The GOFC-GOLD-Fire Program: A Mechanism for International Cooperation in Fire Mapping and Monitoring[1]

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Abstract

Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) is a panel of the Global Terrestrial Observing System (GTOS) and also a partner in the Integrated Global Observing Strategy (IGOS). The GOFC-GOLD Fire Mapping and Monitoring theme is aimed at providing the necessary coordination to improve fire data access and use, and to secure long-term fire observing systems. The GOFC-GOLD-Fire implementation areas address the needs of resource managers, policy makers and the scientific community, covering such topics as fire danger rating, fire detection and characterization, fire affected area mapping, post fire recovery, and fire emissions. The goals include summarising fire management and research information needs for data providers, improving access to and use of fire data and information, standardizing satellite products and determining their accuracy, promoting research and development to improve information provision, and securing long term global operational monitoring of fires. The GOFC-GOLD Fire implementation team is achieving these goals through a program of topical international workshops and regional networks of data providers, data brokers and data users. GOFC-GOLD is partnering with a number of related international organizations including the Global Wildland Fire Network and the Wildland Fire Advisory Group under the United Nations International Strategy for Disaster Reduction (UNISDR). The program also contributes to several Global Earth Observation System of Systems (GEOSS) activities through the development of the Global Wildland Fire Early Warning System, a global geostationary fire monitoring network; and use of satellite-based fire information for disaster monitoring and management. This paper focuses on the recent achievements of the GOFC-GOLD Fire program and its short- and mid-term agenda.

GOFC-GOLD Fire Overview

Background and organizational sturcture

The Global Observation of Forest Cover- Global Observation of Land Cover Dynamics (GOFC-GOLD) program was initiated in response to the Committee on Earth Observation (CEOS) to develop a stronger linkage between the Space Agencies and the users of earth observation technologies (Townshend et al. 2004). GOFC-GOLD is currently a project of the Global Terrestrial Observing System (GTOS), with a project office in Edmonton run by the Natural Resources Canada and the Canadian Forest Service (GOFC 2004). The secretariat for GTOS is at the United Nations Food and Agriculture Organization (FAO) in Rome (GTOS 2005).

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The fire component of GOFC-GOLD was initiated in 1998 at a kick-off meeting at the Joint Research Center, Ispra (Ahern et al. 2001). To help coordinate and guide its fire program, GOFC-GOLD established a secretariat and a fire implementation team consisting of data providers and data users (GOFC FIRE 2007). The aims of this team are to refine and articulate the international requirements for fire related observations, to increase access to and make the best possible use of existing and future observing systems for fire management, policy decision-making and global change research and ensure the provision of long-term, systematic satellite observations necessary for the production of the full suite of recommended fire products (Justice et al. 2003). Following the lead of the Land Cover component of GOFC-GOLD, the implementation team fostered the development of regional networks of data providers and users to capture regional specific information needs and priorities. Regional Fire Networks have been established in Southern Africa, Northern Eurasia, Southeast Asia, Australia and Latin America; a new network in South Asia is under development.

Objectives

Increase user awareness by providing an improved understanding of the utility of satellite fire products for resource management and policy within the United Nations and at regional, national and local levels

The GOFC-GOLD Fire Program is aiming at a continuous dialogue with the user community – with fire managers around the world. GOFC-GOLD Fire has developed strategic partnerships with a number of organizations that share some of the program goals, for example with the U.N. Interagency Strategy for Disaster Reduction (UNISDR) Working Group on Wildland Fire (UNISDR 2007) and its follow-up arrangements, the UNISDR Global Wildland Fire Network and the Wildland Fire Advisory Group, which is focusing on improving fire management capacity around the World.

Representatives of the Regional Wildland Fire Networks are members of the UNISDR Wildland Fire Advisory Group, which is serving as an advisory body to the United Nations. The regional networks are complemented by and closely working with the regional GOFC-GOLD fire implementation teams. Both networks are interacting in regional consultations and workshops aiming at the preparation of targeted proposals to the international community, notably the UN family.

