Weather Observations and Networks. The participants suggested that more workshops are needed to fully discuss weather observations and networks.

Remote Sensing was compared to Surface Networks:

- Hybrid systems: Methods of combining Remote Sensing data and data from surface networks. Hybrid systems may have operational applications, necessary to fill in gaps.
- Remote Sensing can be used for biomass observations.
- Quality and accuracy of remote sensing data (satellite and radar)

Manual and automatic observations were compared:

- Manual observations
  - Confidence in reports – great variability
  - Training of operators
  - Expense
  - More suited for certain data
- Automatic observations
  - Confidence in technology – regular recalibration of equipment.
  - Can take more frequent samples (e.g. minutes) – valuable for data archiving
- Representative Stations
  - Areas of coverage for surface stations (network density)
  - Denser networks required? Topology to determine density?
    - Portugal study: 5000 sqkm spacing. Fujioka, 1986.
    - See Manta et al paper (Portugal), 2002.
  - Keep it simple – develop networks for specific applications
  - Know the accuracy requirements of the application
- Sharing data between different networks.
  - Metadata – documentation of collection, processing, archiving.
  - More efficient use of data for different disciplines.
  - Data standardized across networks
    - Difference of sampling technique/instrument – non standardized
    - Disparity of networks (sophistication)– speed of communicating information: satellite may be quicker
  - Variation of standards developed depending on regions.
  - Changing Climate -- Effect on:
    - changing instrumentation needed
    - species duration
    - length of fire season, increased fire intensity
- Software
  - How to ensure knowledge and availability

4.2 Data Management

Discussions were facilitated by Rod Suddaby (NRCan – Canadian Forest Service). Topics were focused on FDR data collection, storage and retrieval, spatial processing and display, and dissemination.

Data Management in the Canadian Wildland Fire Information System: An IT Perspective

Rod Suddaby from the Canadian Forest Service presented *Data Management in the Canadian Wildland Fire Information System: An IT Perspective* (presentation 32), which outlined an overview and history of the Canadian Wildland Fire Information System (CWFIS), its components, features, and future projects.

The Canadian Wildland Fire Information System website provides current and historical national information including: Fire danger and behaviour, fire and smoke locations, weekly statistics, and links to provincial agencies. Situation maps and information provided by CWFIS support the operational response and emergency preparedness programs of NRCAN-RNCAN, the Public Safety of Canada, and CIFFC. Data is collected from 500 weather stations, transmitted via satellite.

CWFIS Products

National Fire Weather and Fire Behaviour - The CWFIS generates daily maps of actual conditions as well as 48 hour forecasts. Historical maps of fire weather and fire behaviour are available back to 1998.

Fire M3 – Hotspot Monitoring, Mapping, Modeling - Hotspot locations from MODIS and AVHRR satellite sensors are collected daily on a near real time basis. The hotspot locations can be further processed to provide fire perimeter estimates.

National Large Fire Database - A compilation of forest fire data from Canadian fire management agencies: provinces, territories and Parks Canada.

Daily and Weekly Fire Situation Reports - The CWFIS has partnered with the Canadian Interagency Forest Fire Center (CIFFC) to compile and present weekly fire situation reports. The reports are also generated on a daily basis in the event of a problem fire situation.

Emissions from Forest Fires – Modeling Fire Behaviour and Carbon Emissions - A joint NRCan project by CFS and ESS-CCRS.

Monthly Forecasts of Fire Danger for 2008 Fire Season - Forecasts are based upon CWFIS and Environment Canada's seasonal predictions. These contribute to North American seasonal outlooks and Canada's emergency preparedness plan.

Forecast Lightning Products - 24 hour lighting flash counts and probabilities are calculated using forecast data supplied by Environment Canada.

Components of CWFIS IT

Data Collection and Management – executed by the National Fire Data Warehouse, and CWFIS Datamart.

Data Processing – Daily fire weather, fire behavior and hotspot products, forecast products (fire weather/behaviour, lightning), and daily/weekly fire situation reports.

Data and Information Access and Distribution – Information is accessed and distributed through the CWFIS web site, and the National Forest Information System (NFIS)/CFSNet.

National Fire Data Warehouse is a centralized data warehouse for all national fire information. Data is collected from international, federal and provincial/territorial sources. Public safety/emergency emergency preparedness reporting as well as scientific studies and analysis are provided. It is accessed through the National Forest Information System (NFIS) and CFS Net. The National Fire Data Warehouse is the foundation of the Canadian Wildland Fire Information System (CWFIS).

Data Collection and Management

Interpolation and formula calculations are used to generate fire weather/behaviour grids. Hotspot maps are generated through analysis of satellite images. Statistical analysis of fire weather normals and anomalies are applied in Fire Growth Modelling.

The CWFIS Website contains a comprehensive online source of wildland fire information, current conditions, forecast and historical information. There were 100,000+ downloads of maps and data in 2006.

CWFIS Features

Features of the CWFIS are that most products have fully automated processing, open source software is implemented, and supports OGC and CGDI. It has been designed, implemented, and maintained by the WFIS team of 6 people.

CWFIS Future Projects

Future projects of CWFIS include:

- Fire Growth and Fire Occurrence Prediction. Information in the warehouse and data marts can be used to further develop fire growth and fire prediction models, moving from regional scale to national scale.
- Comparison of Current Conditions with Historical Normals. Warehouse data can be analyzed to try to answer a variety of questions, such as: how does this year compare with others in terms of fire danger?

Summary

The Canadian Wildland Fire Information System is a comprehensive source of national scale forest fire data and information that supports the operational emergency preparedness and response programs of Natural Resources Canada, and the Public Safety and Emergency Preparedness Canada. It aids further research and development of better decision support systems and tools for fire management agencies, and provides supplementary information for policy making.

The National and Regional FDR Data Management in Southeast Asia

The National and Regional FDR Data Management in SouthEast Asia (presentation 33) was presented by Guswanto Abdul Ghani. This presentation outlined FDR Data Management, its organizational context, FDR dataflow management, and transitions between database management systems.

Geographic Information Systems (GIS) produce FDR maps using a combination of many tools, especially software, for example: Catalogue Wx Stations, ArcInfo, Oracle etc.

The World Meteorological Organization (WMO) is an organization of the United Nations (UN) that standardizes measurement, reporting, and dissemination of meteorological and hydrological information. Eight technical commissions oversee eight major programs. Of most interest to fire management is the World Weather Watch program. The WMO headquarters is located in Geneva, Switzerland. There are currently about 185 nations with memberships.

There are 331 weather stations distributed in the member nations of the Association of SouthEast Asian Nations (ASEAN).

Weather Station Distribution:

- Brunei – 2
- Indonesia -127
- Laos – 4
- Malaysia - 27
- Myanmar – 23
- Philippines - 59
- Singapore - 4
- Thailand - 64
- Viet Nam - 21

There are three levels of national weather data collection in the Indonesian Meteorological and Geophysical Agency (BMG). Full parameter sets are reported in real-time to a global collection network by 150+ synoptic stations. Roughly the same set of stations are used for operational FDRS in Indonesia. Over 200 climate stations report daily basic parameter sets on a monthly/yearly basis. 6,000+ rainfall stations from collaborative organizations with BMG such as public works, and agriculture report daily rainfall on a monthly basis.

Desirable properties in a FDR Data Management Systems are: key entry capabilities, an electronic input option, a database model, methods of data extraction, quality checks on observation values, and associated metadata. Priority needs and user requirements need to be supported. Documentation, database management and monitoring, as well as security are issues of consideration.

Common types of meteorological data, such as METAR, Rawinsonde, synoptic and climatological data, as well as other data, such as pilot and ship reports, forecasts and warning must be managed and organized.

Metadata documentation and management entails data acquisition, entry, storage of a hard copy record and digital information, and archiving this information. Original data must be managed, and at times rescued. Exchange of, and access to data, administration, and monitoring are additional areas of concentration. Quality assurance and control must be maintained.

Integration with Other BMG/Agency Activities:

- Meteorological center, climate center, data center, FDRS, the internet and multimedia studios
- National and international institutions: MoF, Lapan, Bakornas PB, Pertanian, Pusdalkarhutia, NGOs, etc.

Considerations in choosing a FDR database management system include business needs, design of the required system, scalability, architecture, and technology. Database architecture considerations (normalization) include design considerations to limit data redundancy, data loss, and inconsistencies. A data model in use by the FDR database system is a potential. There are also computer hardware and software considerations, such as current situation analysis, functional solution design (size up requirements), the technical solution design, and system and service transition issues.

Other details of concern in making the transition from the previous system are: level of expertise required, preparation of metadata to be imported, and intensive testing of the new system.

Conclusions

The best practices of FDR data management with some emphasis on building knowledge and capacity in: (a) The phases and stages of managing computerized data; (b) Available database technologies and selecting an appropriate database; (c) Making the transition to a modern weather database system; and (d) Sustaining data management operations.

Data managers also need to be mindful of the principles for long-term FDR monitoring. The ability to maintain the continuity, homogeneity and, ultimately, quality of weather data is greatly influenced by how well observation networks and systems are managed.

One of the key technological decisions to be made is whether to take an existing FDR data management system design, and its associated software, or develop a tailored FDR data management using one of the RDBMSs that are available in the world today.

Weather Data for FDR in Southeast Asia

Ahmad Zaki of the Malaysian Meteorological Department presented *Weather Data for FDR in Southeast Asia* (presentation 34).

FDRS DATA

SYNOP data from meteorological stations in Indonesia, Philippines, Thailand, Myanmar, Malaysia, Vietnam, Laos, Cambodia, Singapore, and Brunei will be extracted through GTS. MMD will run a program to retrieve rainfall data from 0000 SYNOP at 0100 and 0300 UTC and room temperature, RH and wind speed at 0600 and 0700 UTC. All weather data and generated FDRS index and codes will be archived in Access Database. This will include archived data from 2003 to the present.Generated FDRS maps are kept for three months.

Forest Information Management Challenges in the Northwest Territories

Kathleen Groenewegen's presentation, *Forest Information Management Challenges in the Northwest Territories* (presentation 35) discussed network issues, fire perimeter mapping, values at risk management, fuel cache management, and EMBER business components.

Two headquarters offices and five regional offices are responsible for monitoring an area of 1,284,344.72 km^2 for forest fires, where approximately 44,000 Canadians reside. The challenge is increased by intermittently reliable network connections due to low - but improving - bandwidths.

Fire Perimeter Mapping

Challenges to fire perimeter mapping are limited base data, a large land base, reporting requirements, and the expenses in visiting all fires, which is costly due to the remote nature of the Northwest Territories. In addition, forest fires are a natural phenomenon, generally not 'initial attack' driven. It is difficult to estimate the severity of fires. Operational fire mapping standards applied to map templates, and GPS data collection standards aid in generating accurate and consistent information. Research in areas of remote sensing for extent mapping, and severity mapping through Quick Bird are areas of focus to alleviate these challenges. Other helpful actions would be management of fuel cache, and determining values at risk management.

Forest Management Information System

The Forest Management Information System provides Forest Resource and Wildfire Management information. The system is managed with SQL Server databases and ESRI ArcSDE 9.x. UML modeling is done through CASE tools, such as MS Visio Pro 2003. A font-end Wildfire Management module (EMBER) is currently under construction.

Fuel cache tracking in the Forest Management Information System will determine expiry dates, quantities available, spatial locations, and tracked inspections. This would duplicate fire management efforts, and inform managers and fire operations of fuel expiration.

Business components of EMBER are: finance management; resource management (personnel, fuel, training and certification); fire management; information read from Open Source Weather Systems; providing spatial displays and queries, and providing tracking and management of initial assessments, fire assessments, incident response plans, and fire close-out reports.

Synthesis of Data Management Issues

Discussion points revolved around the following questions: a) what are the key requirements in, and key components of a data management system (DMS)?; b) what are the issues and challenges associated with a DMS? ; and the topic of Metadata.

What are the issues and challenges associated with a DMS?

- Data Sharing (institutional constraints, traditional thinking)
- Changing technologies (software and data acquisition)
- Availability of institutional expertise
- Available resources (long term maintenance, skill)
  - Labour intensive – requires human resources
- Metadata

What are the key requirements/components of DMS?

- Data acquisition
- Data sharing/accessibility
  - Agreements in place
- Data entry, storage, archiving
- Quality control
- Security

Recommendations

- Make use of existing resources such as data sources, expertise and networks
- Use established international standards
- Determine expertise level to select software implementation, e.g., Open source vs. proprietary software
- Base system on current needs, keeping in mind a proper design will allow for future expansion
- Establish data collection standards and standard data model
- Develop a contingency plan
  - changing technology
  - lapsing data sharing agreements
- Share data
  - consider liability and related impacts

- Build in redundancy as required
- Data integration into other systems (others integrated into yours)

Metadata

- Get the source
- Build into the design process (before data collection)

4.3 Weather Analysis

Discussions on weather analysis were facilitated by Kerry Anderson (Natural Resources Canada, Canadian Forest Service). Francis Fujioka (USDA Forest Service), Brian Potter (USDA), Karl Kitchen (UK Met Office) and Peitro Ceccato (International Research Institute for Climate and Society; The Earth Institute). Topics of focus were: maps and analyses, vertical components, Numerical Weather Prediction (PNW) products, and seasonal forecasting.

Fire Weather Analyses and Forecasting: Grid Points to Consider

Francis Fujioka of the USDA Forest Service presented *Fire Weather Analyses and Forecasting: Grid Points to Consider* (presentation 25). Topics covered in this presentation were: weather data requirements for the US National Fire Danger Rating System (NFDRS), analysis and forecasting in the Wildland Fire Assessment System (WFAS), interpolation methods meteorological modeling, and points to ponder.

