EWC II
Second International Conference
on Early Warning
16-18 October 2003
Bonn, Germany
www.ewc2.org

# Early Warning of Wildland Fires[1]

## 1. Rationale: Wildland Fire, Early Warning and Sustainable Development

Sustainable development of natural vegetation systems, land-use systems and rural populations in many countries are at risk due to wildland fires that devastate valuable vegetation resources (forests and other wildlands, farmlands, pastures, plantations, etc.), in both the short-term (disruption of ecosystem processes, economic losses, humanitarian problems due to destruction of crops and other values at risk, including human health due to impacts of smoke) and the long-term (degradation of stability and productivity of ecosystems and land-use systems).

These fires often occur as consequence of extreme weather situations and inter-annual climate variability, e.g. during droughts caused by El Niño during which land-use fires escape control, or after precipitation-rich periods (e.g., La Niña) that result in rich growth of vegetation and an increased availability of fuels (combustible material). The underlying causes of damaging wildfires and excessive application of fire in land-use systems are deeply rooted in the problems of rural societies that are undergoing rapid demographic changes and are experiencing the loss of traditional knowledge and skills due to the trend of globalisation, and confrontation with external pressure on limited vegetation resources.

Secondary effects of destructive wildfires include the loss of vegetation that protects the soil. As a consequence the fire-affected sites are often degraded by wind and water erosion. Increased water runoff also leads to disastrous floods and landslides, affecting drinking water availability and quality, or leading to siltation of reservoirs.

## 2. Methodologies and Systems for Early Warning of Wildland Fires

Early warning (EW) of wildland fire and related hazards include a variety of methodological approaches and systems to identify precursor developments and assess / predict the escalation of the wildland fire theatre.

**(a) Assessment of fuel loads.** Ground measurements and to a certain extent also satellite-generated information allow to determine the amount of fuels (= combustible materials) available for wildland fire. This is important because dryness and fire risk alone do not determine the extent and severity (= severity of impact) of fire.

[1] This paper has been compiled by the Global Fire Monitoring Center (GFMC). The names of contributing authors and contacts are provided in Annex IV.

**(b) Prediction of lightning danger.** Methods exist for observing / tracking lightning activities as source of natural ignition (ground-based lightning detection systems; spaceborne monitoring of lightning activities).

**(c) Prediction of human-caused fire factors.** Modelling / predicting human-caused fire starts is critical, since in most countries fires are caused directly or indirectly by human activity. This field of research requires adequate consideration to socio-economic factors (ownerhips, land uses, unemployment problems, etc.).

**(d) Prediction of fuel moisture content.** This term is closely related to the readiness and ease of vegetation to burn. EW systems include meteorological danger indices and spaceborne information on vegetation dryness (intensity and duration of vegetation stress ) and soil dryness. Prediction of inter-annual climate variability / drought, particularly related to ENSO, is important for preparedness planning in many countries.

The above referred factors are related to the ignition danger, which is associated to the starting of the fire. Once the fire stars, it is critical also to consider the propagation patterns, which are related to fuel loads, terrain characteristics and wind flows, basically.

**(f) Prediction of wildfire spread and behaviour:** Airborne and spaceborne monitoring of active fires allows the prediction of movements of fire fronts to areas with values at risk. The technologies used include airborne instruments to monitor fire spread in situations of reduced visibility (smoke obscured) or to cover large areas. A large number of orbiting and geostationary satellites are available to identify active fires. Numerous wildland fire behaviour models are in place that allow the prediction of spread and intensity of wildland fires.

Hazards related to wildland fire include post-fire secondary disasters (water runoff, erosion, landslides, flooding) and air pollution threatening human security and health.

**(g) Assessment of smoke pollution.** *In situ* air quality monitoring systems allow tracking of fire smoke pollution and issue alerts (warnings to populations). Surface wind prediction allows prediction of smoke transport from fire-affected regions to populated areas. Satellite imageries can depict smoke transport.

To predict future of fire occurrence, weather conditions, which have great impact in the beginning and spreading of the fire, should be considered in a medium- to long-term perspective.

**(h) Prediction of climate variability and fire danger:** During El Niño events, for example, sea temperature at the surface in the central and eastern tropical Pacific Ocean becomes substantially higher than normal. During La Niña events, the sea surface temperatures in these regions become lower than normal. These temperature changes can drive major climate fluctuations around the globe and once initiated, such events can last for 12 months or more. Droughts associated with recent El Niño events have resulted in widespread controlled burning and uncontrolled wildfires, resulting in extreme fire and smoke episodes, particularly in South East Asia and in the Americas.

**(i) Prediction of climate change and fire danger:** Recent Intergovernmental Panel on Climate Change (IPCC) reports have emphasized the fact that climate change is a current reality, and that significant impacts can be expected, particularly at northern latitudes, for many decades ahead. Model projections of future climate, at both broad and regional scales, are consistent in this regard. An increase in boreal forest fire numbers and severity, as a result of a warming climate with increased convective activity, is expected to be an early and significant consequence of climate change. Increased lightning and lightning fire occurrence is expected under a warming climate. Fire seasons are expected to be longer, with an increase in the severity and extent of the extreme fire danger conditions that drive major forest fire events.