GOFC-GOLD Fire, through its contributory projects, is also involved in the Group on Earth Observations (GEO) task CB-07-01d aimed at capacity building in developing countries. For example, following the requests of a number of countries GOFC-GOLD has supported the establishment of national to regional Web Fire Mappers.

Politically GOFC-GOLD and the Global Wildland Fire Network, through its Secretariat, the Global Fire Monitoring Center (GFMC), have cooperated in a number of political initiatives, e.g. a proposal for the development of an International Wildland Fire Accord (GFMC 2005). Members of the network and GFMC staff have contributed to the development of initiatives to develop innovative and dedicated global fire observing, such as the BIRD (Bi-Spectral Infrared Detector) project (Oertel et al. 2004) and have contributed to field validation and calibration experiments of various satellite sensors. This partnership has a great value for promoting the use of spaceborne assets in fire management and to include the

experience and needs of the user community to further development of innovative fire detection and monitoring systems.

Encourage the development and testing of standard methods for fire danger rating suited to different ecosystems and to enhance current fire early warning systems

Forest and land management agencies require an early warning system to identify critical time periods of extreme fire danger in advance of their occurrence. Early warning of these conditions will allow fire managers to implement fire prevention, detection and pre-suppression plans before fire problems begin. Remote sensing is one tool that can assist global, spatial early warning. Agencies are trying to improve and expand early warning systems that are based on traditional, ground-based data collection systems. It is imperative to augment our current ground-based approaches with remote sensing data providing new information that would be otherwise impossible or impractical to gather.

In addition to promoting basic research in this field, GOFC-GOLD Fire is a contributor to the emerging Global Wildland Fire Early Warning System (de Groot et al., 2006). This activity is led by the Global Fire Monitoring Center and is also one of the GEO tasks (DI-06-13). Details of this activity are discussed in a separate section below.

Develop an operational global geostationary fire network providing observations of active fires in near real time

An operational global geostationary fire monitoring network would enable monitoring of fires as they occur and capture the diurnal signature of fire activity. Currently the Imager on the US Geostationary Operational Environmental Satellites (GOES-East and GOES-West) allows for diurnal fire detection and monitoring throughout the Western Hemisphere. The European Meteosat-8 Spinning Enhanced Visible and Infrared Imager (SEVIRI) launched in 2002 provides diurnal fire monitoring capabilities in Western Europe and Africa. Sensors on board other geostationary satellites (MTSAT, FY-2 etc.) also provide the capability for fire detection.

GOFC-GOLD Fire has had two workshops on this topic at EUMETSAT, in March 2004 and December 2006. This activity has been also a contributor to GEO task DI-06-09 on the use of virtual constellations for risk management.

Establish operational polar orbiters with fire monitoring capability by providing operational moderate resolution long-term global fire products to meet user requirements and distributed ground stations providing enhanced regional products

The polar systems having full operational status are the NOAA Polar Orbiting Environmental Satellites (POES) the EUOMETSAT Polar System (EPS), operating AVHRR (Advanced Very High Resolution Radiometer). Many of the existing national or regional operational systems for detecting active fires rely on AVHRR data downloaded from direct readout stations (GOFC FIRE 2007). NASA Moderate Resolution Imaging Spectroradiometer (MODIS), which is a research instrument, has demonstrated the value that improved spatial resolution, radiometric calibration,

geolocation accuracy, and an extended suite of spectral bands can bring to fire remote sensing (Justice et al. 2002). Data from the ESA (Advanced) Along-Track Scanning Radiometer ((A)ATSR) have been processed to produce global compilations of night-time active fire and burn scars (Arino et al. 2005), while SPOT-VEGETATION data have been used to produce annual compilations of global burn scar. The U.S. Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) can detect fires at night via low light imaging in the visible wavelength region (Elvidge et al. 2001), a capability used in conjunction with data from other systems, such as AVHRR and MODIS.