The current US National Fire Danger Rating System (NFDRS) descended from versions in 1972, 1978, and 1988. It is based on Rothermel's (1972) mathematical model of fire spread.

Interpolation Methods

Interpolation is used to estimate weather and fire danger variables on a spatial grid from irregularly distributed sampling points within the area of interest. The interpolant is usually a linear function of the observations. Interpolation can be deterministic or statistic.

Deterministic and Statistical Interpolation

Inverse distance-weighted interpolation (power -1 or -2) is an example of a deterministic method. Another deterministic method used for the monthly US fire weather forecast is the biquintic polynomial (a.k.a. Akima, TIN in ESRI GIS).

Statistical Interpolation

If the variable to be mapped has a random additive component, it can, under certain (stationary) conditions be interpolated statistically by *kriging.* Kriging minimizes the mean-square error of the estimate, given the functional form of its spatial auto-covariance

Data Assimilation (Holm 2003)

Data assimilation in meteorology is an analysis of the initial state of the atmosphere which combines time distributed observations and a dynamic model. The initial state, its analysis, observations, and the dynamic model are each subject to random errors. Variability in "accuracy" of different observations is no barrier to analysis, as long as good calibration data are available. Data assimilation algorithms utilize the respective covariance functions for each type of random error.

Points to Ponder

To the extent that weather modeling systems are available:

- Should the analysis of the initial atmospheric state be used to describe current fire weather conditions on a grid?
- Should predictions of future states of the atmosphere be used to describe expected fire weather on a grid?
- Should statistical methods of weather analysis (interpolation, data assimilation) be used to quantify errors for the fire management decision-making process
- Should statistical analysis be extended to grid other variables of interest in fire management? (e.g.: fuel moistures (dead by size class, live) soil moisture, drought indices)

Numerical predictions should include future states of other variables of interest that are functions of weather variables

Atmospheric Profile Representation in Fire Danger

Brian Potter of the USDA Forest Service presented *Atmospheric Profile Representation in Fire Danger* (presentation 26). Discussion following this presentation focused on the issue of vertical structure in terms of atmospheric temperatures' effect on fire danger and fire behaviour. Although available, we do not utilize the information and data we have on vertical structures to the full extent. Questions that arose concerned the factors such as the Byram wind profile, directional components of wind, ventilation index and speed profile of wind that influence fire behaviour and therefore fire danger.

Fire Danger: "Sum of constant danger and variable danger factors affecting the inception, spread, and resistance to control, and subsequent fire damage; often expressed as an index." -NWCG

The only FDR element incorporating any vertical atmospheric property is the Haines Index. This is not a "standard" part of NFDRS or CFFDRS.

Current Opportunities

To directly incorporate vertical elements of vertical structure into FDR calculations, elements that capture stability, wind shear, and moisture profile must be added. Methods of indirect incorporation are also by means of adding elements, in this case those that have an expected variability, such as temperature, relative humidity and wind due to vertical structure. Re-analyses of data from the National Center for Atmospheric Research/National Center for Environmental Prediction (NCAR/NCEP) and the European Center for Medium-Range Weather Forecasts (ECMRWF) contains a wealth of information.

Looking Ahead

Future considerations include: a) numerical forecasts; b) satellite input; c) coupled fire-atmosphere models; d) real-time and climatological analyses; and e) a method to capture the vertical structure from ensemble forecasts.

Errors in Numerical Weather Data and Their Impacts on FDR

Errors in Numerical Weather Data and Their Impacts on FDR Systems (presentation 27) was presented by Karl Kitchen. From manual observations, Automatic Weather Stations, NWPs, RADAR, to ensemble, seasonal and climate forecast, FDRs crucially rely on weather data. We know all data sources suffer from error, but by how much, and does it matter? Particularly in FDRs, weather data biases tend to compound the error over time. His presentation gave an overview of sources, understanding, and errors in numerical weather data, and management of these errors by understanding bias and correction techniques.

Numerical Weather Prediction (NWP)

Numerical Weather Prediction (NWP) data has many benefits:

- Allows predictions over large spatial domains
- Incorporates data from a wide variety of sources
- Data assimilation is the most advanced temporal and spatial interpolation technique
- More accurate than interpolating ground-based observations alone
- Allows predictions as well as analyses of the current situation

However, NWP data has errors and bias. Each NW model behaves differently, and bias can change with the forecast period, and as models improve. Spatial errors, particularly with RADAR data, can occur. It is imperative to assess sensitivity of any FDR against each numerical weather source. Adjustments to fire danger class boundaries must be regularly re-assessed when using operational numerical data of any kind. The question is how best can this be achieved?

Climate Forecast, Early Warning and response to Peatland Fires in Kalimantan, Indonesia

Peitro Ceccato of the International Research Institute for Climate and Society, The Earth Institute, Columbia University, USA presented *Climate Forecast, Early Warning and response to Peatland Fires in Kalimantan, Indonesia* (presentation 28). A project is under way to forecast 3-6 months in advance in the region of Kalimantan. Most fires are caused by human activities, such as brush burning for agricultural purposes. Fires are most frequent in the dry season, from June to August.

An FDR system is used to validate the product, and forecast the fire situation. Probabilities are based on 24 ensemble products. The problem exists in the soil and peat, as it is dead vegetation that is burning. MODIS however, would not pick up on the conditions of the soil/peat. An FDR system is used to validate the product, and forecast the fire situation. A statistical approach is used to validate the forecast globally.

CARE Indonesia funded the International Research Institute for Climate and Society (IRI) to create the Early Warning and Early Action Systems to manage fires in peatland regions. The IRI works in collaboration with Indonesia's Bogor Agriculture Institute (IPB), the National Agency for Aeronautics and Aerospace (LAPAN), and the Indonesia Meteorological and Geophysical Agency (BGM).

Synthesis of Weather Analyses Issues

Topics addressed in the Weather Analyses discussions inlcuded: Maps and Analyses, Numerical Weather Prediction (NWP) Products, Vertical Structure, Seasonal Assessments, and Uncertainty.

Maps and Analyses

Maps are becoming the standard for presenting fire danger rating. Current maps are being created using simple interpolation schemes. Recommendations inlcude:

- Calculate FDR from interpolated weather
- Move towards physical modeling and assimilation using mesoscale/NWP models
- Assimilation should include non-weather variables of interest to fire managers

Numerical Weather Prediction

NWP Products are readily available and are now being incorporated into fire danger rating systems. Recommendations include:

- Explore the use of ensemble products
- Recognize and acknowledge NWP errors

Vertical Structure

Impacts of the upper atmosphere on fire behaviour has been well-established, but poorly applied to fire danger rating. Recommendations include:

- Historical analyses can be done now to provide context
- Can be introduced into variability
- Direct or indirect incorporation

Seasonal Prediction

Weather forecast can be produced for next several months. Concerns identified inlcude:

- Who uses it?
- At what scale?
- Impacts of decisions based on predictions

Uncertainty

Uncertainty takes the form of error biases and variability. This was an all encompassing topic. Recommendations include:

- Acknowledge errors
- Be aware of transition points

4.4 Approaches to Defining and Evaluating Fire Danger Levels

Discussions on approaches to defining and evaluating fire danger levels were facilitated by Steve Taylor and Nathalie Lavoie. Topics of focus included FDR calibration and validation.

FDR Implementation and Calibration in the Alpine Region of Italy

Eva Valese of the University of Padua, Italy presented *FDR Implementation and Calibration in the Alpine Region of Italy* (presentation 36), outlining projects related to the FWI System in the Alpine Region, and approaches to calibration.

Of the 20 administrative regions, each responsible for its own fire management, only a few implement an FDR System. In the Northern Italy (Alpine Context), regions have already implemented, or plan to implement an FDRS. A sub-regional Alpine network, the GFMC and Alpine Space European Project is under construction, at both national and European levels.

The Civil Protection National FDR System is currently accessible only at the national level. It is in the testing phase.

Common Environmental Concerns:

- Snow cover and winter fires
- Complex terrain and continental gradient
- Heterogeneous forest ecosystems
- Land abandonment (land use change)
- Ground fires and persistent smouldering phase
- Boundaries regions
- Lack of fire culture – Landslides and floods are dominant concerns/issues

Implementation of the FWI in the Aosta Valley began in 1994, in response to concerns about the few but large wild fires in pine stands. The FWI system was chosen for its easy prediction models for critical needle moisture. FWI can be used to predict eruptive behaviour.

Crown fires were found to occur even when pine needle moisture levels are quite high (115% - 130%, depending on the type and age of the needle). Crown fire intensity increases when pine needle moisture decreases from 95% - 110%, depending on the needle type. This range is the critical live needles moisture.

Prior to 2006, fire danger was not monitored in the Veneto Region, after which, the FWI System was implemented. We needed to 1) find a simple way to spatialize the index, and 2) start an automatic and user-friendly rating system.

Preliminary Climatic Analysis included:

- Principal Components Analysis
- Interpolated by *Cokriging* method: elevation – latitude – distance from the sea
- Dataset: monthly min & max temperatures; monthly cumulative rains;
    - 62 meteo stations, 30 year data-series
    - 11 homogeneous areas
- Selection of 11 representative meteo stations (providing input data) / *Residual Analysis*
- Output: Web-accessible daily map of fire danger and table

12 Months Threshold Values:

- Highest Class levels should be changed to lower FWI levels
- Such difference depends on climate. Verona is closer to the Adriatic Sea, Aosta Valley in the most continental Alps (fall wind/fohn)

Conclusions

- A specific calibration is necessary for Veneto Region (NE Italy)
- Pilot dataset should be extended to get reliable results
- The test indicates that the methodology is suitable, however other methodologies should be taken into account
- The comparison between different methods could lead to better results, even when the amount of data is limited
- A comparison between all days/fire days/multiple-fire-days/large-fire days (90th & 97th pct)
- The next step will consist of merging data from winter months (fire season) into a more sound data set
- To simplify threshold danger levels (just one season)
- The continental gradient (distance from the sea) and threshold values
- Sensitivity of the Alpine Environment to climate anomalies (droughts, global warming) should be taken into account

Challenges

- Obtaining a landscape view of fires
- Improving and promotion of coordination between regions
- Promotion of a “culture of fire,” towards a multi-scale approach, and an “Alpine Forest Fire Rating System”

Statistical Modeling of Fire Risk

Statistical Modeling of Fire Risk (presentation 39) was presented by Francis M. Fujioka, of the USDA Forest Service. Topics covered ranged from: Approaches to fire risk assessment in the US Forest Service, WFDSS, modeling components, fire behaviour, weather, spread probabilities and modeling fire probabilities.

The USFS determined a need to modernize the decision-making tools used by line officers and incident commanders to manage wildfires effectively. The existing Wildland Fire Situation Analysis has been used for nearly 30 years. Decision-making tools ought to take advantage of advances in weather and fire behaviour modeling, geospatial analysis and remote sensing.

The annual cost of US firefighting has consistently exceeded $1 billion, the current average, since 2000, is $1.3 billion. From 1995-99, the annual average cost had been $500 million.

Wildland Fire Decision Support System (WFDSS)

The Wildland Fire Decision Support System (WFDSS) is a USFS work in progress, designed for use by other federal land agencies. This scalable decision support tool for land officers includes modeling systems to predict the fire spread probabilities and assess economic risks through FS-PRO and RAVAR. The tools required are estimated to cost more than $10 million.

Inputs to a fire behaviour model include: Surface weather, vegetation type (fuels), and terrain elevation. Variables for predicted weather include: air temperature, relative humidity, wind direction, wind speed, and precipitation amounts.

FARSITE

FARSITE, developed by Finney in 1993 is a fire modeling system based on Rothermel's fire spread model (1972). This modeling system integrates gridded weather, fuel, and topographic influences and simulates two-dimensional fire spread. Local fire spread is assumed to be elliptic.

FS-PRO Fire Spread Probability Computation Procedure:

- Locate weather, fire index data representative of incident
- Analyze fuel moisture, wind climatology
- Generate wind, fuel moisture time series by Monte Carlo methods
- Simulate fire spread for each weather scenario
- Compute fire spread probabilities from the simulated fire spread ensemble

Pitfalls in Quantifying Fire Spread Probabilities

Pitfalls in quantifying fire spread probabilities are that there are many potential sources of error that contribute to incorrect fire spread predictions. Some of these sources may be model(s) mis-specification, erroneous model inputs, and measurement errors. Other difficulties are the lack of data to model probabilities, and the complication of statistical analysis by spatial and temporal dependencies of data.

Framework for Quantifying Probabilities of Fire Spread Predictions (Fujioka 2002)

Fujioka (2002) developed a framework for quantifying probabilities of fire spread predictions, derived from comparisons of predicted and actual fire spreads - this requires fire growth data. The framework can be applied to any fire spread modeling system, but is limited to incident-scale, single, free-burning fires (continuous growth, no spotting, no suppression). Analysis accounts for observational errors, but does not attribute errors to sources; not a limitation for incident management.

Calculated Risk: Expected Net Value Change

Expected Net Value Change from Fire = Expected Benefits – Expected Loss

Summary and Recommendations

The USFS is developing a decision support system that assesses fire risk by modeling fire spread probabilities. The system is designed to support incident management, but could conceivably be modified for fire danger assessment (pre-suppression planning). Further research is needed to develop spatial/temporal probability models to simulate human caused ignitions. Given ignitions, weather/fire simulations can be used to generate probability surfaces for the area/time period of interest.