## Application: Policies, Gaps and Trends

Most industrial countries have EW systems and institutional capabilities in place to address the above-mentioned issues. In countries where fire occurrence and fire smoke pollution is of minor importance such systems are not in use or are restricted to the prediction of fire danger (item 2.c).

The majority of developing countries and countries in transition do not have in place most of the systems. These countries are seeking technical and scientific cooperation with donor countries to develop locally applicable EW systems. There is a new trend to support decentralized approaches such as the use of "simple" EW indices to be used at local (community) level.

At international level it has been recognized that the EW component in fire research and development has received less attention than fire monitoring.

Consequently, it has been decided recently to push R&D in early warning of wildland fires. A focussed scientific workshop has been convened in June 2003 to address the contribution of remote sensing to EW of wildland fire (Annex I). The World Weather Research Programme (WWRP) is currently preparing a new international collaborative activity. A kick-off workshop "International Collaboration in Fire Weather Research" will be held in Australia, 9-10 October 2003, prior to EWC II (Annex II). The recommendations from these two international workshops will be transmitted to the Early Warning Conference-II. The UN-ISDR Working Group on

Wildland Fire through the GFMC and in collaboration with the UN-ISDR Working Group on Early Warning is monitoring and facilitating international collaborative efforts in EW of wildland fire.

In the following selected examples are given for global to local early warning systems for wildland fire. A complete inventory of systems available worldwide is found on the web page "Global, Regional and National Fire Weather and Climate Forecasts" of the Global Fire Monitoring Center (GFMC).

## 3. Global to Local Forecasts of Fire Potential

### 3.1 Global and Regional Predictions

Predicting the influence of weather on fire ignition and spread is an operational requirement for national and global fire planning by the US National Interagency Coordination Center (NICC), which is the support center for wildland firefighting in the U.S.A.. NICC is home to seven federal agencies including the Bureau of Land Management, National Park Service, Fish and Wildlife Service, and Bureau of Indian Affairs, all in the Department of the Interior; and the Forest Service, in the Department of Agriculture. NICC's Predictive Services produces national wildland fire outlook and assessment products at weekly to seasonal time scales. This is currently done by considering standard National Weather Service seasonal forecast products of temperature and precipitation (see Brown et al. 2002, 2003) along with other indicators, and carefully exercised human judgment.

By contrast, nowcasts of fire danger potential at individual locations have been carried out for decades at individual US station locations using the US Forest Service (USFS) National Fire Danger Rating System (NFDRS; Deeming and others, 1977). This process has been automated and implemented nationwide, resulting in web-based displays of the NFDRS indices. The NFDRS explicitly describes the effects of local topography, fuels and weather on fire potential. Fuel moisture models relate moisture content to cumulative precipitation, precipitation extent and variation, temperature, and relative humidity. These fire danger nowcasts are updated almost daily, but they only allow fire managers to react to the current weather and climate conditions, rather than plan for the upcoming fire season. Can NFDRS indices also be forecast with a state of the art dynamical seasonal prediction model? Again, official NWS forecasts are only issued for temperature and precipitation. Forecasts for a number of more fire relevant variables, such as relative humidity, and wind speed, are still experimental and in many cases the fire community has had to empirically adapt to the official NWS forecasts of temperature and precipitation.

Now, as described previously by Roads et al. (2001a,b, 2002, 2003c,d) the Scripps Experimental Climate Prediction Center (ECPC) has been routinely making experimental, near real-time, long-range dynamical forecasts since 27 September

1997 of a number of additional variables relevant to fire danger forecasts. Images from these forecasts are regularly shown on the worldwide web (http://ecpc.ucsd.edu/; Roads et al. 2003c). The global model is a version of the National Centers for Environmental Prediction's (NCEP's) global spectral model (GSM; Kalnay et al. 1996, Roads et al. 1999) used for the NCEP/NCAR reanalysis. With the GSM forecasts as boundary conditions a higher resolution regional spectral model (RSM; Juang et al. 1997) is also run for various regions (US, SW, CA, BZ; see e.g. Roads et al. 2003a,b) to provide increased geophysical detail. The initial conditions and SST boundary conditions for these experimental global forecasts come from the NCEP Global Data Assimilation (GDAS) 00UTC operational analysis, which is available nearly every day in near real time on NCEP rotating disk archives, to interested researchers. Transforming NCEP's higher-resolution operational global analyses to lower (vertical and horizontal) resolution initial conditions for the global model, 7-day global and regional forecasts are made every day and every weekend these global and regional forecasts are extended to 16 weeks. ECPC's experimental forecasts are certainly not superior to official forecasts from NCEP, which use not only similar dynamical models (ECPC models are actually older fixed versions of NCEP's constantly improving models), but also take into account other climatic features that are not yet adequately represented in any dynamic model, (i.e. various climatic trends, tropical teleconnections, innate human forecast experience, etc.). However, the documented skill of the dynamical system (e.g. Roads et al. 2001a) does seem to at least be comparable to official forecasts, which indicates that these experimental forecasts may at least be a useful research tool for developing various forecast applications at short and long time leads.