GOFC-GOLD Fire is currently focusing on ensuring fire detection capabilities from future systems, such as NPP/NPOESS Visible Infrared Imagery Radiometer Suite (VIIRS) and sensors on Global Monitoring for Environment and Security (GMES) Sentinel satellites.

Develop long-term fire data records by combining data from multiple satellite sources

To generate a long-term, science quality, homogeneous fire data record, a number of issues related to inter-satellite and inter-sensor continuity need to be addressed. In this process the advancement of technology and the consequent improvement of data quality and the availability of an increasing number of sensors need to be considered. Specifics of such dynamic continuity for fire products need to be defined. A fundamental component of this process is product validation, which also allows the linkage of products from different sensors.

GOFC-GOLD Fire has been supporting the Global Climate Observing System (GCOS) and CEOS in defining requirements and capabilities for long-term fire data records and the generation of a white paper on a NASA Fire Earth System Data Record (Justice et al. 2006).

Establish operational polar orbiters with fire monitoring capability by providing operational high resolution data acquisition allowing fire monitoring and post-fire assessments

GOFC-GOLD Fire is supporting the development of new technologies for higher resolution, higher quality fire detection such as the experimental BIRD satellite developed by the German Aerospace Center DLR. Experience gained from the BIRD mission is being utilized by future systems currently in design and planning phase in various countries such as Germany, Australia, Canada and Argentina.

Continuity of a Landsat-class instrument is also essential for fire mapping and validation, including both active fires and burned areas. GOFC-GOLD Fire is supporting the efforts to coordinate data acquisition and utilization of data from various sensors, such as Terra/ASTER (Advanced Spacebrone Thermal Emission and Reflection Radiometer), and sensors on the IRS (Indian Remote Sensing) and CBERS (China-Brazil Earth Resources Satellite) platforms.

Enhance fire product use and access by developing operational multi-source fire and GIS data and making these available over the Internet

A considerable investment has been made by the space agencies around the World to develop improved satellite monitoring of the planet. To maximize the societal benefit of these systems to support natural resource management and decision-making, there needs to be a continued emphasis on ensuring that the data are converted to useable information and made available in a timely fashion. This process is becoming easier with advances in web technology and improved access to broadband Internet.

Recent advances in information technology make it easier integrate remote sensing products and GIS data within web-based GIS systems to provide resource managers with information that is timely accurate, and delivered in a readily accessible format.

Technologies already exist to create interactive web maps that incorporate data from a wide range of servers (in different locations); a key obstacle to improving these maps for active fire managers, is finding suitable data that are up-to-date, accurate, readily available and consistent across regions. There are a number of regional initiatives that also serve fire data from a direct broadcast station. GOFC-GOLD Fire is coordinating regional activities and is organizing a workshop on Direct Broadcast land applications in October 2007.

Establish an operational network of fire validation sites and protocols, providing accuracy assessment for operational products and a testbed for new or enhanced products

Validation of satellite active fire products is difficult because of practical problems in collecting independent reference data that characterize the location and physical properties of actively burning fires (e.g Csiszar et al. 2006). The validation of burned area products is less sensitive to the need for simultaneous collection of independent reference data with satellite overpasses, as the surface effects of fire are persistent.

GOFC-GOLD, in coordination with CEOS Working Group on Calibration and Validation Land Product Validation subgroup is developing and promoting validation protocols (e.g. Roy et al. 2005), which are primarily based on coincident higher resolution imagery (typically 30m). Product standardization and standardization of product accuracy reporting are also of high priority.

Operationally generate fire emission product suites of known accuracy providing annual and near real-time emission estimates with available input data sets

The common approach used in land-based emission quantifications relies on a combination of satellite burned area information, modeled fuel load amounts, estimates of combustion completeness and ground and/or airborne measured emission factors. Considering the advances in burned area mapping, likely the largest persistent challenge in global emissions modeling is the spatio-temporal quantification of different fuel types available for burning (Kasischke and Penner 2004). Satellite measures of global net primary productivity adjusted by region specific available fuel maps and validated through regionally representative field measurements can provide the means to estimate fuel loads more accurately.