Use of the Fine Fuel Moisture Code in China

Yonghe Wang presented *The Adoption of the Fine Fuel Moisture Code of the Canadian Forest Fire Weather Index System for Forest Fire Danger Rating in Zhejiang Province, China* (presentation 38) on behalf of S. Yu, H. Jiang, and Y. Wang, M. Wotton.

The Fine Fuel Moisture Code (FFMC), Duff Moisture Code (DMC), and Drought Codes (DC) were evaluated for the forests in the province of Zhejiang. Relationships between fire ignition locations and the fire danger ratings at the locations were examined. Spectral analysis was conducted on the fire and fire weather indexes to look for possible periodicities in the data. Although the system was originally developed in Canada, based on Canada's cold weather and its temperate and boreal forests, the system appeared to work well for the sub-tropical and densely populated Zhejiang province.

Calibration of the Canadian Fire Weather System for SE Asia

Robert Field, University of Toronto, presented *Calibration of the Canadian Fire Weather System for SE Asia* (presentation 37), a collective work of Bill de Groot, Yonghe Wang, Michael Brady, Caren Dymond - Canadian Forest Service; Robert Field - University of Toronto; Orbita Roswintiari - Indonesian National Institute of Aeronautic and Space; Guswanto - Indonesian Bureau of Meteorology and Geophysics; Wardati - University of Riau, Sumatra, Indonesia; and Maznorizan Mohamad - Malaysian Meteorological Service.

SE Asia FDRS Project

The aim of South East Asia's Fire Danger Rating System Project is to enhance the capacity of resource management organizations in Southeast Asia to manage land and forest fires and associated haze through the development and application of a fire danger rating system. Select components of the Canadian Fire Weather Index system were calibrated to conditions in Indonesia and Malaysia, focusing on: i) ignition potential and difficulty of control in tall grass, and; ii) smoke potential. A combination of field studies, laboratory experiments, and historical analyses were used in the calibration.

Ignition Potential – Fine Fuel Moisture Code

Field studies in the province of Riau, Sumatra determines ignition potential using the FFMC. The identified relationship between fuel moisture in 'alang-alang' grass and FFMC is computed from meteorological observations. Laboratory studies are used to identify fuel moisture thresholds of 35%, below which grass becomes ignitable, corresponding to an FFMC of ~83. Ignition studies were compared with hotspot occurrences. 78% of hotspots were found to occur when the FFMC > 81, but this represented only 20% of all days.

Smoke Potential – Drought Code

At its most severe, the haze in Indonesia is worse than the worst conditions in the world's most polluted cities, by a factor of 5.

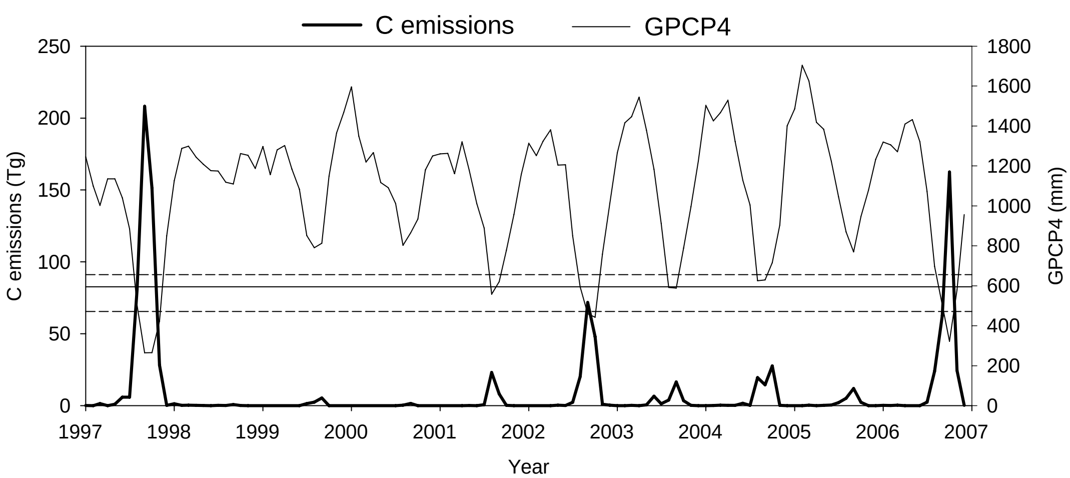
Serious smoke emissions occur when groundwater levels in peatlands drop, allowing organic soils to dry below their ignition threshold. The Drought Code is an indicator of moisture content in deep organic soil layers, and was selected as an indicator of smoke potential. Visibility at airports was used as an indicator of haze. Severe haze events were identified using the visibility at airports, and associated with DC > 350, compared to DC > 425 in Canada.

Simple Drought Monitoring

Precipitation over Indonesia is heavily influenced by SST anomalies in the Pacific and Indian Oceans

Seasonal C emissions are well-explained by rainfall totals from 1997 to 2006. Piecewise linear regression is used to estimate threshold below which severe emissions occur.

Comparison of Seasonal C emissions and rainfall totals (1997 – 2006):



Long-term Drought and Haze

Drought controls on haze in Kalimantan have only been in place since the 1980s. During this period, large-scale Indonesian transmigration to Central Kalimantan began, accelerating deforestation.

Summary

The Canadian FWI system required significant calibration to suit conditions in Indonesia and Malaysia. Initial FDRS implementation was designed to be as simple as possible. Further studies are required to better understand meteorological controls on moisture content and fire behaviour in: i) heavier surface fuels, such as logging slash; ii) open and closed forests, and; iii) drained and un-drained peatlands. Simple rainfall indices can be useful for interpretation of seasonal climate outlooks.

Synthesis of Approaches to Defining and Evaluating Fire Danger Levels

Goals for Fire Danger Rating Systems (FDRS) vary between countries and agencies, because of differences in space and time. The validation approach depends on the application. This in turn depends on what the most important problems are.

Other considerations in determining the application for an FDRS are the decision-making scale it is to be used in (fire danger vs. management scale); and the operational applications vs. scientific research. Many technologies are available, but are not always incorporated into operational systems. We must try to facilitate the use of more technologies in operational systems.

Challenges to defining fire danger levels are:

- A lack of historical weather data and fire records
- Coping with variations in vegetation/terrain
- Reinforcing/determining/implementing standards in data collection, ie: hotspots/fire location
- Understanding high risk conditions – we can use remote sensing to find the correlation between precipitation and fuel moisture content
- Historical reconstructions, and anthropogenic movements/trends – changes in legislation, population movements, etc
- Significant calibrations are sometimes needed, but simplicity must also be considered – some regions may experience fire danger values outside the normal range found in the country that developed the system.
- Understanding fuel moisture dynamics and fire behaviour in various material/fuel complexes

Experimental Fires

Experimental fires have been a research tool used in the past to better understand many aspects of real forest fires. Currently, cultural, social, and institutional barrier limit this practice. However, documenting existing fires (such as those resulting from agricultural land-clearing, or naturally caused fires) are alternative methods to researching live fires. The information can help calibrate FDRS in a new place of implementation, or to re-evaluate the FRDS currently in place. They can also be used to educate people on the proper use of fire. Case studies are useful:

- Corollary to operational experience
- Involvement of users helps ensure confidence and understanding of system
- Dissemination methods of how the fire danger/behaviour system works must then be developed.
- Countries with existing systems need to support regions lacking adequate resources.

Is a global fire danger rating system needed?

- As no global FDRS is yet in existence, it would be new or a hybrid of existing systems
- Ensemble systems
- Local needs would still need to be determined by local laws, but can be accommodated at a larger scale
- Identify way to provide data
- Categories of output values and scale of application differs (list)

Recommendations

1. Explore development of systems based on attributes of climate zones (vegetation, etc)
    - Catalogue main fuel types and models (can help both developing system in country where system originates and other regions where it is applied)
    - Need standard way of describing fuel types and common way of including new types

2. Explore reanalysis as alternative to weather observations (N. Am, European products?) probably works well in some regions. Remote sensing data can provide good temporal record.
3. Standards for collection of data e.g. hotspots – fire location
4. Case study database (See USA site "Lessons Learned" for way to catalogue case studies)
5. Build capacity by supporting e-infrastructure to provide access to systems and sites
    - Learn from existing education sites such as UCAR-COMET (need to devise way to facilitate site)
    - Open Source GIS tools
    - Organize practical training sessions-workshops
    - Translation
6. Institutional framework/voice for global/universal system

4.5 Additional Indices of Fire Danger

Discussions on additional indices of fire danger were facilitated by Emilio Chuvieco, University of Alcala, Spain, and Peter Englefield, Canadian Forest Service. Presentations addressed topics on live vegetation, curing, soil moisture, human behavior, etc.

Fuel Moisture Measurement in Fire Danger Ratings: The National Fuel Moisture Database and the Need for Fuel Sampling Standards

Edward Delgado of the Bureau of Land Management, USA presented *Fuel Moisture Measurement in Fire Danger Ratings: The National Fuel Moisture Database and the Need for Fuel Sampling Standards* (presentation 30). Developed regionally in the Easer Great Basin in 2006, the National Fuel Moisture Database (NFMD) expanded nationally in 2007. This web-based database of live and deal fuel moisture data is collected throughout the country. Data is available for use in fire danger and behaviour assessments, historical analyses, model inputs, validation of remote sensing technologies, and more. Fuel moisture data is tabular and graphically displayed.

Currently no national, interagency standard exists for data quality in the fuels program. Concerns have arisen regarding collection methods (old vs. new growth, leaf to stem ratio, storage and transportation, etc.), sample size (is it statistically valid? Is it dependent upon fuel types?), and cooking samples (type of oven; calibration standards; optimum temperatures; whether it is fuel dependant, etc).

Historical References

- Countryman and Dean (1979) - Standards for chaparral used in CA during 1980s. Separated old and new growth. Gradually faltered.
- Norum and Miller (1984) - Standards for Alaska fuels included lichen and mosses. Old and new growth handled differently. Designed for Rx but could be modified into permanent site sampling program.
- Rice (1989) - Similar to Countryman and Dean but expanded to desert environment.

- South Canyon IMR (1995) - Recommends a comprehensive live fuel moisture collection approach, combining elements of earlier work by Countryman and Dean and by Norum and Miller.
- Florida Division of Forestry (2002) - Details collection methods. Allows mix of old and new growth. Gives oven temperature recommendations.
- Pollet and Brown (2007) - Based on South Canyon IMR approach. Allows for mix of old and new growth. Developed for Utah BLM fuels program and adopted as a first attempt by NFMD. Modified versions used in Southwest and other GACCs.

Current Efforts

- Haase and Zahn (2008) - Developing national field guide for sampling live and dead fuels using standardized methods and procedures.
- Producing a sampling site plan that includes: site selection, documentation and installation; sampling frequency; determining sample size and number.
- Equipment requirements for collecting samples.
- Storing and transporting samples.
- Weighting and drying samples.
- Calculating fuel moisture.
- Comparison of quick-response ovens and convection drying ovens.

Recommendations

- Multi-discipline working group with an emphasis on fire environment develop interagency standards for fuels collection and sampling.
- Build on previous works as well as work currently underway at USFS/San Dimas Technology and Development Center.
- Obtain interagency acceptance and implement nationally.

Estimating Canopy Water Content from Airborne and Satellite Platforms

Susan L. Ustin presented *Estimating Canopy Water Content from Airborne and Satellite Platforms* (presentation 29) concentrating on topics: predicting wildfire risk, measuring canopy water content, operational CWV model, estimating fuel moisture content, early fire detection, and false positive reduction.

A key question is whether Fuel Moisture be estimated from Spectral Measurements? Numerous correlations between biochemicals and spectral indexes

$\boldsymbol{C = f(\rho(\lambda_1),\ldots,\rho(\lambda_\eta))}$, where

Water:

- Canopy Structure Index (CSI)
- Global Vegetation Moisture Index (GVMI)
- Relative Depth Index (RDI)
- Modified Normalized Difference Water Index (MNDWI)
- Normalized Difference Water Index (NDWI)
- Simple Ratio Water Index (SRWI)
- Water Band Index (WBI)

- etc.

Plant Dry Matter: Cellulose, Lignin, Nitrogen:

- Cellulose Absorption Index (CAI)
- Normalized Difference Lignin Index (NDLI),
- Normalized Difference Nitrogen Index (NDNI), etc.

PROSPECT: A Physically Based Leaf Radiative Transfer Model

The original model has been used many times. Among the major changes was that the early model attempted to identify N, lignin and cellulose. N has been dropped, and lignin and cellulose are combined into “dry matter”.

PROSPECT accounts for most of the reflectance from leaves. Water absorbs at 970, 1200, 1450, 1940 nm.

Research on the topic of physically based approach to estimating plant biochemicals: coupling RD models: prospect + sail using 18 Years of vegetation characterization was presented. An explanation of modeling CWC Using ANN Trained with PROSPECT – SAILH was provided.

Canopy Scale Validation: trained and validated from independent samples generated from PROSPECT-SAILH model. ANN training from different samples generated from the same canopy model (r2=0.98).

RBF networks reproduced PROSPECT-SAILH very well (r2=0.98), even though it did not use steps in each range to cover the entire variation space. The number of training samples was high. Further research should be conducted with this ANN to test it on real data.