The ECPC has therefore been attempting (Roads et al. 2003e) to develop experimental forecasts of the NFDRS indices in order to augment current nowcasts from station observations and current seasonal forecast output of only temperature and precipitation. Basically, since dynamical models have demonstrated some skill for forecasting various meteorological variables like temperature, relative humidity, and mean wind speed at seasonal time scales, a goal of the ECPC has been determine whether the perceived meteorological forecast skill can carry over to forecasts of fire danger and whether the federal fire agencies should develop a more comprehensive seasonal fire danger forecasting capability. Encouragingly, Roads et al. (2001a) did show that a simplified measure of fire danger, namely the Fosberg (1972) Fire Weather Index (FWI) was capable of being predicted at seasonal time scales, mainly because of the inherent predictability of relative humidity, which is a significant component of the FWI, and other NFDRS indices. In addition, the FWI is forecast globally as well as just over the US and given its US skill, the FWI may eventually prove to be useful in other global regions.

### 3.2 The U.S. National Fire Plan

A very large and high profile effort is underway in the U.S.A. related to regional predictions of fire potential and fire weather. Under the U.S. National Fire Plan put together in 2000-2001, five regional Fire Consortia for the Advanced Modeling of Meteorology and Smoke (FCAMMS) have been established in the U.S. to conduct research and develop new products to address the following:

1. Increase understanding of fire-weather, fire danger, fire behaviour, and smoke transport/diffusion from fires
2. Provide tools to enhance fire-fighter abilities to manage fires
3. Enhance our ability to predict and respond to the dangers of wildfire
4. Develop products and transfer new technologies related to national and regional fire weather and air quality
5. Expand our knowledge of the physics of fire-atmosphere interactions.

Each Consortium is heavily involved in regional fire-weather predictions and smoke transport/diffusion predictions, using state-of-the-art high resolution atmospheric mesoscale models. The FCAMMS represent one of the most comprehensive fire-weather prediction programs in place world wide.

### 3.3 A National Forest Fire Information and Early Warning System: The Mexico Case

Following the extreme fire events of 1998, fire management agencies in Mexico realized the need for an integrated fire information system. Therefore, at their request, the Canadian Forest Service developed an operational prototype system for Mexico. The Mexico Fire Information System (Sistema de Información de Incendios Forestales) was developed in cooperation with the Secretariat of the Environment and Natural Resources (SEMARNAT) of Mexico. This system was launched on the Web in the spring of 1999 (http://fms.nofc.cfs.nrcan.gc.ca/Mexico/). The web site offers daily maps of fire weather and fire behaviour potential for Mexico based on real-time weather data observed in Mexico and disseminated by the World Meteorological Organization through a Canadian weather satellite. The production of the maps is accomplished with the Canadian Forest Fire Danger Rating System (CFFDRS), which is used by Canadian fire management agencies for preparedness planning and fire-fighting resource allocation.

The system serves the following purposes:

- to help Mexico coordinate fire management at a national level
- to help Mexico reduce the risk of future fire disasters by developing and implementing an automated national system to monitor forest fire danger

- to demonstrate an example of Canadian/Mexican cooperation in mitigating a natural disaster common to both countries
- to demonstrate Canadian science and technology internationally

Over a period of three years, the system was evaluated by SEMARNAT to determine its applicability to Mexican climatic and forest conditions. Various strengths and weaknesses were identified, but in general the system was deemed to be of significant value and worth pursuing. In the meantime, it became integrated into SEMARNAT's reporting process and alertness level determination. Suggestions for improving the system came from both SEMARNAT and the CFS. These included:

- Derive a new fuel types map from Mexican forest inventory data
- Incorporate Mexican weather and hotspot data
- Increase the functionality of the web site
- Incorporate forecasted weather data
- Establish a mirror web site in Mexico

These proposals would significantly improve the accuracy and usefulness of the system.

In September 2002, two visitors from Mexico came to Canada to discuss these and other suggestions. At that time the data sources, models, software, and processes involved in the implementation of the system were demonstrated and explained, with a view to exploring opportunities to transfer operations to Mexico, adapting the system to Mexican fuel types and weather conditions, and outlining a methodology to calibrate the system outputs to make them applicable and meaningful in Mexico. The result of this visit was a joint proposal to implement the system in Mexico and to adapt the system for Mexican conditions. In December 2002, the North American Forestry Commission approved funding for this project, to be administered by the Mexican Nature Conservation Fund (Fondo Mexicano para la Conservación de la Naturaleza).

The proposed activities fall into three phases. The first phase, *System Implementation*, involves turning over daily processing to the Mexican agencies, adapting the CFFDRS to Mexican conditions, and making improvements to the web site. The second phase, *Training*, involves training Mexican personnel to run and apply the system and working with Mexican researchers and fire management personnel to develop a network of individuals specialized in fire danger rating system application. The third phase, *Scientific Calibration*, includes initiating research in the areas of fire occurrence prediction, fuel model development, fire threat analysis, and fire weather forecasting.