Experimental satellite based measurements of the fire radiative power (FRP) may offer an important new way of directly estimating the amount of fuel consumed. GOFC-GOLD Fire fosters the evaluation of FRP and is actively promoting future sensor design to enable the continuous production of FRP.

Example GOFC-GOLD Fire contributions to GEOSS

Global Wildland Fire Early Warning System

Earth observation data is important to forest and land (or wildland) fire management through fire monitoring and early warning programs. Several hundred million hectares of vegetation burn every year on the global landscape, and many regions have reported increasing trends in fire activity. Wildland fires occur annually in all global vegetation zones and most fire is unmonitored and undocumented. Wildland fires can have many serious negative impacts on human safety, health, regional economies, and global climate change (others cited in de Groot et al. 2006). Many fire-related problems can be avoided, or at least mitigated, if forest and land management agencies (including land owners and communities) are provided with advanced warning of critical periods of extreme fire danger. Early warning allows fire managers to implement fire prevention, detection, and pre-suppression plans before fire problems begin.

The goal of a global early warning system for wildland fire is to provide a scientifically supported, systematic procedure for predicting and assessing international fire danger that can be applied from local to global scales. The system will support existing national fire management programs by providing longer term predictions of fire danger based on advanced numerical weather models, and it will provide a common international metric for implementing international resource sharing agreements during times of fire disaster. It will also provide early warning for countries where national systems do not exist. Because the system can be used at the local level, it can support local capacity building by providing a foundation for community-based fire management programs.

Early warning of wildland fire is based on fire danger rating, which originates from ground-based weather information and forecast models. Early warning is enhanced with satellite data, such as hot spots for early fire detection, and with spectral data on land cover and fuel conditions. The proposed global early warning system will provide both current and forecasted fire danger information, because both are important for fire management decision-making. For example, current and forecasted fire danger products will use actual and forecasted weather data to calculate component values (Figure 1a). Overlaying current fire danger maps with hot spot data (e.g., AVHRR, MODIS) indicates areas where ongoing fires combine with high fire danger to create the greatest current priority (Figure 1b, 1c). Combining forecasted fire danger maps with hot spot data will indicate critical areas where serious fire problems will occur if current fire activity persists. Such maps of potential future fire threat can be used for advanced planning of suppression resource acquisition and deployment.

Hot spot databases are also very valuable for calibrating early warning products to different global regions. For example, hot spot data has demonstrated robust capacity to calibrate a general fire danger code as a regional indicator of ignition potential in Southeast Asia (de Groot et al. 2005), which is used to plan daily

fire prevention and detection activities (de Groot and Field 2004). Hot spot data is ideal for calibrating fire danger codes for large-scale early warning purposes because of its frequent global coverage (see Csiszar et al. 2005) and rapid availability.