Modeling of Regional Scales with MODIS:

- ANN trained with PROSPECT-SAILH to generate EWT*LAI
- ANN run on MODIS MOD09A1
- Validation with AVIRIS EWT

Relationship of CWC to Weather Parameters in Different Eco-Regions:

- Major drought in May/June
- CWC starts decreasing in June
- Only grassland shows a response to the successive increase in rainfall
- Same trend reported by Taylor (1974) in terms of flowering time

Comparison of CWC to FMC (USFS Data)

Some are good fits, while others are poor. The likely issues being:

- Representativeness of FMC to MODIS pixel area
- Differences in data collection, processing or other problems
- Characterization of vegetation type in relation to MODIS pixel
- Suitability of ecotype calibration of the CWC algorithm to the specific site

Operational Awareness

There is a need for near-real time fire detection capability. Estimates of CWC and FWC with Early Detection of Wildfire Events will i) reduce false alarms in early fire detection predictions; and ii) increase understanding of fire risk following detection of event.

Relevance of Remote Sensing and Socio-Economic Data in Fire Danger Assessment

Emilio Chuvieco of University of Alaca, Spain presented *What Else is Needed? Relevance of Remote Sensing and Socio-Economic Data in Fire Danger Assessment* (presentation 31), examining factors required for operational FDR, potential remote sensing and GIS, estimations of live fuel moisture codes, and human factors in assessment of fire danger.

Potentials of RS/GIS to define:

- Fuel:
  - Type: optical sensors (2D), Radar, Lidar
  - Slope: Lidar, Interferometric radar
- Human ignition factors
- Vulnerability:
  - Socio-economic
  - Ecological
- Validation:
  - Hot-spots
  - Burned area maps

Estimation of Live FMC

Both empirical fittings and simulation models are used in the estimation of live fuel moisture codes. Fuel properties inlcude:

- Biomass loads
- Live/dead material
- Vertical-horizon continuity

There are methods to map fuel types including:

- Reclassification of land cover/vegetation maps
- Ecological gradients
- Direct classification
  - Regional – Global scale (Landsat, AVHRR, MODIS)
  - Local – Radar - Lidar

Variables for Vulnerability Assessment

Socio-economic values such as houses, power lines, industries, wood products, recreational sources, and carbon sinks must be considered as well as ecological values including degradation potentials, regeneration potentials, soil erosion, and natural protected areas in assessing vulnerability.

Uses of remote sensing, for detection of hot spots (active fires) via: MIR temperature and night lights and burned area, permit validation and calibration of Fire Danger Rating.

- Hot spots: Stronger contrast, high frequency is required
- Burned area: longer persistency of signal, full size of the fire
- One concern is the bias towards large fires

Conclusion

Remote Sensing and Geographic Information Systems techniques will help combine weather data with fuel characterizations (moisture, types) and human factors to validate and calibrate FDR.

Synthesis of Additional Indices of Fire Danger

Discussions in the break out group *Additional Indices of Fire Danger* covered topics on digital evaluation models, fuel moisture content, fuel type maps, human factors, fire history (methods of integration, validation), and the question of what additional variables are more critical than others.

Digital Elevation Models

Digital Elevation Models such as Globe USGS DEM (1 sq km) and SRTM are simple to access and readily available. SRTM would complement moisture content estimations and fire behaviour predictions.

Live Fuel Moisture Content

MODIS CWC will be available soon. It measures EWT – ground validation data (FMC databases, National Fuel Moisture Database) – but not FMC (dry matter). This model is species and weather dependent. It requires common protocols, and an establishment of critical thresholds for grass curing and moisture of extinction.

Fuel Type Maps

Fuel type maps are a critical factor for fire danger estimation (ignition and propagation), but are not readily available. They rely mostly on reclassifying land-cover or vegetation maps – and indirect estimation. Different levels of detail for fuel types, and periodic updating of burned area maps are needed. Other uses of fuel type maps are for fire behaviour modeling, and fire effects assessment.

Human Factors

Human factors explain the spatial variability of fire occurrences in most countries. They are related to ignition potential, and vulnerability (fire impacts, values at risk). Some factors such as distances to roads, power-lines, camp grounds, and land use interfaces can be modeled through GIS analysis. Temporal trends were also observed.

Fire History

Fire histories of hotspots are detected by MODIS, ATSR and AVHRR; burned scars by MODIS, SPOT-Vegetation and Landsat; and fire perimeters by fire ignition points.

Validation Methods

Validation methods need to use an independent sample. Satellite data for hotspots and burned area are one method of validation. Risk and actual occurrence need to be differentiated. A consideration to be taken regarding calibration purposes is how dangerous it is; for validation purposes, how accurate it is.

Recommendations

Specific actions to take are:

- Implement DEM into FDR
- Common database of FMC ground measurements / RS estimations
- Generation of fuel type maps and fuel models
- Characterization of human factors
- Integrate historical fire occurrence

- Common protocols for validation

4.6 Smoke Forecasting and Monitoring

Discussions on smoke forecasting and monitoring were facilitated by Kerry Anderson and Orbita Roswintiarti. Topics of focus included modeling smoke emissions and dispersion.

Long-range Air Quality Modeling: The impact of Large Fires

Bryce Nordgren of the USDA Forest Service presented *Long-range Air Quality Modeling: The impact of large fires* (presentation 42), giving an overview of near real time satellite observations of fire – algorithm, validation, emissions modeling, plume rise modeling, and dispersion with "online" photochemistry.

Fire Observation – Algorithm

MODerate resolution Imaging Spectroradiometer (MODIS) Direct Broadcast (DB) is used for fire detection and burned area measurement because:

- It is timely, spatially resolved measurements of burned areas to provide emission estimates for air quality forecasting and management activities;
- It produces temporal resolution for emissions inventories (Daily resolution is needed for emission inventories); and
- It is a consistent methodology across regions.

The Fire Sciences Laboratory has developed a MODIS-DB burned area algorithm to develop Wildland fire emission inventories for the western US, and provide 'rapid response' Wildland fire emissions for air quality forecasting and management activities. The MODIS-DB demonstrates a prototype smoke dispersion – air quality forecasting system (assimilation of MODIS derived emissions for predicting fire impacts on regional air quality).

Raw MODIS to burned area:

- Active fire detection
  - Thermal anomalies 4µm, 10µm band difference
  - 1-km resolution, day and night
- Burn scar detection
  - Surface reflectance (1.24, 2.13µm bands)
  - 7 tests on 0.86, 1.24, 1.64, 2.13µm bands to filter false alarms (sun glint, clouds, etc.)
  - 500-m resolution, day only
- Burned area product
  - Fire perimeters created from active fire and burn scar detection products
  - ~1-km resolution, up to 4 times daily per location

MODIS fire detection in the 2006 SIT reports for western states detected 96% of burned area from fires exceeded 400 hectares, and 78% of burned area from fires exceeding 4000 hectares (2003-2007 NIFC-SIT).

Air Quality Modeling Components

Fire Information: Daily fire occurrence and burned area growth is recorded with $1km^2$ resolution, using MODIS. MODIS is deployed on polar orbiting Terra and Aqua satellites, making four observations per location (a day and night pass for each satellite). Terra and Aqua have been active since 2000 and 2002, respectively. The fire lab – DB receives up to 12 passes per day.

Fuel Loading:

- Land Cover Map
    - Fuel Characteristic Classification System (FCCS)
- Fuel Loading
    - FCCS; or
    - First Order Fire Effects Model (FOFEM) reference database
- At each 1-km^2 that burns

Hourly Burned Area and Fuel Consumption:

- NFDRS Equations detect fuel moisture
- BEHAVE model (fireLib) detects intensity, and fire rate of spread
- FOFEM determines fuel consumption and heat released by the fire phase
- Fire rate of spread provides weighting to derive hourly fire growth profile from satellite observed daily burned area
- At each 1-km^2 that burns

Hourly Emissions:

- Hourly Emissions
    - Emission Factor Database
    - ~65 gas-phase species and organic, elemental-C, and total $PM_{2.5}$ & PM_{10}

Transport/Chemistry:

- Transport/Chemistry
    - Weather Research and Forecasting with online Chemistry (WRF-Chem)
        - 22 km horizontal grid over CONUS
        - 2 day forecast
        - Photochemical model tracks chemical evolution of aerosols during plume transport

Challenges

Challenges to air quality modelling components are that a) non-standard perimeters are in place; b) validation datasets are limited to fire environment (fuels/weather/typography), fire behaviour , Rate of Spread (ROS) Fire Line Intensity (FLI), smouldering, plume height and heat release, and smoke observations (surface/airborne); and c) there is a lack of emissions factors, and fire effects fuel models outside of the United States and Canada.

Recommendations

Suggested actions include: a) standardizing fire environment and fire behaviour reporting (mainly weather, fuels, and observations of perimeter); b) developing emissions factors for fuels in other regions; and c) assemble test cases or validation data sets.

Smoke Emissions Estimates from Forest Fire Behaviour

Kerry Anderson of the Northern Forestry Center presented *Smoke Emissions Estimates from Forest Fire Behaviour* (presentation 43).

Fire characteristics and behaviour play an important role in smoke emissions. The amount of fuel consumed by the fire is directly related to the amount and types of smoke emissions from a fire while the intensity of a fire can determine the height of the smoke plume.

Fire management systems such as the Canadian Wildland Fire Information System (CWFIS) monitor the current fire situation on a daily basis. These systems can provide the necessary information to calculate inputs for a smoke forecasting system. CWFIS calculates the fire weather and fire behaviour conditions across the country. Daily maps are displayed over the Internet.

Smoke and the resulting emissions from forest fires can be estimated from the fire characteristics and behaviour. The amount of fuel consumed by a fire can be used to estimate the amount of smoke emissions from the fire while the completeness of the combustion is related to the emission composition. Through timely monitoring and reporting of forest fires along with the characteristics of the fire behaviour, the amount of smoke generated can be estimated

Fire detection and monitoring is the first component needed for a smoke forecasting system. The CWFIS presents detected fires based on the MODIS and NOAA/AVHRR sensors. These sensors provide fire detections four times a day at 1km resolution. While fire detection is not complete, hotspots serve as a valuable and timely data source.

The CWFIS is currently producing Total Fuel Consumption (TFC) maps on a daily basis. Total Fuel Consumption (TFC) is a value predicted by the FBP. It predicts the total amount of fuel (surface and crown) that would be consumed by a fire [kg/m^2]. It depends on fuels and on current weather conditions. TFC can be related to smoke emissions.

Currently we see two approaches to estimating the smoke emissions from a forest fire, based on the total fuel consumption and hotspots.

1. Use the hotspots to sample the TFC grid and estimate an amount of fuel consumed,
2. Use the hotspots to build fire progression maps and from the daily perimeter, estimate the fuel consumed within the perimeter.

Emissions – Method 1

Daily hotspots can be dropped on the landscape to determine fuel type and fire behaviour conditions. Area coverage can be assumed for each hotspot based on the sensor resolution (1 km). Using the daily Total Fuel Consumption grid from the CWFIS, an estimate of the emissions for each hotspot can be derived.

The advantages of this method are that it is fast, easy to share with users, and to incorporated into software, and currently available. Disadvantages are that buffer zones overlap, and the method is dependent on the fuel grid.

Emissions – Method 2

A daily fire progress map can determined through cluster analysis. The daily fire progress map can determine the area burned each day. Total fuel consumption within the daily fire growth grids can be used to estimate the smoke emissions.

The advantages to this method are that it fills in fire progress, and provides better spatial resolutions. One disadvantage of this method is that it misses islands within past growth. This method also requires further development.

Regardless of the method, there are other, more general problems:

1. Both are dependent on hotspots, which have a threshold for detection (a function of size and intensity), errors in location and can be blocked by clouds or smoke plumes.
2. Both are dependent on the CFFDRS at a scale not normally managed within the CWFIS.
3. Fuel consumption does not provide specific rates of emissions (PM2.5, etc.).

Penetration height of smoke plumes is related to the buoyancy created from wildfires. If we know the fire size and intensity, the buoyancy can be calculated and from this, the penetration height.

Using the simple relationship:

$Q = H * w$

where

H = 18 000 kJ/kg and

w = weight consumed [kg/m^2]

the amount of heat injected into the atmosphere can be calculated.

NB: This assumes the entire area is burning.

When applied to the landscape, total fuel consumption is again used, this time to calculate the energy released. In theory, the heat input into the atmosphere will modify the environmental lapse rate to the dry adiabat and from this the penetration height can be determined. On the other hand, such an approach does not capture the actual atmospheric profiles and excludes:

- moisture
- inversions
- entrainment
- wind shears
- fire spread

A more rigorous approach would capture the environmental conditions as well as the changing fire characteristics.

Summary

Many of the needed inputs required for smoke forecasting are available through current fire management systems:

- Hotspots provide timely fire detection and monitoring
- Total Fuel Consumption (TFC) provides the total mass of smoke released plus the heat used for buoyancy.

The CWFIS currently provides these necessary inputs and can be used to develop the prototype system for BC and Alberta. In turn, more rigorous systems can be used in its place.

Fire Danger Rating-related Haze Early Warning in Southeast Asia

Orbita Roswintiarti, a member of the Indonesian National Institute of Aeronautics and Space (LAPAN), as well as the SE Asia Regional Research Information Netork (SEARRIN) provided a presentation on *Fire Danger Rating-related Haze Early Warning and Issues Regarding Haze Forecasting in Southeast Asia* (presentation 40), which outlined the Drought Code (DC) as a smoke/haze potential, development of the Fuel-Explicit Model and its outputs for the haze event of 1997/98, and issues regarding haze forecasting.

Trans-boundary haze associated with uncontrolled biomass burning is a critical problem in SE Asia. Severe wildfire and haze events usually occur during ENSO events (ie: 1997/98, 2002/03, 2004/05, 2006). Factors related to trans-boundary haze problems in Southeast Asia are emissions from peat burning and wind speed and direction.