According to the proposal, the first step in Phase 1 was to train key Mexican personnel in the principles and use of the operational information system and the underlying fire danger rating models. In March 2003, three Mexicans came to Canada to be trained in the data requirements, scientific models, and computer processing involved in the implementation and operation of the system. The training was successfully completed and plans were made for the next step of the project, which involves Canadian personnel travelling to Mexico to assist in the installation and configuration of the system there. A very busy forest fire season in Mexico has delayed these plans somewhat.

Two visits to Mexico are planned, one technical and one scientific. The goal of the technical visit will be to get the system running in Mexico City. It was decided that the existing Canadian weather feed will be used until a suitable agreement is reached between SEMARNAT and the Mexican meteorological service. All other aspects of the system will be independent of the current demonstration implementation, including the web site. The goal of the scientific visit will be to characterize the Mexican fire environment in order to calibrate the system outputs and develop a best-fit fuels map based on existing fuel types. Development of new fuel types, if necessary, will be left to the third phase of the project.

## 3.4 The Development of an Early Warning System for Forest Fire Management in East Kalimantan, Indonesia

During the 1980s and 1990s forest and land fires destroyed large parts of Indonesia's forest resources. Especially on the islands of Sumatra and Borneo forest and land fires have become a regular event during the yearly drought seasons. In 1997-98 during a drought season prolonged by the El Niño phenomena the worst fires in Indonesia's history affected 5.2 million hectare of forests, agricultural and grass land in East Kalimantan. The economic losses were estimated to be between three and six billion US Dollars. The haze from these fires affected national and international air traffic and forced the airports in Singapore and Kuala Lumpur to temporarily close down. The German supported Integrated Forest Fire Management Project (IFFM) developed an Early Warning / Predictive System for the Province of East Kalimantan in order to assess and reduce the risks of disastrous forest and land fires. Based on the fire risk assessment of the newly established Provincial and District Fire Centers early warning information is sent out to all stakeholders through already existing communication structures. The newly developed prevention concept guides the actions of governmental institutions, communities and concessionaires in order to prevent fires and consequently the destruction of forest resources which play an important role in the country's social and economic development.

Reliable and accurate data sources have been identified for this early warning system and a simple-to-use data processing system has been developed. To adequately respond to the early warning information a prevention concept with short term and long term fire prevention measures has been developed for the Province of East Kalimantan. To ensure that both, the early warning and the prevention system are functional, effective and efficient the improvement of the policy framework conditions for fire management have been supported and decentralized institutional and communication structures have been built up. Education, training and extension concepts have been developed to increase awareness of the public about fire issues and to train people in interpreting the information received and to make sure that they react accordingly.

The early warning system developed for East Kalimantan uses two tools: a) the Fire Danger Rating Index (FDR) based on the Keetch-Byram-Drought-Code and b) the Preparedness Level which is defined by the actual FDR, the actual fire occurrence, weather forecast, haze conditions and hot spots (hot temperature events) detected by using NOAA-AVHRR data. Due to the absence of weather data for remote areas in East Kalimantan (FDR for the province is currently based on only six meteorological stations along the east cost of the province). NOAA-AVHRR thermal channels will be used to include land surface temperature and rainfall probability data in dynamic fire risk mapping to assess the fire risks of remote areas more precisely. This method currently being tested could be a cheap and extremely valuable alternative for many countries facing the same problem of lacking sufficient meteorological stations to assess their fire risks adequately.

### 3.5 Long-Term Trends: Climate Change and Wildland Fire - The Boreal Forest Example

Recent Intergovernmental Panel on Climate Change (IPCC) reports have emphasized the fact that climate change is a current reality, and that significant impacts can be expected, particularly at northern latitudes, for many decades ahead. Model projections of future climate, at both broad and regional scales, are consistent in this regard. An increase in boreal forest fire numbers and severity, as a result of a warming climate with increased convective activity, is expected to be an early and significant consequence of climate change. Increased lightning and lightning fire occurrence is expected under a warming climate. Fire seasons are expected to be longer, with an increase in the severity and extent of the extreme fire danger conditions that drive major forest fire events. Increased forest fire activity and severity will result in shorter fire return intervals, a shift in forest age class distribution towards younger stands, and a resultant decrease in terrestrial carbon storage in the boreal zone. Increased fire activity will also likely produce a positive feedback to climate change, and will drive vegetation shifting at northern latitudes. The boreal zone is estimated to contain 35-40% of global terrestrial carbon, and any increase in the frequency and severity of boreal fires will release carbon to the atmosphere at a faster rate than it can be re-sequestered. This would have global implications, and must be considered in post-Kyoto climate change negotiations.