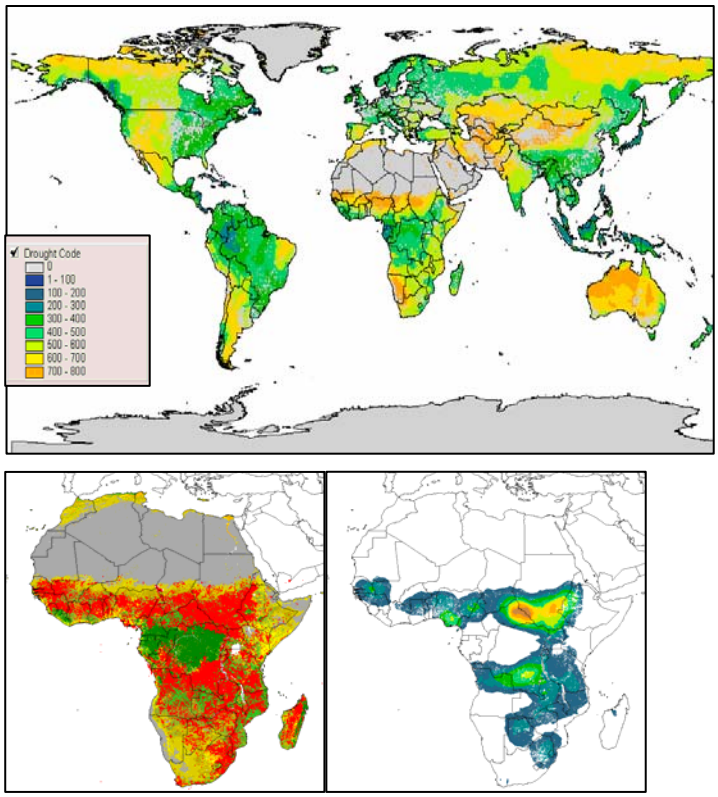

Figure 1—Examples of potential early warning products, including a) global fire danger using the Drought Code (DC) component of the Canadian Forest Fire Weather Index System (van Wagner 1987); b) DC overlaid by hot spot data (red); and c) spatial fire threat as assessed by DC and hot spot density.

Satellite-based Fire Information for Disaster Monitoring and Management

MODIS active fire detections

In recent years strategic fire management in Protected Areas has been enhanced by tools that integrate remote sensing and GIS data. With funding from NASA, the University of Maryland in collaboration with MODIS Rapid Response have developed a global near-real time mapping system to notify protected areas managers of fires in the area of interest. The Fire Information for Resource Management System (FIRMS 2007) uses data transmitted the MODIS instrument on board NASA's Terra and Aqua satellites. These data are processed to produce images and text files pertaining to active fire locations. These are ingested into a geo-database and disseminated to users using Web GIS (known as Web Fire Mapper), email alert and SMS/Text messages, and downloadable shape and text files of fires locations. Future developments will include the addition of the MODIS (Collection 5) burned area product.

Where possible, FIRMS works with regional networks to customize the Web GIS; in this way users are able to integrate fire information with local geospatial information (such as park boundaries and roads) enabling them to place MODIS active fires in their geographic context. FIRMS provides MODIS active fire data to natural resource managers, scientists and policy makers working in 38 countries. This worldwide group of users regularly accesses the system through querying the interactive map interface, downloading shape and text files. Users include the Tanzania National Parks Authority, WWF Indonesia, SERVIR in Central America and a range of scientists and natural resource managers from the Southern African Fire Network (SAFNet). NASA and University of Maryland also helped establish a fire early warning system in South Africa which distributes active fire information to a range of users including Eskom, South Africa's largest power company.

DMSP Fire Detection Services

It has been known since the early 1970's that fires can be detected at night using low light imaging data from DMSP/OLS. However, it has taken many years to develop ingest and processing capabilities to enable civil agencies use of near-real time OLS data in operational fire detection. In 1992 NOAA's National Geophysical Data Center established an archive for OLS data but was bound by a 72 hour hold on data distribution. NGDC began working on fire detection algorithms in 1994 and provided the first OLS based fire detection products in 1995. In 2000 the U.S. Air Force relaxed the hold on OLS data distribution down to 3 hours. Later that year NGDC began delivering regional OLS data in near-real time to the governments of Japan and Singapore for use in fire detection and provided software and training for OLS fire detection. In 2005 NGDC produced an integrated IDL toolkit designed for OLS fire detection, which was installed at the Indian National Remote Sensing Agency (NRSA). In 2006 NGDC rebuilt the near-real time processing and delivery system for OLS data and began to provide geolocated visible and thermal band (30 arc second) grids to subscribers. NGDC has demonstrated near-real time generation of fire detection pixels with reporting made as text files containing latitude / longitude and visible band digital number values for fires. Additional development would be required to turn this demonstration into an ongoing service.

Global Fire Monitoring Center contribution

GOFC-GOLD Fire is partnering with GFMC in its outreach to the fire data user and management communities. GFMC has been established in 1998 as a contribution of the Germany to the UNISDR (and its predecessor arrangement, the IDNDR). GFMC's global portal for wildland fire documentation, information and monitoring is publicly accessible through the Internet.