An early warning system which includes FDR, weather, and haze forecasting is needed to assess the impacts of haze problems in advance of their occurrence.

Drought Code (DC) as Smoke/Haze Potential

The Drought Code measures moisture content in deep organic soil layers, such as peat. It is a good indicator of the potential for deep-smouldering fires. Haze potential was calibrated explicitly in Field et al. (2004).

The bootstrap analyses of DC and visibility from 8 stations between 1994-1998 yielded a DC threshold of 388.2 with a 95% confidence interval of (379.5, 397.5).

Using a DC threshold value of 388.2, the mobilization class levels were calculated on the basis of the number of dry days required to reach that threshold level. The result was that the High-Extreme boundary was defined by a DC of 346.9, the Moderate-High boundary by a DC of 264.4, and the Low-Moderate boundary by a DC of 140.7.

Input Data for a 1997/98 Haze Simulation:

- Location and dates of fires: ATSR fire hotspots
- Surface and Sub-surface fuel map: The Global Land Cover Facility (GLCF) and The Oak Ridge National Laboratory (ORNL) global datasets
- TPM emissions: see figure 1, below
- The dispersion and transport model: The Hybrid-Single Particle Lagrangian Integrated Trajectory (HYSPLIT)
- Atmospheric conditions: NCEP/NCAR Reanalysis data (2.5˚ x 2.5˚)

Table 1 - Summary of Emission Rates for Surface and Sub-Surface fuels:

Fuel Type	**Fuel Load (t ha-1)**	**Combustion Factor**	**TPM emission factor (kg t-1)**	**TPM emissions per unit area (kg ha-1)6**
Grassland [1]	4.37	1	8.3	36.2 kg/ha
Shrubland [2]	7.5	0.84		52.5 kg/ha
Open Forest [3]	6.5	0.43	8.5	23.7 kg/ha
Closed Forest [4]	10	0.53		44.7 kg/ha
Peat [5]	22.5	0.5	35	393.8 kg/ha/cm

Meteorological Input Data for HYSPLIT Model

The NCEP/NCAR Reanalysis data (2.5˚ x 2.5˚):

- 17 pressure levels in vertical (1000, 925, 850, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, and 10 hPa)
- The surface-level variables: pressure at surface, temperature at 2m AGL, U-component of wind at 10 m AGL, V-component of wind at 10 m AGL, and total precipitation (6-hr accumulation)
- The upper-level variables: geopotential height, temperature, U-component of wind with respect to grid, V-component of wind with respect to grid, pressure vertical velocity, and relative humidity

Issues regarding Haze Forecasting

Main obstacles in conducting the near-real time haze forecasting are:

- Near-real time meteorological input data for the transport model (Reanalysis data, products from NWM such as MM5, etc)
- The infrastructure and fees of high-speed internet connection

The framework for a proposed “FireWatch Indonesia” network connection (Indonesia-Australia, 2008-2009) was presented.

Minimum Requirements of the Meteorological Data for HYSPLIT Model

Surface Parameters:

- Pressure at surface [hPa]
- Temperature at 2m [K]
- U-component of wind at 10 m [m/s]
- V-component of wind at 10 m [m/s]

Upper-Level Parameters:

- U-component of wind (respect to grid) [m/s]
- V-component of wind (respect to grid) [m/s]
- Temperature [K]
- Relative humidity [%]

Time interval: every 1-hr, or 3-hr, or 6-hr

Conclusions

The Drought Code (DC) is a good indicator for smoke potential/early warning.

The Fuel-Explicit Model has shown a remarkably good correspondence between the modeled TPM emissions and observed TOMS signal, particularly with respect to the onset of the peak haze episode of 1997. The Fuel-Explicit Model has worked effectively in simulating the long-range haze transport from biomass burning emissions in the region, particularly in terms of temporal variations. The differences in the spatial variations may be attributed to:

- the simplification of haze deposition and transformation mechanisms; and
- the relatively coarse horizontal and vertical resolutions adopted for the simulations.

The main problems of conducting the Haze Forecasting in Indonesia are unavailability of the near-real time/forecasting meteorological parameters and access to high-speed internet connections.

Toward a Wildfire Smoke Forecasting System in Canada: The Bluesky Pilot Project

Steve Sakiyama of the British Columbia Ministry of Environment presented *Toward a Wildfire Smoke Forecasting System in Canada: The Bluesky Western Canada (BC/Alberta) Pilot Project* (presentation 41).

There is a need for smoke forecasts where hourly plume trajectory and concentrations of PM2.5 are displayed in a user-friendly format. Users of this project are members of the medical community, tourism sector, fire managers, transportation operators, the public, weather forecasters, regulatory agencies, park managers, and others. Many groups of decision and policy makers, as well as researchers would find the information useful. In Canada, tools and data are available. What we seek is the co-ordination required to develop an operational system.

The initial steps towards building a Wildfire Smoke Forecasting System in Canada composed of two options. They are 1) a system made in Canada; and 2) build on an existing system, such as the US Forest Service’s BlueSkyRAINS system.

Option two was chosen as a pilot project, as this existing system can accept Canadian components to be substituted in.

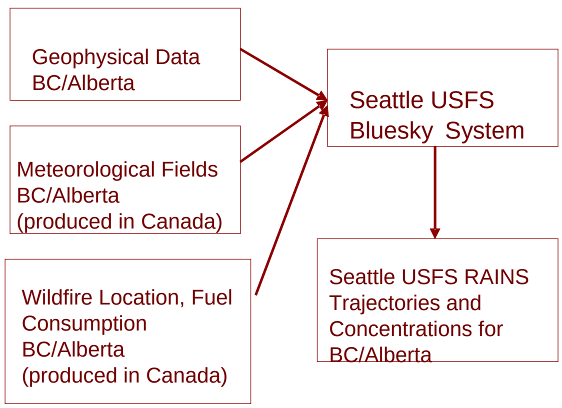
Bluesky is a product, of the US Forest Service, which consists of data and models of fuel consumption, emissions, fire, weather, and smoke dispersion all linked into a single system. Hourly forecasts up to two days are generated for ground-level concentrations of PM2.5 from wildfires, prescribed burns, and agricultural fire. Domains have been added to the Pacific North West domain (Idaho, Montana, Washington, Oregon, and Northern California).

RAINS, which stands for Rapid Access Information System, is a GIS-based display via web where users can overlay layers (topography, census data, sensitive areas, etc.), zoom and plan, and query for additional data.

Pilot Project: The Process

The Steering Group is composed of a partnership of British Columbia and Alberta provincial agencies, University of British Columbia, US Forest Service, Environment Canada, and Natural Resources Canada.

Original Concept:



Meteorological Fields

Hourly, meteorological forecast at sufficient spatial resolution are needed to resolve complex terrain. This information is provided by the University of British Columbia (UBC) - 4 km grid resolution MM5 meteorological forecast model for all of British Columbia and Alberta. Since Jan 2008, hourly meteorological field forecasts have been produced.

The current Bluesky spatial domain has been extended to cover both British Columbia and Alberta and includes geophysical (GIS) layers. A separate western Canada site is established on the USFS server. The RAINS (display) portion for the Western Canada domain is ready to be populated from Bluesky system.

Location and fuel consumption for every wildfire is provided.

Current Efforts for BC:

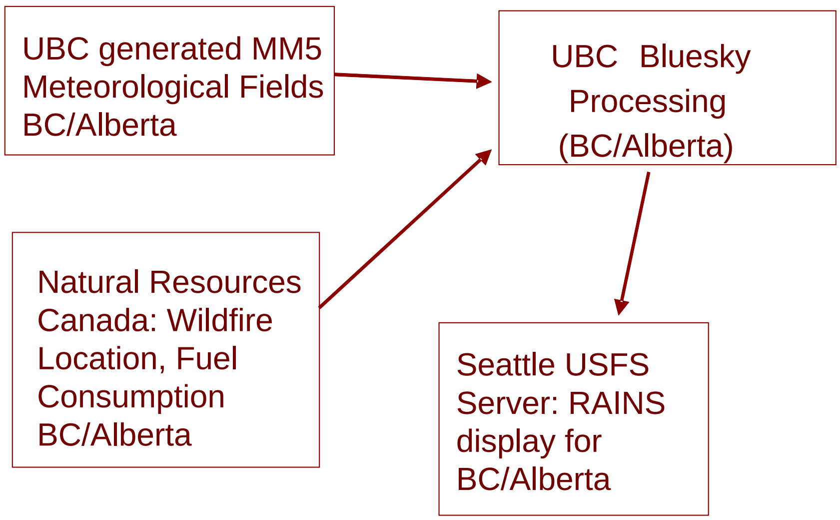
- FireM3 (Canadian Forest Service system: satellite based hotspot detection), combined with National Forest Inventory data for fuel consumption estimates
- data links and transformations to Bluekshy system requirements currently underway

Running BlueSky Locally - A Computer with BlueSky from the US Forest Service:

- MM5 (meteorological model) output – too much output for timely transfer to Seattle USFS server
- Computer from USFS with Bluesky set up at UBC to solve data transfer problem and process meteorological and emissions data

- USFS computer with Bluesky now installed at UBC
- Further support from USFS before system operational

Western Canada BlueSky Pilot: Revised Approach:



Summary

- Vision: A National Smoke Forecasting System
- Multi-agency workgroup established to provide direction to the Pilot project
- Multi-agency support is essential to achieve the National vision.
- Western Canada Pilot project based on BlueskyRAINS platform
    - geophysical, meteorological and display components now operational
    - emissions module development underway
    - Bluesky machine at UBC awaits further support from US Forest Service
- Operational System: Goal of Fall of 2008

Synthesis of Smoke Forecasting and Monitoring Approaches

In order to better understand the vertical distribution of smoke plumes, models for smoke plumes are needed. There is a need for plume models for smoke, specifically from fires. MISR datasets are used for validation at the moment. Although CALIPSO data has a smaller swath, it may be an alternative. ARCTAS can also be used to compare and validate findings. However, plume rise information is not sufficient on its own; someone on the ground to analyze the fire behaviour and other data is necessary.

Ideally, the model we seek will not only validate fires, but capture them in 3D, as the geometry of a fire front is also important in evaluating the effects of the fire.

Known inputs are required to generate an expected output.

A large dataset can hamper efficiency, in that sorting through it all is time consuming, and storage of it can be costly.

Recommendations to maximize efficiency included assembling a necessary data set for validation, and collecting good and accurate observations. The question remains regarding who is to be in charge of these responsibilities. Those who are on the ground at the scene of the fire may have the most accurate observations, however they are often prioritizing controlling and managing the fire.

There should be a parallel evolution between models and theory.

The Smoke and Emissions Inter-Comparison Project (SEMIP Project) is a model inter-comparison project for any model and catalogue that exists. Contact Neil Wheeler for more information.

Applications

Users of models, products, and associated programs: pilots, those in the aviation industry, heath industry (smoke models), EPA, Environment Canada, the general public, organizers of public events (ie: Olympics), policy makers (ie: for generating regulations, determining the carbon budget, public transportation (highways), etc)

There are a broad range of agencies, organization, and policy makers who would utilize the information. However, their needs, demands, and expectations may exceed what can be provided. Limiting the range of objectives, and the types of products generated may keep the product and/or program focused to a specific objective. Fire management, decision making (planning and reactionary purposes), land management (operational, planning), and health and safety (air quality determination) were suggested areas of application with high priority.

It is also important to remember that all models have limitations.

Other Considerations:

- Does it make more sense to have a specific output? Or rather, a wider, all-encompassing project? Collegial competition is a reality.
- The creators of the product/program need to have some say as to how the product/program is used. If those for whom the product/program has been created do not make use of the product/program, it may be a waste, as it may not suit the needs of those who other wise find it "interesting", but unable to utilize the information/models.
- Datasets are scattered; Bandwidth scarcity is a problem
- Getting an operational model that can be used in the field. What are options for people in the operational part of the field?

Validation

We must be more accurate in calculating the area burned, and validation of the calculations must be validated, as this will in turn affect other calculations, ie: emissions calculations. One recommendation to this issue is integration of agricultural burning into the BlueSky project – this is currently in progress. Prioritizing the task, product, and issues will focus and direct the action. In determining the priorities, choices must be made as to who gets to use it, who benefits most, and who the stake holders are. Areas where validation is needed in calculations and the models themselves include: area burned and plume heights. It is also important to keep in mind that all models have limitations.

Availability of Information

The issue of whether there are emission factors not being published was also raised. Holding literature reviews, or list service can get people together and start compiling this. Gathering the fire community together, seeing what is already out there and what is not, is an initial step. Key attendees include experimenters, those with access to and/or research local emission rates, ratios, factors (ratio of ratios per combustion – depends on combustion types, fuel types etc.) and fire ecologists.

Smouldering

The current state of smouldering, and how smouldering combustion is reported were of interest to the break out group. Additional research and clarification of how emission rates and emission factors differ were suggested actions towards this issue.

Technology Infrastructures

Challenges to technology infrastructures are the expected lifetimes of satellites, replacement plans, remote sensing longevity, and data storage. Are we moving backwards in terms of revolution? Ivan Csiszar was not present in this particular break out group, but was suggested as someone who may help address these issues and/or clarify questions. Pooling capital can generate the funds necessary to replace the equipment. Pooling data may reduce the replication of the same data.

5. Status of Operational Guidelines for Weather-based FDR

5.1 WMO Operational Guidelines

WMO Operational Guidelines (presentation 45) was presented by M.V.K Sivakumar, outlining general information on the World Meteorological Organization (WMO), the Commission for Agricultural Meteorology (CAgM) – Forestry Issues, CAgM activities related to forestry: reports and operational guidelines, and other activities in the WMO relevant to forestry issues.