Increased protection of boreal forests from fire is not a valid option at this time. Fire management agencies are currently operating a maximum efficiency, controlling unwanted fires quite effectively. There is a law of diminishing effects at work here though, as increasing efficiency would require huge increases in infrastructure and resources. While it is physically and economically impossible to further reduce the area burned by boreal fires, it is also not ecologically desirable, as fire plays a major and vital role in boreal ecosystem structure and maintenance. Given these facts, it would appear that, if the climate changes as expected over the next century, northern forest managers will have to constantly adapt to increasing fire activity. The likely result would be a change in protection policies to protect more valuable resources, while permitting more natural fire at a landscape scale.

## 4. Community Involvement in Fire Management including Early Warning

Wildland fire risk, hazard and danger are determined by the ignition sources (mainly humans; lightning), ecosystem properties (presence and characteristics of fuels that determine fire intensity and severity; topography) and weather (desiccation of the vegetation, fire behaviour).

A lot can be done to prevent unwanted wildland fires. Fire prevention at community level traditionally involves instruments such as awareness raising, public information and incentive elements (e.g. participatory approaches). Integrated fire management systems include fuel management for fire hazard reduction.

On the other side, weather as the natural driver of fire danger is the only element that cannot be manipulated. However, it can be predicted. Early warning systems of fire danger have been developed for many climate and vegetation types. They are mainly designed or operational at national or regional levels and are of low resolution. Some pilot products have been designed for application at community level. Widespread application or technology transfer, however, is still in its infancy stages.

The greatest challenges ahead are transfer of knowledge and adapted technologies to the grassroot levels of those population groups that are dependent on using the ecologically beneficial effects of fire in their land-use systems, while at the same time becoming increasingly vulnerable to the destructive effects of uncontrolled wildfires. These population groups cannot take advantage of sophisticated fire warning and information systems that are outside their reach.

Thus, it is required to facilitate the transfer of knowledge in fire management to the most vulnerable population groups and vegetation systems, e.g.:

- Integrated Fire Management (Community-Based Fire Management) Systems
- Locally applicable fire management information systems including early warning components
- Fire management training for local application.

**Delivery Systems**

Local bodies (e.g., "Fire Management Committees") must be entrusted to take responsibility for fire management, including early warning. They can range from a strong federal or national system down to a local, community-based group. The full range of systems exist and work well in various parts of the world. The particular organization needed is dependent on the local/regional social and political system.

They are responsible, with the assistance of regional/international experts, to:

- develop the mechanisms
- organise collection and processing of data
- produce the indices, and
- communicate the risk to the local population who would then commit to a series of actions to mitigate the risk.

The delivery system for developing the local expertise is a key activity that includes:

- application of a "system" for predicting fire danger and risk
- organization to implement the process, and
- provision of the needed equipment and protocols.

Mechanisms for developing such community-based fire management approaches exist but they are not widely applied. What is needed are the resources to organize the transfer of the technical knowledge and provide training and support.

The establishment of fire management networks can be a very effective tool for providing support to local communities. As with the "Fire Management Committees", the networks can be at various levels; regional, national, or local groups. The network's purpose will also vary from assisting with the highly technical use of remote sensing data and products, to the application of local fire risk methods for communities.

**ANNEX I**

**4th International Workshop on Remote Sensing and GIS Applications to Forest Fire Management: Innovative Concepts and Methods in Fire Danger Estimation**
Ghent, Belgium, 5-7 June 2003

**Workshop Report** (published in UN ECE/FAO International Forest Fire News No. 28)

This technical workshop was co-organised by the EARSeL Special Interest Group (SIG) on Forest Fires and the Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) Fire Implementation Team. The SIG workshop followed three previous technical meetings held in Alcalá de Henares (1995), Luso (1998) and Paris (2001) and was focused on fire prevention, although other topics related to fire effects assessment were also covered.

More than 60 scientist from 15 different countries attended the meeting. Most of the attendees came from European Mediterranean states (Spain, Portugal, Italy, Greece and France), but there were also representatives of other European countries (U.K., Belgium, Germany, Ukraine, Switzerland). There were also attendees from Canada, Argentina, India and the USA.

The structure of the workshop was based on six invited lectures, four poster sessions and 3 round table discussion sessions. The lectures were organized around 3 topics: fuel characterization, fire risk mapping and burned land assessment. The techniques covered to improve fuel description were the application of radiative transfer models to moisture content estimation, developed by Stéphane Jacquemoud (University of Paris); the use of hyperspectral technologies for wildland fuel mapping, presented by Dar Roberts (University of California, Santa Barbara), and the derivation of canopy structure for fire modelling from lidar, illustrated by. Ralph Dubayah (University of Maryland). These lectures were followed by two poster sessions, one focussed on fuel moisture content estimation, and the other one on fuel type mapping, where 9 and 7 posters were presented, respectively. The lecture by S. Jacquemoud focused on the basis of radiative transfer models and the determination of plant water content, the importance of these physical models to better understand the contributions of different factors affecting plant reflectance and the potential to invert these models to estimate biochemical properties of plants. Ralph Dubayah offered a global view of the different available lidar systems, stressing the role of large-footprint full waveform digitising systems that his group are developing with NASA. Several study cases of tropical and temperate forests illustrated his lecture, showing the connection between lidar data and fire behaviour modelling. Dar Roberts presented research being conducted at his department using hyperspectral data from AVIRIS and Hyperion instruments to derive fuel moisture content and other biophysical properties of plants. The interest of developing spectral libraries was also emphasised.