Since 2004 the GFMC is working with a number of UN and other international organizations on the preparation of an international wildland fire accord (an international agreement on cooperation in wildland fire management). The development of a strategic framework for international cooperation in wildland fire management together with the FAO, UNISDR and countries has been recommended by a ministerial meeting at the FAO in Rome, 14 March 2005, and resulted in the development of several documents that are constituting the main pillars for a "Strategy to Enhance International Cooperation in Fire Management": The Fire Management Global Assessment 2006 (FAO 2007a), the Fire Management Voluntary

Guidelines (FAO 2007b), and the Review of International Cooperation 2006 (FAO 2007c).

In 2004 two Joint UN Inter-Agency Advanced Wildland Fire Management Training Courses (one of them a "Training Course for Instructors in Community Based Forest Fire Management" financed by the FAO) were conducted by the GFMC for the SADC Region, in South Africa. The objectives of the courses aimed at training of medium- to high-level decision makers responsible for sustainable land management, forestry, agriculture, disaster management etc., to utilize existing knowledge and tools for appropriate planning and capacity building in wildland fire management. The training course objectives and procedures were coordinated with UNU-EHS and supported by UNEP-OCHA and FAO. Course participants received a certificate of attendance signed jointly by the heads of UNU-EHS and GFMC.

The GFMC aims at enlarging the cooperation with UNU-EHS. The contribution of the GFMC to UNU-EHC's mandate includes applied research for the development of concepts for capacity building in advanced wildland fire management. Depending on projects and requests the GFMC services would be able to cover:

• Methods of science and technology transfer for application in local fire management (wildland fire prevention, preparedness, suppression, rehabilitation) under different cultural, socio-economic and ecological environments

• Methods and application of people-centered fire management (Community-Based Fire Management)

• Development of national strategies and policies for wildland fire management, including legislation

• Development of standards for international cooperation in wildland fire management (common terminology, standard procedures for cooperation in wildland fire emergencies)

• Training courses for international wildland fire management specialists, including experts for assessment and intervention missions

Conclusion

GOFC-GOLD was established to improve the utility of existing observing systems for science and applications and to make the case for continued and improved observations. Since the inception of the fire component of GOFC-GOLD there has been a noticeable increase in fire science as indicated by the number of peer reviewed journal articles. This has been fueled in part by a large number of extreme fire events and the resulting investment in fire science but also by the increase in the availability of satellite fire data sets.

Attention has been given by GOFC-GOLD to improving the accessibility of satellite fire data for different user communities. This in turn has been aided by the increased use of internet delivery systems. Consistent global multi-year data sets are starting to be developed and made available for the first time. For some regions of the World this presents a unique view of fire extent and frequency at a small geographic scale. This is enabling scientists to study interannual variability in global fire extent and distributions and ultimately fire regimes. Burned area products are providing improved information use in modeling trace gas and particulate emissions from

biomass burning and to give comprehensive data on monthly and annual area burned. These data are currently being evaluated and validated by the GOFC-GOLD Regional networks, thereby exposing regional scientists to early versions of the products, helping to get feedback on data quality for regional and local applications and building a user community that understands the utility and limitations of the newly available data sets. With the participation of the Global Fire Monitoring Center, and the regional networks, GOFC-GOLD Fire is assembling these various data sets to complement existing national ground based and aerial records to provide a global fire assessment as a contribution the U.N.

Countries with fire problems are using these satellite data to provide strategic information for national fire management. Web fire mapping systems developed under contributory projects to GOFC/GOLD have enabled near real time access to satellite fire locations. Email alert systems working with SMS Text messaging are starting to meet the immediate and local needs of resource managers. Satellite fire images are now being shown as part of daily television weather and newspaper reports. Pictures of fires raise public awareness of fire management issues and fire hazards. However the digital divide remains and efforts need to be redoubled to meet the needs of fire data users without good internet connection.

The inclusion of satellite observations in fire early warning systems will help improve the spatial resolution of systems currently driven by weather data. Experiments with unmanned airborne vehicles (UAV's) and sensor webs are laying the ground work for improved observations of fires in support of real time tactical fire management.