World Meteorological Organization

The World Meteorological Organization (WMO) was established 23 March, 1950, successor to the International Meteorological Organization (IMO, created in 1873). The WMO is a specialized agency of the United Nations for meteorology (weather and climate), operational hydrology and related geophysical sciences. It is the UN system's authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting WMO's vision is to provide world leadership in expertise and international cooperation in weather, climate, hydrology and water resources, and related environmental issues, thereby contributing to the safety and well being of people throughout the world and to the economic benefit of all nations.

Commission for Agricultural Meteorology of WMO

The Commission for Agricultural Meteorology (CAgM) of WMO is responsible for matters relating to:

- Applications of meteorology to agricultural cropping systems, forestry, and agricultural land use and livestock management, taking into account meteorological and agricultural developments both in the scientific and practical fields; and
- Methods, procedures and techniques for the provision of meteorological services to agriculture including farmers and forestry and rangeland operators.

CAgM Activities Related to Forestry, Including Fire Danger Rating

- Symposium on Forest Meteorology (1978)
- Special Environmental Report 11 - Systems for evaluating and predicting the effects of weather and climate on wildland fires (1978)
- CAgM Report 10 – Wildland fires particularly in the tropical regions (1982)

- Special Environmental Report 11 (Revised) – with additional material on the use of remote sensing techniques in forest-fire management (1994)
- Chapter 8, Guide for Agricultural Meteorological Practices (GAMP) (2008)

Symposium on Forest Meteorology (1978)

A Symposium for Forest Meteorology sponsored by WMO and hosted by the Canadian Forestry Service and the Atmospheric and Environment Service of the Department of Fisheries and Environment, was held at the University of Ottawa, 21-25 August, 1979.

Dr W.E. Reifsnyder of Yale University, USA was symposium director. Local coordinators included: J.B. Harrington, Canadian Forestry Service; W. Baier, President of CAgM and Agriculture Canada; and M.K.Thomas, Atmospheric Environment Service . M.J. Connaughton was WMO Coordinator.

Proceedings from this symposium were published as WMO No. 527 on behalf of WMO by the Canadian Forestry Service. Of the 130 participants from 14 countries that attended, 75 participants were from Canada. Keen interest of the forestry professionals in the subject was evidenced by the attendance of about 40 representatives from forestry.

The programme of the Symposium has been divided into eight sessions, composed of seven technical sessions and a poster session. Technical session 4 dealt with meteorology and climatology in relation to the management of forest fires.

Conclusions of the Symposium on Forest Meteorology (1978)

The symposium had been most useful in providing a forum for discussion of meteorological aspects of forestry. Symposia of this kind are needed at fairly frequent intervals, perhaps every 2-3 years with venues at different parts of the world.

While various meteorological aspects of forestry in temperate zones had been comprehensively dealt with, forest meteorology in the tropics had not received the same attention.

The subject of forest meteorology merited inclusion in the programme of national and international institutions. There is an urgent need for closer liaison between meteorologists and forest scientists at the national level.

Recommendations of the Symposium on Forest Meteorology

- National forestry services should take steps, in consultation with national meteorological services, to standardize instruments and methods of observation at forestry weather stations to bring them into conformity with the weather observing networks of meteorological services.
- National meteorological services should become more involved in forest meteorology.
- In view of the fact that special methodologies were now available for the examination of tree-rings as climatic indicators, the use of such methodologies should be studied by a working group of CAgM.
- In view of extensive deforestation in some tropical areas and of the possible change in global CO2 patterns, CAgM should consider ways and means of studying this question.
- In planning future meetings or studies on forest meteorology, emphasis should be placed on problems related to tropical forestry.

Special Environmental Report 11 (1978)

The recommendations of the UN Conference of the Human Environment in Stockholm in 1972, led to a report on *Research Needs in Forest Meteorology*.

At its sixth session in 1974, the WMO/FAO/UNESCO Interagency Group on Agricultural Biometeorology reviewed this report and proposed a project on forest fires and their relationship with the human environment. Subsequently a sub-project on Atmospheric Aspects of Forest Fires was submitted by FAO and WMO to UNEP. As part of that sub-project, Prof. Reifsnyder of Yale University prepared a report dealing with systems for evaluating and predicting the effects of weather and climate on wildland fires which was later published as WMO Special Environmental Report 11.

WMO Special Environmental Report 11 contains a discussion on the general principles of forest fire forecasting and presents proposals for the development of a universal fire-danger rating system. A hierarchy of fire-danger-rating system was presented which includes ignition, occurrence, spread, energy release, burning, fire load and seasonal severity. The hierarchy of fire-weather forecasting services includes fire weather warnings, fire danger forecasts and on-site forecast services. Proposals for the development of universal systems of rating fire danger and forecasting fire weather were presented. Developments of fire climatology, ignition index, rate-of-spread index, and a fire-weather forecasting system were discussed. Comparison of several fire danger rating systems and forest fire weather forecasting systems was presented in Annex of the report.

CAgM Report 10 – Wildland fires particularly in the tropical regions (1982)

A.B. Oguntala (Nigeria) was appointed as Rapporteur on Wildland Fires particularly in the tropical regions by the seventh session of CAgM. The report highlighted that fire-danger rating system has hardly been developed in Africa, Latin America, Asia and the Mediterranean regions. The study highlights the necessity and feasibility of developing forest fire weather forecasting and the development of a fire-danger rating system for tropical regions.

Questionnaires were sent out to 98 Member countries and 31 responses were received. In Africa, 15 countries responded to the questionnaire. Maximum economic losses were reported from Senegal ($ 60 millions). In Central America, Columbia reported the largest area under wildland fires. Argentina reported economic losses of $ 62 millions. Literature survey, consultations and discussions also contributed to the report.

Most wildland fires occurred in the dry season and are usually associated with droughts. All savannas burn repeatedly at intervals varying from a few months to several years, and the great majority of them burn at least once every year or two. The main period of burning is during the last half of the dry season or during short rainless intervals.

The key operative factor in the savannah climate is the constantly high temperature throughout the year, with alternations of a very rainy season and a prolonged, almost completely rainless dry season. Examples of fire weather in Africa, Asia, and Latin America were given.

Most tropical countries have inadequate personnel and equipment to monitor fire climates. Consequently over 80% of the countries do not have meteorological observations recorded in areas where wildland fires occur. Most of the countries also reported that their meteorological services do not prepare forecasts of fire-weather elements or provide fire-weather services.

Reasons for this include scant networks; communication problems; lack of experience and basic studies; lack of infrastructure etc. In most countries there is little or no economic analysis of the losses due to fires which could serve as the basis for deciding on making studies and providing forecast services.

The real problem is not lack of meteorological stations, but lack of knowledge of the applications of meteorological data to predict wildland fires in the tropical regions.

There is a great potential for the development of forest fire-weather forecasting and fire danger rating systems in the tropics. For this, it is important to address the following issues:

- Level of awareness
- Improvement of meteorological and forecasting services
- Training and technical assistance
- Inter-departmental cooperation
- Communication
- Research and development

Special Environmental Report 11 - (Revised 1994)

As a result of the recommendations at the eighth session of CAgM, Prof. Reifsnyder and Dr B. Alders of the USA were requested to revise and update the report. The revised version includes new information on remote sensing techniques in the management and control of wildland fires. A new section on fire-weather observations was added with guidelines on general rules concerning the representativeness of an area for fire-weather stations. Equipment and accuracy standards for different weather elements such as temperature, relative humidity, wind direction and wind speed, daily precipitation, daily evaporation, and fuel moisture content from sticks were also given. An application of lightning locators for forest fire detection was described. Remote sensing systems including airborne systems, high spatial resolution satellite systems, and TIROS-AVHRR sensor system and their selected applications in fire management were described. A section on remote sensing in the GIS environment was also presented. Annex I of the report presents recommendations relating to fire danger rating systems for the following regions: Mediterranean Region, Central America, and Africa.

Chapter 8 – Guide for Agricultural Meteorological Practices (GAMP)

Chapter 8 of GAMP is entitled “Applications of Meteorology to Forestry and Non-Forest Trees.” It is in essence a 107 page report compiled by J. Paulo De Melo-Abreu et al. The chapter has been internally reviewed and edited by J. Paulo De Melo-Abreu and externally reviewed by Al Riebau.

Contents of Chapter 8 – GAMP:

- Climate and weather analysis for forestry and non-forest tree operations
    - Tree response to meteorological elements
    - Pest and diseases in relation to weather
    - Weather hazards to forest and non-forest trees*
    - Tree nursery location and operation
    - Applications of meteorology and climatology to forestry and non-forest operations
    - Prescribed burning*
    - Implications of climate change to forestry production
- Meteorological observations for forestry applications
    - Measurements of wind and precipitation*
    - Specialised observations for orchard pest and disease management
    - Specialized fire weather observations*
- Computer simulation models applied to forestry and non-forest trees
    - Growth and production models
    - Management models
        - fire ecology and fuel management*
    - Fire weather applications and models*

- Fuel-state assessment for forest, bush and grass fires*
    - weather-related elements
    - Grassland fuel state assessment
    - Forest fuel-state assessment
    - Treatment of fuel state after precipitation
    - Discussion of climate-based indices
    - Phenomena associated with fires
- Appendix A presents a case study on climate and rubber growth under natural and agricultural ecosystems in Brazilian Amazon Basin

Other activities in WMO relevant to Forestry Issues

- Global Atmospheric Watch (GAW)
- Disaster Risk Reduction Programme (DRR)
- World Weather Research Programme
- Publications relevant to forest fire issues

Global Atmospheric Watch (GAW) Monitoring Themes:

GAW Station Information System (GAWSIS) provides comprehensive information on all GAW stations. Information from the database, search/updates, and inventory/audits may be found (http://gaw.empa.ch/gawsis/).

Disaster Risk Reduction Programme

The Disaster Risk Reduction Programme provides early warning and prevention for 90% of the natural disasters of meteorological or hydrological origin.

World Weather Research Programme (WWRP)

A WWRP Wildfire Weather Workshop took place in Melbourne Oct 2003, covering topics on:

- Short range forecasting
- Smoke transport
- Fire behaviour
- Seasonal range forecasts/climate
- Decision support systems
- Economic analysis of fire weather services
- Scientific visitors programme

WWRP Science Steering Committee at Boulder Oct 2004 discussed the potential for a WWRP Forecast Demonstration Project, with possible themes on:

- comparison and assessment of fire weather indices
- assessment of smoke dispersion/air quality forecast parameters
- on urban/regional scales
- Ad Hoc WG on Fire Weather

Role of WMO

The role of the WMO is to assist in enhancing regional capabilities in providing meteorological support in the form of improved ENSO/ Climate variability/predictions. Daily smoke trajectories and dispersion forecasts are generated, improving remote sensing capabilities for characterizing fire activity, and tracking the movement of smoke and haze. The WMO also assists in strengthening regional monitoring efforts, and improves management of smoke and haze (trans-boundary) pollution events through efforts directed at enhanced information exchange and coordination.

Publications relevant to forest fire issues

WMO Workshop on Regional Transboundary Smoke and Haze in Southeast Asia (Singapore, 2-5 June 1998), Vol. 1-2, GAW Report No 131, WMO TD - No. 948. The workshop came up with recommendations on: i) modelling; ii) remote sensing; iii) measurements and monitoring; and iv) information exchange. These recommendations were incorporated into the following publication:

> Health Guidelines for Vegetation Fire Events, Guideline Document, Editors Dietrich Schwela, Johann G. Goldammer, Lidia Morawska, Orman Simpson; joint publication of UNEP, WHO, WMO and IEE (Institute for Environmental Epidemiology, Singapore); WHO 1999, ISBN 981-04-1460-9

There are also "Teacher's guide" and "Background Papers" Volumes for the Health Guidelines.

5.2 Agrometeorology and Sustainable Agricultural Development

Antonio Mestre led the presentation *Expert Team 1.3 of the CAgM on Agrometeorological Aspects of Sustainable Agricultural Development* (presentation 46).

CAgM Open Programme Area Groups (OPAGs)

At the 14th session of the Commission of Agricultural Meteorology in India in 2006, the Commission continued to use an Open Programme Area Group (OPAG) concept.

OPAG 1: Agrometeorological Services for Agricultural Production

- 1.1 –ICT for Agrometeorological Services (ICAS)
- 1.2 –ET on the Content and Use of Agrometeorological Products by Farmers and Extension Services (ETCUAP)
- 1.3 -ET on Agrometeorological Aspects of Sustainable Agricultural Development (ETASAD)

Terms of Reference for ETASAD

a) To review and evaluate the status of agrometeorological applications to conserve and manage natural and environmental resources for the benefit of agriculture, rangelands, forestry, fisheries and other relevant rural activities.

b) To collect and evaluate case studies of successful measures to manage land use, protect land and mitigate land degradation; and, promote a better understanding of the agrometeorological aspects of land degradation at the national and regional levels.

c) To review and summarize the different agrometeorological aspects of increasing water use efficiency including watershed management in collaboration with the WMO Commission of Hydrology (CHy), where appropriate.

<u>d) To establish operational guidelines for fire weather agrometeorology.</u>

e) To review and summarize the impact of weather and climate information on fisheries.

f) To provide liaison with JCOMM on the inter-Commission activities on natural disaster reduction in coastal lowland areas.

g) To prepare reports in accordance with timetables established by the OPAGs and/or MG.