The topics discussed on fire risk mapping issues covered: "Human fire causes: a challenge for modelling", presented by Vittorio Leone (University of Basilicata, Italy), and "Fire risk mapping methods", by Bryan Lee (Forestry Canada). V. Leone presented some thoughts on the different socio-economic motivations leading to fire ignition, from pure criminal attitudes to the advantage of economic interests. He made a strong case for considering fire as a natural factor in Mediterranean ecosystems. Bryan Lee presented different applications of the Canadian Fire Information System, which makes extensive use of remote sensing data and GIS analysis tools. In addition seven posters were exhibited on fire risk mapping.

The final lecture dealt with burned land mapping, focusing on "Fire regimes in protected areas of Sub-Saharan Africa, derived from the GBA2000 dataset", presented by Jean-Marie Grégoire (Joint Research Center, European Union). J.-M. Gregoire presented a spatial analysis of patterns of fire occurrence in several nature reserves of Africa, stressing the interest of fire managers of these areas in having access to temporal and spatial information on fire occurrence patterns. The general discussion on this lecture and the subsequent poster session (which included 20 contributions), emphasized the importance of providing well documented accuracy assessments for the burned land products, so they could be easily understandable by end-users. The average seasonal cycle and inter-annual variability deduced from the analysis of global burned surfaces and active fire long time series was identified as a key indicator contributing to the generation of global fire danger products.

The three round tables were focused on: Burned land mapping as an input to fire danger assessment, moderated by Bryan Lee (Forestry Canada), Operational problems for the estimation of fuel properties, chaired by Jan W van Wagtendonk (USGS Western Ecological Research Center, Yosemite Field Station), and operational integration of remotely sensed and socio-economic data for fire danger rating, coordinated by Vittorio Leone (University of Basilicata, Italy). In all cases, the importance of addressing the needs of information end-users was underlined. Different levels of end-users should also be distinguished, from fire managers (with different interests depending on their scale of planning), to scientist working in atmospheric or ecological modelling.

Additionally, a general discussion on future activities of the Forest Fires SIG, covering the potential participation in Global networks (VI Framework Program) was coordinated by Pilar Martin (National Council for Scientific Research, Spain).

As part of the meeting format, poster sessions were designed to allow detailed one-on-one discussions with poster authors and after each poster session a general summary discussion was held on the poster topics. These general discussions offered an excellent opportunity to share ideas about the application of remote sensing techniques to improve fire danger assessment and fire mapping.

One of the general recommendations of the workshop was to stress the importance of deriving global products for fire danger estimation, which could serve regional managers interested in strategic planning, as well as global scientist dealing with the impacts of fire upon atmosphere and vegetation. This global fire danger product may be designed in a hierarchical way, serving the various interests of end-users in different geographical regions: from more qualitative systems, where input data is scarce, to more quantitative-detailed frameworks, in those countries or regions where the required spatial information is more readily available. The global product should include a proper characterization of fuel properties (moisture content, fuel loads, fuel geometry, etc.), as well as meteorological patterns and the assessment of those human activities related to fire occurrence. This global fire danger product might be developed in the framework of the GOFC/GOLD-Fire program, bringing together the international pool of expertise in this research area. The workshop also underlined the importance of providing well documented products both in terms of the physical variables they include (considering temporal and spatial scales), and in terms of documenting the quality/reliability of the product.

Within European research programs, the development of a specific network addressing remote sensing and fire danger was also recommended. This network could be presented within the available instruments of the VI Research Framework Program of the European Union, and linked to the global components of European research, such as the GMES. Close connections to GOFC-GOLD and other international network development initiatives (UN International Strategy for Disaster Reduction; Global Fire Monitoring Center, FAO, etc.) would also help to reinforce the global perspective.

Web page of this report:
http://www.fire.uni-freiburg.de/iffn/iffn_28/research2.pdf

## ANNEX II

**Workshop on International Collaboration in Fire Weather Research**
Bureau of Meteorology, Melbourne, Australia, 9-10 October 2003

The involvement of the Australian Bureau of Meteorology in the new Bushfire Cooperative Research Centre has enhanced a number of pre-existing bilateral discussions between different parties, including the Bureau of Meteorology Research Centre, US Forest Service, and the World Weather Research Program, with a common theme of seeking to collaborate to further common aims and needs. It has been decided that a workshop, to be held under the auspices of the WWRP and to which all interested parties are invited, will be held on 9-10 October 2003 to further these discussions. The purpose of the workshop will be to explore common needs in fire weather research, and identify opportunities to establish collaborative research plans between different agencies. The workshop program is yet to be fully developed, but will follow the broad plan below. At the end of the two days, we would aim to have established plans that are practical, achievable, and funded, and which will lead to an on-going international program of fire weather research.