Progress is being made to include fire observations as part of the next generation of geostationary and polar orbiting operational satellite monitoring although requirements of operational users are still secondary to the weather community. GOFC-GOLD is facilitating a global geostationary network of satellites monitoring the diurnal cycle of fire activity using the next generation of weather satellites. New sensor technologies are being developed and tested to improve fire detection and characterization. Development of small satellite technologies and constellation systems for fire monitoring will lead to considerable improvements in fire monitoring.

The MODIS fire program was specifically designed to not only generate high quality, global, systematic fire products but also to ensure the most efficient utilization of the information by the various user communities. The program builds on and contributes to internationally agreed procedures and protocols for data generation and distribution. GOFC-GOLD Fire also acts as a platform to facilitate communication and collaboration between the fire programs run by various agencies around the globe.

During the recent years the GOFC-GOLD Fire program has entered in its implementation stage. A number of contributory projects have now formed geographically or thematically organized networks that work in a coordinated fashion towards the goal of GOFC-GOLD Fire. The program is also a major partner of international initiatives, such GCOS, CEOS GEOSS. Strategic goals for the forthcoming years include the further integration of specific GOFC-GOLD Fire activities into the global observing systems.

A current priority is intensifying activities and cooperation in Africa. GOFC-GOLD is supporting a Pan African Regional network meeting, including a workshop

on fire early warning, planned to be held in Accra, Ghana later this year. Other GOFC-GOLD Fire supported meetings in 2007 include a fire session at the 32rd International Symposium on Remote Sensing of Environment (San Jose, Costa Rica), the 6th International Workshop of the EARSeL Special Interest Group on Forest Fires (Thessaloniki, Greece), a Land Direct Broadcast workshop in Mexico City, and meetings of the Latin American and Northern Eurasian regional fire networks in Argentina and Russia respectively.

All in all, good progress is being made through national programs and activities cooperating and coordinating through this international framework to put in place the integrated global earth observing system which is much needed to support both science and applications for societal benefit. GOFC-GOLD is making a real contribution to the development of GEOSS.

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References

Ahern F.; Goldammer J.G.; Justice C.O. 2001. **Global and Regional Vegetation Fire Monitoring From Space: Planning a Coordinated International Effort.** SPB Academic Publishing, The Hague, The Netherlands.

Arino, O.; Plummer, S.; Defrenne, D. 2005. **Fire Disturbance: The Ten Years Time Series of The ATSR World Fire Atlas**, In: Proceedings of the MERIS-AATSR Symposium, ESA publication, Frascati, 26-30 September, 2005.

Csiszar, I.; Denis, L., Giglio, L., Justice, C.O., Hewson, J. 2005. **Global fire activity from two years of MODIS data.** International Journal of Wildland Fire 14: 117-130.

Csiszar, I.; Morisette, J.; Giglio, L. 2006. **Validation of active fire detection from moderate resolution satellite sensors: the MODIS example in Northern Eurasia.** IEEE Transactions on Geoscience and Remote Sensing , vol. 44, no. 7, 1757-1764.

de Groot, W.J.; Field, R.D. 2004. **Southeast Asia Fire Danger Rating System Manual. Report to the Canadian International Development Agency.** Canadian Forest Service, Edmonton, Alberta. Unpubl. File Rep.

de Groot, W.J.; Wardati ; Wang, Y. 2005. **Calibrating the Fine Fuel Moisture Code for grass ignition potential in Sumatra, Indonesia.** International Journal of Wildland Fire 14: 161-168.

de Groot, W.J.; Goldammer, J.G.; Keenan, T.; Brady, M.A.; Lynham, T.J.; Justice, C.O.; Csiszar, I.A,; O'Loughlin, K. 2006. **Developing a global early warning system for wildland fire.** In: Viegas, D.X., editor. Proceedings of the V International Conference on Forest Fire Research; 2006, Nov. 27-30; Figueira da Foz, Portugal. Elsevier, B.V.: Amsterdam.