6. Conclusions and Recommendations

History and Legacy of Fire Danger Rating

The review of the history and legacy of fire danger rating shows that nearly every country in the world with fire-prone vegetation utilizes some form of a fire danger rating system. Fire danger rating research and operational use of fire danger rating systems has a very rich history which is well chronicled from the early part or the twentieth century onwards in many agency publications, textbooks and journals

Recommendation: A comprehensive bibliography and synthesis on fire danger rating does not presently exist, and should be commissioned.

Operational FDR Systems around the Globe

International reports from 19 countries across seven continents indicate a general consensus that approaches to FDR and weather information play a critical role in fire management decisions and both personal and public safety. The many benefits of establishing a FDRS include access to information which can be used in at least the following areas of decision making: prevention, preparedness and detection planning, initial attack dispatching, suppression planning, and escaped fire situation analysis.

Recommendations: Among the international reports from 19 countries there were a number of common challenges and needs identified to improve fire danger rating:

- The need for on-going calibration and validation
- Incorporate local knowledge of quickly-changing synoptic conditions in the context of a national system
- Making use of new forecast products
- Improve consistency between state/provincial, national, regional, global systems

FDR Enhancement

Opportunities were identified to enhance operational FDR in the following six areas:

1. Weather observations and networks with a focus on access and adequacy of in situ data, use of remote sensing, etc.

Recommendation: Standardized and validated methods are needed to combine remote sensing data and data from surface networks for FDR use. Hybrid systems would have operational applications and are necessary to fill in the in-situ data gaps.

~*Recommendation:* Automatic observations are growing in use, but require careful attention to regular recalibration of equipment.

Recommendation: There are differences in sampling techniques and instruments, which can lead to non standardized data. Data collection needs to be standardized within and across networks in order to generate spatial FDR information.

2. Data management includes collection, storage and retrieval, spatial processing and display, and dissemination.

Recommendation: Data managers need to be mindful of the principles for long-term FDR monitoring. The ability to maintain the continuity, homogeneity and, ultimately, quality of weather data is greatly influenced by how well observation networks and systems are managed.

Recommendation: Make use of existing resources such as data sources, expertise and networks, while ensuring the use of established international standards.

Recommendation: In addition to FDR use, fire weather data should be collected and stored for longer term fire research purposes such as estimating fire weather normals, etc.

3. Weather analysis included topics such as: Maps and Analyses, Numerical Weather Prediction (NWP) Products, Vertical Structure, Seasonal Assessments, and Uncertainty.

Recommendation: Maps are becoming the standard for presenting fire danger rating. Maps should be based on: a) calculated FDR from interpolated weather; and b) physical modeling and assimilation using mesoscale/NWP models.

Recommendation: NWP Products are readily available and are now being incorporated into fire danger rating systems. The use of ensemble products should be explored, while recognizing and acknowledging NWP errors.

Recommendation: Uncertainty in the form of error biases and variability must be made more explicit in FDR analyses, including the awareness of transition points.

4. Approaches to defining and evaluating fire danger levels with a focus on calibration and validation.

Recommendation: As the validation approach depends on the application, it is important to determine the goals for FDR use, which may vary between countries and agencies.

Recommendation: Explore the development of FDR systems based on attributes of climate zones and main fuel types. A standard way of describing fuel types is needed.

Recommendation: Establish a case study database of FDR calibration approaches, which are now emerging but are not widely known.

5. Additional indices of fire danger including factors such as live vegetation, curing, soil moisture, human behaviour, etc.

Recommendation: Digital Elevation Models are simple to access and should be incorporated in to FDR to complement moisture content estimations and fire behaviour predictions.

Recommendation: Establish common databases of fuel moisture content (FMC) ground measurements and remote sensing estimations.

Recommendation: Increase development and use of fuel type maps as they are a critical factor for fire danger estimation (ignition and propagation), but are not readily available. Periodic updating of burned area maps are needed for fire effects assessments.

6. Smoke forecasting and monitoring that address emissions, dispersion, etc.

Recommendation: There is a need for plume models for smoke, specifically from fires. This includes assembling a necessary data set for validation, and collecting good and accurate observations. As well, there should be a parallel evolution between models and theory.

Recommendation: Greater accuracy is required in calculating area burned and plume height, and the calculations must be validated, as this will in turn affect other calculations, i.e. emissions calculations.

Recommendation: A literature review is required for published emission factors, followed by an analysis of where there are knowledge gaps. For example, little was known about the current state of knowledge on smouldering, and how smouldering combustion is reported.

Guidelines for FDR Including Operational Weather Systems

Guidelines for weather-based FDR have been prepared at several levels including: operational provincial and national fire agencies, and international guide on best practices. The World Meteorological Organization (WMO), through its Commission on Agrometeorology (CAgM), has addressed meteorology applications and services related to forestry, including fire danger rating. Since 1978 the CAgM has supported several symposia and produced reference materials on methods, procedures and techniques on the meteorological aspects of fire management and supporting information systems. References to these materials are included in section 5.1 of this report.

Recommendation: Stated in 1978 and still relevant today, ther is a need for national forestry services to take steps, in consultation with national meteorological services, to standardize instruments and methods of observation at forestry weather stations to bring them into conformity with the weather observing networks of meteorological services.

Recommendation: Chapter 8 of the WMO Guide for Agricultural Meteorological Practices (GAMP) includes several sections on climate and weather observations and analysis for forestry and non-forest tree operations, including wildland fire. The revised GAMP should be completed and distributed as soon as possible.

7. Appendices

Appendix 1. Principal Workshop Sponsors and Steering Committee

Natural Resources Canada - Canadian Forest Service (**CFS**) conducts research to develop information and decision support systems to monitor and predict wildland fire activity to enhance fire management efficiency and effectiveness in Canada and internationally.

Global Observation of Forest and Land Cover Dynamics (**GOFC-GOLD**) is a coordinated international effort to ensure a continuous program of space-based and in situ forest and land cover observations, including the effects of fire. The Fire Mapping and Monitoring theme focuses on refining international requirements for fire-related observations and making the best possible use of fire products from existing and future satellite observing systems to support fire management, policy decision-making, and global change research.

Key goals are to ensure enhanced operational fire monitoring from space and ground measurements, better access and use of data, and standard products of known accuracy.

The GOFC-GOLD fire monitoring and mapping implementation team works closely with a series of regional networks to bring together fire data providers and users to exchange information on capabilities and needs and to promote strengthening of regional and national fire activities. Regional networks are located in South East Asia, Central and Southern Africa, Northern Eurasia, Latin America, and East Asia, and are in partnership with the UNISDR Global Wildland Fire Network and its 13 Regional Wildland Fire Networks in all continents.

GOFC-GOLD is a Panel of the Global Terrestrial Observing System (GTOS), sponsored by FAO, UNESCO, WMO, ICSU and UNEP. The GOFC-GOLD Secretariat is hosted by Canada and supported by the Canadian Space Agency (**CSA**) and Natural Resources Canada. Other contributing agencies include NASA, ESA, START and JRC. Further information can be obtained at http://www.fao.org/gtos/gofc-gold

The World Meteorological Organization (**WMO**), founded in 1950, is a specialized agency of the United Nations for weather, climate, and water. WMO contributes to the understanding of the interactions between climate and agriculture through dedicated observations of the climate system; improvements in the application of agrometeorological methods especially with climate predictions; proper assessment and management of water resources; and promotion of capacity building in the application of meteorological and hydrological data.

The global change SysTem for Analysis, Research and Training (**START**), provides an international framework for capacity building. START fosters regional networks of collaborating scientists and institutions in developing countries to conduct research on regional aspects of environmental change, assess impacts and vulnerabilities to such changes, and provide information to policy-makers.

The 2007-2009 work plan of the Group on Earth Observation (**GEO**) includes activities concerning land cover / land cover change and a specific task concerning the progressive setup of a Wildland Fire Warning System at Global Level.

The Global Fire Monitoring Centre (**GFMC**) provides a global portal for wildland fire documentation, information and monitoring. The regularly updated national to global wildland fire products of the GFMC are generated by a worldwide network of cooperating institutions. The online and offline products include early warning of fire danger and near-real time monitoring of fire events.

The **Government of Alberta** encourages balanced and responsible use of its forest resources through the application of leading practices in management, science, and stewardship.

The Alberta Sustainable Resource (**SRD**) Department encourages balanced and responsible use of Alberta's natural resources through the application of leading practices in management, science and stewardship. SRD Forestry ensures the multiple benefits received from the province's forests are realized by utilizing a combination of leading forest management, forest wildfire protection and forest industry practices to provide leadership and oversight in the management of Alberta's forests.

The Alberta Forestry Research Institute (**AFRI**) is comprised of representatives from industry, academia and government whose mission is to enhance the contribution of science and research to the economic, environmental and community sustainability of Alberta and to promote the global competitiveness of its forestry sector. Prioritizing, coordinating and promoting research and development and encouraging their application in the Alberta forest sector are the key responsibilities of AFRI.

Appendix 2. List of Participants and Contributors

No.	Participant	Representing
1	Alarcon, Constantino	National Meteorology and Hydrology Service, Peru
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	Archibald, Beverly	True North Weather Consulting, Canada
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79	Wiebe, Bram	Saskatchewan Fire Management and Forest Protection Branch, Canada
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82	Zhan Shu	Northeast Forestry University, China

Appendix 3. Detailed Agenda

SUNDAY, 13 JULY 2008

Participants arrive in Edmonton

19:00-21:00 Registration and welcome reception at Crowne Plaza Chateau Lacombe, River Valley Room, collection of posters, (coordination meeting for Chairs and Facilitators, 19:30)

MONDAY, 14 JULY 2008

08:00 Bus leaves Crowne Plaza Chateau Lacombe

08:30 Registration at Northern Forestry Centre, Pine Room, poster set up

SESSION 1
Opening of the Workshop
(Chair 1: Michael Brady)

09:15 **Welcome and workshop overview**
Michael Brady, Executive Director GOFC-GOLD, Canadian Forest Service

09:25 **Welcoming statements**
Gordon Miller, Director General, Canadian Forest Service
M.V.K. Sivakumar, Chief, Agricultural Meteorology Division, World Meteorological Organization (WMO)
Jim Salinger, President, Commission for Agricultural Meteorology of WMO
Tim Goos, Regional Director General, Prairie and Northern Region, Environment Canada

10:00 **Keynote Address – History and Legacy of Fire Danger Rating in Wildland Fire Management**
Martin Alexander, Canadian Forest Service

10:30 Group Photo, Break and Poster Session

SESSION 2
Fire Danger Rating (FDR) Approaches and Role of Weather Information – International Reports
(Chair 2: Cristina Vega Rapporteur: S. Kinuthia)

11:00 **Operational FDR in Argentina**
Carlos Di Bella, INTA/Redlatif Regional Network; Fernando Epele, Chubut Prov. Fire Management Service, Argentina

11:20 **Wildfire Weather Analysis in Croatia Using Numerical Modeling and CFFWIS Products**
Marko Vucetic and Visnja Vucetic, Meteorological and Hydrological Service

11:40 **Forest Fires and FDR in China**
Yonghe Wang, CFS; Xueying Di, Zhan Shu, Guang Yang, Northeast Forestry University

12:00 **FDR in the European Forest Fire Information System (EFFIS) of the European Commission**
Andrea Camia, EC Joint Research Centre

12:20 **Discussion**

12:30 Lunch

SESSION 2 continued

Chair 3: Robert Field Rapporteur: Rizaldi Boer)

14:00 **Developing a FDR System for the United Kingdom**
Karl Kitchen, UK Meteorological Service

14:20 **Operational FDR in Indonesia**
Guswanto Abdul Gani, Agency for Meteorology and Geophysics; Israr Albar, Department of Forestry; Orbita Roswintiarti, Indonesia Space Agency

14:40 **Operational FDR in Malaysia and Association of Southeast Asia Nations**
Ahmad Zaki, Malaysian Meteorological Department; Orbita Roswintiarti, Indonesia

15:00 **Operational FDR in New Zealand and Prediction of Fire Season Severity**
Jim Salinger, National Institute of Water & Atmospheric Research; WMO Commission for Agricultural Meteorology

15:20 **Operational FDR in Peru**
Maria Isabel Manta, Universidad Nacional Agraria La Molina; Constantino Alarco, National Meteorology and Hydrology Service

15:40 Break and Poster Session

SESSION 2 continued

Chair 4: Tim Lynham Rapporteur: V.R.K Murthy)

16:00 **Assessment of a Forest-fire Danger Index for Russia using NOAA Information**
Ivan Csiszar, University of Maryland; Anatoly Sukhinin, Eugene Ponomarev Sukhachev Institute of Forest; Douglas McRae, CFS

16:20 **Operational FDR in South Africa: Lowveld FDR; Advanced Fire Information System**
Christopher de Bruno Austin, Working on Fire, South Africa; Karen Steenkamp, Philip Frost, Council for Scientific and Industrial Research (CSIR), South Africa

16:40 **Operational FDR in Spain**
Antonio Mestre, State Meteorological Agency et al

17:00 Discussion and organization of break-out groups on FDR enhancements

17:20 Adjournment

17:30 Bus leaves Northern Forestry Centre to downtown hotel

Evening Free

TUESDAY, 15 JULY 2008

08:00 Bus leaves Crowne Plaza Chateau Lacombe for Northern Forestry Centre

SESSION 2 continued

(Chair 4: Narisara Thongboonchoo Rapporteur: Eva Valese)

08:40 **US National FDR: Past, Present and Future**
Matt Jolly, Francis M. Fujioka, USDA Forest Service

09:00 **Assessing the Fire Danger in Alberta: Application of the Canadian FDR System**
Nick Nimchuck, Alberta Sustainable Resources Development