Areas for discussion include

- Short-range fire weather prediction
- Medium range to seasonal fire weather outlooks
- Fire weather under climate /climate variability change
- Fire behaviour models
- Impact of weather on fuel state
- Smoke transport
- Decision support systems
- Remote sensing issues
- Training/stakeholder education
- Identification of operational user requirements

## ANNEX III References

### Section 1

Global Fire Monitoring Center (GFMC) website:
http://www.fire.uni-freiburg.de/

Global, regional and national fire weather and climate forecasts:
http://www.fire.uni-freiburg.de/fwf/fwf.htm

Regional and global vegetation fire emissions:
http://www.fire.uni-freiburg.de/vfe/vfe.htm

Wildland fire monitoring:
http://www.fire.uni-freiburg.de/current/globalfire.htm

IDNDR Report on Early Warning for Fire and Other Environmental Hazards
http://www.fire.uni-freiburg.de/programmes/un/idndr/idndr_co.htm

Global Observation of Forest Cover/Global Observation of Landcover Dynamics (GOFC/GOLD) - Fire Mapping and Monitoring:
http://gofc-fire.umd.edu/

World Health Organization (WHO), Health Guidelines for Vegetation Fire Events
http://www.fire.uni-freiburg.de/programmes/un/who/who.html

UN-ISDR Working Group on Wildland Fire:
http://www.unisdr.org/unisdr/WGroup4.htm

Wildland fire meetings in 2003, including EW of Wildland Fires:
http://www.fire.uni-freiburg.de/course/meeting.htm

Innovative Concepts and Methods in Fire Danger Estimation by Remote Sensing
http://www.fire.uni-freiburg.de/iffn/iffn_28/research2.pdf

State-of-the-art synthesis volume on spaceborne wildland fire monitoring, dedicated to the ISDR:

Ahern, F., J.G. Goldammer, and C. Justice (eds.), 2001. Global and regional vegetation fire monitoring from space: Planning a coordinated international effort. SPB Academic Publishing bv, The Hague, The Netherlands, 302 p.

State-of-the-art synthesis volume on spaceborne wildland fire danger estimation and mapping:

Chuvieco, E. (ed), 2003. Wildland fire danger estimation and mapping: the role of remote sensing data. World Scientific Publishing, Singapore.

**Section 3.1**

Brown, T. J., A. Barnston, J.O. Roads, R. Martin, K.E. Wolter, 2003. 2003 Seasonal Consensus Climate Forecasts for Wildland Fire Management. Experimental Long-Lead Forecasts Bulletin, Vol. 12.

Deeming, John E., Robert E. Burgan, and Jack D. Cohen, 1977. The National Fire-Danger Rating System-1978. Gen. Tech. Rep. INT-39. Ogden, UT. U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 63 pp.

Fosberg, M.A., and F.M. Fujioka. 1987. Medium- and extended-range fire severity forecasting: A national research plan. Preprints of the Ninth Conference on Fire and Forest Meteorology, San Diego, American Meteorological Society, 273-277.

Juang, H., S. Hong, and M. Kanamitsu 1997. The NMC nested regional spectral model. An update. Bull. Amer. Meteor. Soc. 78, 2125-2143.

Kalnay, E., M. Kanamitsu, R. Kistler, W. Collins, D. Deaven, L. Gandin, M. Iredell, S. Saha, G. White, J. Woolen, Y. Zhu, A. Leetma, R. Reynolds, M. Chelliah, W. Ebisuzaki, W. Higgins, J. Janowiak, K.C. Mo, R. Jenne, and D. Joseph, 1996. The NCEP/NCAR 40-Year Reanalysis Project, Bulletin of the American Meteorological Society 77, 437-471.

Roads, J. O., K. Ueyoshi, S.-C. Chen, J. Alpert, and F. Fujioka, 1991. Medium-Range Fire Weather Forecasts, Intern. Jour. of Wildland Fire 1, 159-176.

Roads, J.O., S-C. Chen, F. Fujioka, M. Kanamitsu and H., Juang, 1997. Global to Regional Fire Weather Forecasts. Int. Forest Fire News No. 17, 33-37.

Roads, J., S.-C. Chen, M. Kanamitsu, H. Juang, 1999. Surface water characteristics in NCEP global spectral model reanalysis. J. Geophys. Res. 104, 19307-19327.

Roads, J.O. and S-C. Chen, 2000. Surface Water and Energy Budgets in the NCEP Regional Spectral Model. JGR-Atmospheres 105, 29539-29550.

Roads, J.O., S-C. Chen and F. Fujioka, 2001a. ECPC's Weekly to Seasonal Global Forecasts. Bull. Amer. Meteor. Soc. 82, 639-658

Roads, J., B. Rockel, E. Raschke, 2001b. Evaluation of ECPC's Seasonal Forecasts Over the BALTEX Region and Europe. Meteorologische Zeitschrift Vol. 10 (4), 283-294.

Roads, J. and S. Brenner, 2002. Global Model Seasonal Forecasts for the Mediterranean Region. Israel Journal of Earth Sciences 51 (1), 1-16.