Elvidge, C.D.; Nelson, I.; Hobson, V.R.; Safran, J.; Baugh, K.E. 2001. **Detection of fires at night using DMSP-OLS data.** In: Global and Regional Vegetation Fire Monitoring from Space: Planning a Coordinated International Effort. Ahern F.J.; Goldammer J.G.,; Justice, C.O. ed. SPB Academic Publishing, The Hague, The Netherlands, pp 125-144.

FAO 2007a. **Fire Management - Global Assessment 2006**. FAO Forestry Paper 151, 160 p.

FAO 2007b. **Fire Management: Voluntary Guidelines – Principles and strategic actions.** FAO Fire Management Working Paper FM17E, 61 p.

FAO 2007c. **Fire Management: Review of International Cooperation 2006.**, by the Global Fire Monitoring Center. Fire Management Working Paper FM18E, 45 p.

FIRMS, 2007 **Fire Information for Resource Management System** <http://maps.geog.umd.edu/firms/>, 2007.

GFMC 2005. **Framework for the Development of the International Wildland Fire Accord. Rationale, Status and Future Activities.** http://www.fire.uni-freiburg.de/GlobalNetworks/Global-Wildland-Fire-Framework-12-April-2005.pdf

GOFC 2004. **Global Observation of Forest Cover - Global Observation of Land Cover Dynamics**. 2004 Jan 27. GOFC-GOLD home page. <http://www.fao.org/gtos/gofc-gold/index.html>.

GOFC FIRE 2007. **University of Maryland. GOFC-GOLD Fire Implementation Team home page.** <http://gofc-fire.umd.edu/>.

Justice, C.O.; Smith, R.; Gill, M.; Csiszar, I. 2003. **Satellite-based Fire Monitoring: current capabilities and future directions and applications in Australia**, International. Journal of Wildland Fire 12:247-258.

Justice, C.O.; Giglio, L.; Roy, D.P.; Csiszar, I.; Boschetti, L.; Korontzi, S.; Wooster, M. 2006. **A community land Earth System Data Record (ESDR) white paper on fire**, ftp://ftp.iluci.org/Land_ESDR/Fire_Justice_whitepaper.pdf.

Kasischke E.S.; Penner, J.E. 2004. **Improving global estimates of atmospheric emissions from biomass burning.** Journal of Geophysical Research 109, D14S01, doi:10.1029/2004JD004972.

Oertel, D.; Briess, K.; Lorenz, E.; Skrbek, W.; Zhukov, B. 2004. **Detection, monitoring and quantitative analysis of wildfires with the BIRD satellite.** Proceedings of. SPIE, 5232, 208-218.

Roy, D.P.; Frost, P.; Justice, C.O.; Landmann, T.; Le Roux, J.; Gumbo, K.; Makungwa, S.; Dunham, K.; Du Toit, R.; Mhwandagara, K.; Zacarias, A.; Tacheba, B.; Dube, O.; Pereira, J.; Mushove, P.; Morisette, J.; Vannan, S.; Davies, D. 2005. **The Southern Africa Fire Network (SAFNet) regional burned area product validation protocol.** International Journal of Remote Sensing, 26:4265-4292.

Townshend , J.R.G.; Justice, C.O.; Skole, D.L.; Belward, A.; Janetos, A., Gunawan, I.; Goldammer, J.; Lee, B. 2004. **Meeting the goals of GOFC: an evaluation of progress and steps for the future.** In: Land Change Science: Observing, Monitoring and Understanding Trajectories of Change on the Earth's Surface. Gutman G., Janetos A.C., Justice C.O. et al. eds. Kluwer Press, pp 31-51.

UNISDR 2007. **United Nations Interagency Strategy for Disaster Reduction Working Group. Wildland Fire home page.** <http://www.unisdr.org/eng/task%20force/tf-working-groups4-eng.htm>.

Van Wagner, C.E. 1987. **Development and Structure of the Canadian Forest Fire Weather Index System.** Ottawa, Ontario. Canadian Forestry Service, Tech. Rep. 35.