09:20 **Development of a Global Early Warning System for Wildland Fires**
Tim Lynham, Natural Resources Canada; Ivan Csiszar, GOFC-GOLD, University of Maryland

09:40 Discussion

10:00 Break and Poster Session

10:30 **Webcast of Alberta fire weather briefing**
Nick Nimchuck, Alberta Sustainable Resources Development

10:50 **Synthesis of international reports on operational FDR approaches**
(Session 2 Chairs and Rapporteurs)

SESSION 3

11:20	FDR System Enhancement – Parallel Breakout Groups (BG) 1, 2 & 3 **Chair 5: Michael Brady Rapporteur: Lisa Bowker)** **Overview and directions for break-out group room locations**		
11:30	**BG 1. Weather Observations and Networks** Facilitators: Richard Carr and Antonio Mestre Rapporteur: Rod Suddaby Review of BG issues and questions to address	**BG 2. Weather Analyses** Facilitators: Kerry Anderson, Francis Fujioka and Brian Potter Rapporteur: Janet Kwan Review of BG issues and questions to address	**BG 3. Additional Indices of Fire Danger** Facilitators: Peter Englefield and Emilio Chuvieco Rapporteur: Erin Naydenov Review of BG issues and questions to address
	Weather in the Canadian Wildland Fire Information System & FDRS for West Africa, The GOFC-GOLD/WARN initiative Richard Carr,CFS; Cheikh Mbow, Senegal	**Fire Weather Analysis and Forecasting: Grid Points to Ponder** Francis Fujioka, USDA Forest Service	**Estimating Canopy Water Content from Airborne and Satellite Platforms** Susan Ustin, University of California, USA
	Remotely-Sensed FDRS to Support Forest/Land Fire Management in Indonesia Orbita Roswintiarti, Indonesian Space Agency	**Atmospheric Profile Representation in Fire Danger** Brian Potter, USDA Forest Service	**Fuel Moisture Measurements in FDR** Edward Delgado, Bureau of Land Management, USA
	Fire Weather Program - Province of Ontario Mick Rice, Ontario Ministry of Natural Resources	**Errors in Numerical Weather Data and Their Impacts on FDR Systems** Karl Kitchen, UK Met. Service	**Remote Sensing and Human Factors in FDR** Emilio Chuvieco, University of Alcala, Spain
	Agrometeorological Networks in Argentina Carlos Di Bella, INTA /Redlatif Regional Fire Network, Argentina	**Climate Forecast, Early Warming and Response to Peatland Fires in Central Kalimantan, Indonesia** Pietro Ceccato, International Research, USA	
12:30	Lunch		

13:30	**Discussion**	**Discussion**	**Discussion**
	Prepare summary	Prepare summary	Prepare summary

SESSION 3 continued

FDR System Enhancement – Plenary 1 to consider Breakout Group Reports
Chair 5: Michael Brady Rapporteur: Lisa Bowker

15:00 **BG 1 Presentation of Summary on Weather Observations and Networks**
Richard Carr and Antonio Mestre Rapporteur: Rod Suddaby

15:30 Break and Poster Session

16:00 **BG 2 Presentation on Summary of Weather Analyses**
Kerry Anderson, Francis Fujioka and Brian Potter Rapporteur: Janet Kwan

16:30 **BG 3 Presentation of Summary on Complimentary Indices of Fire Danger**
Peter Englefield and Emilio Chuvieco Rapporteur: Erin Naydenov

17:00 Overview of breakout session II and room locations, and adjournment

17:20 Bus leaves Northern Forestry Centre to downtown hotel

Evening Free

WEDNESDAY, 16 JULY 2008

08:00 Bus leaves Crowne Plaza Chateau Lacombe for Northern Forestry Centre

SESSION 3 continued

FDR System Enhancement – Parallel Breakout Groups (BG) 4, 5 & 6
(Chair 6: Matt Jolly Rapporteur: Michael Brady)

08:40	**BG 4. Data Management** Facilitators: Rod Suddaby and Guswanto Abdul Gani Rapporteur: Erin Naydenov Review of BG issues and questions to address	**BG 5. Approaches to Defining and Evaluating Fire Danger Levels** Facilitators: Steve Taylor and Nathalie Lavoie Rapporteur: Richard Carr Review of BG issues and questions to address	**BG 6. Smoke Forecasting and Monitoring** Facilitators: Kerry Anderson and Orbita Roswintiarti Rapporteur: Janet Kwan Review of BG issues and questions to address
	Data Management in the CWFIS: An IT Perspective Rod Suddaby, Canadian Forest Service	**FDR Implementation and Calibration in the Alpine Region of Italy** Eva Valese, University of Padova, Italy	**FDR-related Haze Early Warning and Issues Re: Haze Forecasting in SE Asia** Orbita Roswintiarti, Indonesia Space Agency
	National and Regional FDR Data Management in Southeast Asia Guswanto Abdul Gani, Indonesia Geophysical and Meteorological Agency	**Adoption of the FFMC for the Canadian FWI System for FDR in the Province of Zhejiang, China** Y. Wang, CFS	**The Bluesky Western Canada (BC/Alberta) Pilot Project** Steve Sakiyama, BC Ministry of Environment, Canada
	Weather Data for FDR in Southeast Asia Ahmad Zaki, Malaysian Meteorological Department	**Calibration of the Canadian FWI System for SE Asia** Robert Field, University of Toronto;	**Long-Range Air Quality Modeling: The Impact of Large Fires** Bryce Nordgren, USDA Forest Service
	Forest Information Management Challenges in the Northwest Territories Kathleen Groenewegen, Government of NWT	**Statistical Modeling of Fire Risk Using NFDRS Outputs** Francis Fujioka, USDA Forest Service	**Smoke Emissions Estimates from Forest Fire Behaviour** Kerry Anderson, CFS
			Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAsS) Amber Soja, National Institute of Aerospace, USA
09:40	Discussion	Discussion	Discussion
10:30	**Break**		
10:50	**Discussion continued** Prepare summary	**Discussion continued** Prepare summary	**Discussion continued** Prepare summary

12:30 Lunch

SESSION 3 continued

FDR System Enhancement – Plenary 2 to consider Breakout Group Reports
Chair 6: Matt Jolly Rapporteur: Michael Brady

13:30 BG 4. Presentation on Summary of Data Management
Rod Suddaby and Guswanto Abdul Gani Rapporteur: Erin Naydenov

14:00 BG 5. Approaches to Defining and Evaluating Fire Danger Levels
Steve Taylor and Nathalie Lavoie Rapporteur: Peter Englefield

14:30 BG 6. Presentation on Summary of Smoke Forecasting and Monitoring
Kerry Anderson and Orbita Roswintiarti Rapporteur: Janet Kwan

15:00 Break

SESSION 4

Status of Operational Guidelines for Weather-based FDR
Chair 7: Jim Salinger Rapporteur: Robert Stefanski

15:20 WMO Operational Guidelines
M.V.K. Sivakumar, World Meteorological Organization

15:40 Commission on Agrometeorology Expert Team on Agrometeorological Aspects of Sustainable Agricultural Development (ET 1.3)
Antonio Mestre, Meteorology Agency of Spain

16:00 General Discussion

SESSION 5
Closing Session

16:20 Plans for reporting, follow-on events and workshop closure
Michael Brady, Canadian Forest Service

16:25 Vote of Thanks
M.V.K. Sivakumar, WMO, Geneva, Switzerland

16:40 Bus leaves Northern Forestry Centre to Fort Edmonton for evening event, including: tour of historic Fort Edmonton; western dinner (hosted) with cash bar; and First Nations dancers with music

21:00 Bus leaves Fort Edmonton to hotel downtown

THURSDAY 17 and FRIDAY 18 JULY 2008

09:00–16:30	Meeting of the WMO Commission for Agricultural Meteorology Expert Team 1.3. Crowne Plaza Chateau Lacombe, River Valley Room

Appendix 4. List of Presentations

	Presentation	Participant	Affiliation
	Session 1: Plenary		
1	Welcoming Statements	Jim Salinger	President, Commission for Agricultural Meteorology of WMO
2	Keynote Address- History and Legacy of Fire Danger Rating (FDR) in Wildland Fire Management	Martin Alexander	Canadian Forest Service
	Session 2: Plenary		
3	Operational FDR in Argentina	Carlos Di Bella	INTA/Redlatif Regional Network
4	Operational FDR in Argentina	Fernando Epele	Chubut Prov. Fire Management Service, Argentina
5	Wildfire Weather Analysis in Croatia using numerical modeling and CFFWIS products	Marko Vucetic	Meteorological and Hydrological Service
6	Operational FDR in China	Guang Yang; Zhan Shu Presented by: Yonghe Wang	Northern Forestry University – Canadian Forest Service (CFS)
7	Operational FDR in European Commission	Andrea Camia	EC Joint Research Center
8	Operational FDR in the United Kingdom	Karl Kitchen	UK Meteorological Service
9	Operational FDR in Indonesia	Guswanto Abdul Gani; Orbita Roswintiarti; Israr Albar	Indonesia Agency for Meteorology and Geophysics; Indonesia Space Agency; Department of

			Forestry
10	Operational FDR in Malaysia and Association of Southeast Asia Nations	Ahmad Zaki; Orbita Roswintiarti	Malaysia Meteorological Department; Indonesia Space Agency
11	Operational FDR in New Zealand	Jim Salinger	National Institute of Water and Atmospheric Research; WMO Commission for Agricultural Meteorology
12	Operational FRD in Peru	Constantino Alarco; Maria Isabel Manta Nolasco	National Meteorology and Hydrology Service; Universidad Nacional Agraria La Molina
13	Operational FDR in Russia	Anatoly Sukhinin; Ivan Csiszar	Akademgorodok; University of Maryland
14	Operational FDR in South Africa (C.A)	Christopher de Bruno Austin	Working on Fire, South Africa
15	Operational FDR in South Africa	Karen Steenkamp	Council for Scientific and Industrial Research (CSIR)
16	Operational FDR in Spain	Antonio Mestre	State Meteorological Agency
17	Operational FDR in the United States of America	Matt Jolly; Francis M. Fujioka	USDA Forest Service
18	Operational FDR in Alberta	Nick Nimchuck	Alberta Sustainable Resources Development

19	Global EWS for wildfires	Tim Lynham	Development of a Global Early Warning System for Wildland Fires
BG 1: Weather Observations and Networks			
20	Weather in the Candian Wildland Fire Information System	Richard Carr	
21	FDR for West Africa, the GOFC-GOLD/WARN initiative	Cheikh Mbow	Senegal
22	Remotely-Sensed FDRS to Support Forest/Land Fire Management in Indonesia	Orbita Roswintiarti	Indonesia Space Agency
23	Fire Weather Program – Province of Ontario	Mick Rice	Ontario Ministry of Natural Resources
24	Agrometeorological Networks in Argentina	Carlos Di Bella	INTA/Redlatif Regional Fire Network, Argentina
BG 2: Weather Analyses			
25	Fire Weather Analysis and Forecasting: Grid Points to Ponder	Francis Fujioka	USDA Forest Service
26	Atmospheric Profile Representation in Fire Danger	Brian Potter	USDA Forest Service
27	Forecasting Short, Medium, and Long Range	Karl Kitchen	UK Met. Service
28	Climate Forecast, Early Warning and Response to Peatland Fires in Kalimantan, Indonesia	Pietro Ceccato	International Research Institute for Climate and Society, Columbia University, USA
BG 3: Additional Indices of Fire Danger			
29	Estimating Canopy Water Content from Airborne and Satellite Platforms	Susan Ustin	University of California, USA

30	Fuel Moisture Measurements in FDR	Edward Delgado	Bureau of Land Management, USA
31	Remote Sensing and Human Factors in FDR	Emilio Chuvieco	University of Alcala, Spain
BG 4: Data Management			
32	Data Architecture of the CWFIS	Rod Suddaby	CFS
33	National and Regional FDR Data Management in Southeast Asia	Guswanto Abdul Gani	Indonesia Geophysical and Meteorology Agency
34	Regional Weather Data SE Asia	Ahmed Zaki	Malaysia Meteorological Department
35	Management of Natural Resources and Fire Data in the Northwest Territories	Kathleen Groenewegen	Government of NWT
BG5: Approaches to Defining and Evaluating Fire Danger Levels			
36	FDR Implementation and Calibration in the Alpine Region of Italy	Eva Valese	University of Padova
37	FDR collaboration in South East Asia	Robert Field	University of Toronto
38	FDR calibration in China	Yonghe Wang	CFS
39	Statistical Modeling of Fire Risk Using NFDRS Outputs	Francis Fujioka	USDA Forest Service
BG6: Smoke forecasting and monitoring			
40	Regional Haze Forecasting in South East Asia	Orbita Roswintiarti	Indonesia Space Agency
41	Western Canada Bluesky Pilot Project	Steve Sakiyama	BC Environment
42	Air Quality Forecasting	Bryce Nordgren	US Forest Service
43	Smoke Emissions Estimates	Kerry Anderson	CFS

44	Preview of ARCTAS 2008 study	Amber Soja	National Institute of Aerospace, USA
	Session 4: Plenary		
45	WMO Operational Guidelines	M.V.K. Sivakumar	WMO
46	Commission on Agrometeorology Expert Team on Agrometeorology for Sustainable Development (ET 1.3)	Antonio Mestre	Meteorology Agency of Spain
	Session 5: Plenary		
47	Plans for reporting, follow-on events and workshop closure	Michael Brady	Executive Director GOFC-GOLD, Canadian Forest Service