Roads, J., S.-C. Chen, M. Kanamitsu, 2003a. US Regional Climate Simulations and Seasonal Forecasts. Journal of Geophysical Research-Atmospheres (in press).

Roads, J.O., S.-C. Chen, S. Cocke, L. Druyan, M. Fulakeza, T. LaRow, P. Lonergan, J. Qian and S. Zebiak, 2003b. The IRI/ARCs Regional Model Intercomparison Over Brazil. J. Geophys. Res. (in press)

Roads, J., S.-C. Chen, J. Ritchie, 2003c. ECPC's Mar. 2003 Atmospheric Forecasts. Experimental Long-Lead Forecasts Bulletin, Vol 12, 6 p.

Roads, J.O., 2003d. Experimental Weekly to Seasonal, Global to Regional US Precipitation Forecasts. J. Hydrology (submitted)

Roads, J., F. Fujioka, R. Burgan, 2003e. Seasonal Fire Danger Forecasts. Int. J. Wildland Fire (submitted)

**Section 3.2**

FCAMMS website:
http://www.fs.fed.us/fcamms/

Eastern Area Modeling Consortium:
http://www.ncrs.fs.fed.us/eamc

Southern High Resolution Modeling Consortium:
http://shrmc.ggy.uga.edu/

California and Nevada Smoke and Air Committee:
http://www.cefa.dri.edu/COFF/coffframe.html

Northwest Regional Modeling Consortium:
http://www.atmos.washington.edu/%7Ecliff/consortium.html

Rocky Mountain Center:
http://www.fs.fed.us/rmc/

**Section 3.3**

México Wildland Fire Information System:
http://fms.nofc.cfs.nrcan.gc.ca/mexico/index.html

**Section 3.4**

Buchholz, G. and D. Weidemann. 2000. The use of simple fire danger rating systems as a tool for early warning in forestry. Int. Forest Fire News No. 23, 32-37.

IFFM Website: http://www.iffm.org/

**Section 3.5**

Stocks, B.J., Wotton, B.M., Flannigan, M.D., Fosberg, M.A., Cahoon, D.R., and Goldammer, J.G., 2001. Boreal forest fire regimes and climate change. p. 233-246 in Remote Sensing and Climate Modeling: Synergies and Limitations. M. Beniston and M.M. Verstraete (eds), Advances in Global Change Research, Kluwer Academic Publishers, Dordrecht and Boston.

Stocks, B.J., 2001. Forest Fires, Climate Change and Carbon Storage in Boreal Forests. In: ISDR Working Group on Wildland Fire 2002. UN International Strategy for Disaster Reduction (ISDR) Inter-Agency Task Force for Disaster Reduction, Working Group 4 on Wildland Fire, Report of the Second Meeting, Geneva, 3-4 December 2001.
Source: http://www.unisdr.org/unisdr/WGroup4.htm

## ANNEX IV Authors and Contacts

**Section 1**
Johann G. Goldammer, The Global Fire Monitoring Center (GFMC), Fire Ecology Research Group, Max Planck Institute for Chemistry, c/o Freiburg University, P.O. Box, 79085 Freiburg, Germany, e-mail: johann.goldammer@fire.uni-freiburg.de

**Section 3.1**
John Roads, Francis Fujioka, Robert Burgan
Contact: John Roads, Scripps Experimental Climate Prediction Center, UCSD, 0224, La Jolla, California 92093, U.S.A., e-mail: jroads@ucsd.edu

**Section 3.2**
Warren E. Heilman, USDA Forest Service, North Central Research Station, 1407 S. Harrison Road, Room 220, East Lansing, Michigan 48823, U.S.A., e-mail: wheilman@fs.fed.us

Al Ribeau (Coordinator for the FCAMMS and program leader for atmospheric research in the USDA Forest Service), USDA Forest Service, Washington, DC, U.S.A. e-mail: ariebau@fs.fed.us

**Section 3.3**
Peter Englefield and Arturo Raygoza
Contact: Peter Englefield, Fire Management Systems, Canadian Forest Service, Northern Forestry Centre, 5320-122 Street, Edmonton, Alberta T6H 3S5, Canada, e-mail: penglefi@nrcan.gc.ca

**Section 3.4**
Helmut Dotzauer and Lenny Christy
Integrated Forest Fire Management (IFFM), Kotak Pos 1202, 75001 Samarinda, KT, Indonesia, e-mail: iffmfire@samarinda.org

**Section 3.5**
Brian J. Stocks, Forest Fire and Global Change, Canadian Forest Service, Natural Resources Canada, 1219 Queen Street East, Sault Ste. Marie, Ontario P6A 2E5, Canada
e-mail: bstocks@nrcan.gc.ca

**Annex I**
Emilio Chuvieco, Departamento de Geografía, Universidad de Alcala, C/Colegios 2, 28801 Alcala de Henares, Spain, e-mail: emilio.chuvieco@uah.es

**Annex II**
Graham Mills Graham Mills, Bureau of Meteorology Research Centre, Box1289K Melbourne 3001 Australia, e-mail: g.mills@bom.gov.au