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# APPLICATIONS OF METEOROLOGICAL AND ENVIRONMENTAL RESEARCH SATELLITES FOR ACTIVE FIRE DETECTION AND MONITORING IN THE U.S.

SUMMARY AND PURPOSE OF DOCUMENT

This paper summarizes the current NOAA/NESDIS operational fire product suite and their uses. This paper responds to an action from CGMS XXXII

ACTION REQUESTED: NONE

# APPLICATIONS OF METEOROLOGICAL AND ENVIRONMENTAL RESEARCH SATELLITES FOR ACTIVE FIRE DETECTION AND MONITORING IN THE U.S.

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## 1. Background

Geostationary and polar orbiting meteorological and environmental research satellites have been used to detect and monitor active fires for over 20 years. Some of the initial studies on meteorological satellite fire detection were performed using the NOAA-6 Advanced Very High Resolution Radiometer (AVHRR) (Matson and Dozier, 1981). This work demonstrated how the different brightness temperature responses between the shortwave infrared (SWIR at 3.74 µm) and the longwave infrared windows (LWIR at 10.8 µm) can be used in principle to locate fires and determine sub-pixel fire characteristics (e.g. estimates of instantaneous fire size and temperature). Since then a number of polar orbiting instruments have been used in various capacities to monitor fire activity in the U.S. and around the globe, including, in addition to AVHRR, the Tropical Rainfall Measuring Mission (TRMM) Visible and Infrared Scanner (VIRS), the ERS Along Track Scanning Radiometer (ATSR) and ENVISAT Advanced ATSR (AATSR), and most recently the EOS MODerate-resolution Imaging Spectroradiometer (MODIS). All of the fire products produced from these instruments rely on the sensitivity of the SWIR band to sub-pixel hot spots. To date fire monitoring efforts using polar orbiting satellite sensors have focused on identifying hot spots and not sub-pixel fire characteristics, primarily due to sensor limitations. The Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) has also been used to identify fires by comparing night-time visible near-IR emission sources with a reference set of stable lights to identify emission sources associated with fires. In the mid-latitudes polar orbiting instruments provide several observations of a given region each day with more frequent observations near the poles. The advantages of using polar orbiters for fire monitoring are higher spatial resolution (1 km with MODIS) and global observation from a single platform. For higher spatial resolution instruments (≤ 1km) this requires elevated saturation thresholds in primarily the SWIR band, but also the LWIR band to minimize false alarms and omission errors and to enable the retrieval of sub-pixel fire characteristics for a wide range of conditions.

The NOAA series of Geostationary Operational Environmental Satellites (GOES) have had the necessary spectral bands to monitor active fires since the early 1980's although with limited capability until the implementation of the GOES-8 Imager in 1994. With the launch of the European Meteosat-8 Spinning Enhanced Visible and Infrared Imager (SEVIRI), the Chinese FY-2C stretched Visible and Infrared Spin Scan Radiometer (S-VISSR), and the Japanese Advanced Meteorological Imager (JAMI) on the Multi-functional Transport Satellite (MTSAT-1R), nearly global geostationary fire monitoring is possible. Although these geostationary sensors have a reduced spatial resolution (4-5 km in the IR) compared to polar orbiters, they offer enhanced temporal resolution (full disk every 15 minutes with Meteosat-8) providing valuable diurnal information that is complementary to polar orbiting fire products. Furthermore, saturation in the SWIR and LWIR bands is less of an issue due to the lower spatial resolution. One of the primary challenges in global geostationary fire monitoring is creating a consistent product that accounts for the unique fire monitoring capabilities and limitations of each platform.

Although the current suite of polar orbiting and geostationary satellites do not meet all user needs, the scientific research and environmental monitoring communities in the U.S. and abroad have recognized the vital role these environmental satellites can play in detecting and monitoring active fires for hazards applications and to better understand the extent and impact of biomass burning on the environment.

## 2. Applications

Over the past 10 years, the use of satellite derived fire products has grown appreciably with applications in hazards monitoring, fire weather forecasting, climate change, emissions monitoring, aerosol and trace gas transport modeling, air quality, and land-use and land-cover change detection. The user community includes government agencies (such as NOAA, NASA, EPA, and USFS), resource and emergency managers, fire managers, international policy and decision makers, educational institutions, and the general public. In particular, the EOS MODIS fire product has proven to be extremely popular with a broad user community. The following sections provide examples of satellite derived fire products and applications in the United States.

### *2.1 NOAA Products and Applications*

Since 2002 the NOAA NESDIS Satellite Service Division has provided fire products on-line via the Hazard Mapping System (HMS) (http://www.firedetect.noaa.gov). The HMS is an operational interactive processing system that integrates fire products from 7 different sensors on NOAA (POES AVHRR, GOES Imager, DMSP OLS) and NASA (EOS MODIS) satellites to produce fire and smoke product analyses for the U.S. and parts of Canada and Mexico. Automated algorithms including the MODIS Fire and Thermal Anomalies team algorithm (Kaufman et al, 1998, Justice et al., 2002), the GOES Wildfire Automated Biomass Burning Algorithm (WF_ABBA) (Prins et al., 1992, 1998), the AVHRR Fire Identification Mapping and Monitoring Algorithm (FIMMA) (Giglio et al., 1999, Li et al., 2001), and the DMSP OLS algorithm (Elvidge et al., 1996) are used to generate the fire products while smoke is delineated by an image analyst. Analyses are quality controlled by an analyst who inspects all available imagery and automated fire detects, deleting suspected false detects and adding fires that the automated routines miss. Graphical, text, and GIS compatible analyses are posted to the HMS web site. Products are available in text (ASCII), graphic or GIS formats. All products are archived at NOAA's National Geophysical Data Center (http://map.ngdc.noaa.gov/website/firedetects). The primary user communities for the HMS products include land and air quality managers, weather forecasters and emergency planners. Recently, NOAA's Air Resources Laboratory initiated a Smoke Forecasting Demo Project which utilizes the HMS fire and smoke products to monitor and forecast smoke (http://www.arl.noaa.gov/smoke/forecast.html) (McNamara et al., 2004; Stephens, 2005).

At NOAA's National Severe Storms Laboratory (NSSL) Storm Prediction Center (SPC) GOES WF_ABBA fire products provide by UW-Madison CIMSS are used in fire weather forecasting. The SPC Fire Weather Analysis Page (http://www.spc.noaa.gov/exper/firecom) integrates the GOES WF_ABBA fire product with other meteorological data and fire weather and danger indices (Haines, SPC LASI, Fosberg Index, etc.) to provide an overview of existing fires and fire danger in the continental U.S.

### *2.2 U.S. Forest Service Applications*

The USDA Forest Service is currently using a combination of satellite and airborne remote sensing systems to map and monitor active wildland fires, and to map burn severity for post-fire rehabilitation. Remote sensing systems are used to provide national scale - strategic planning level, and local scale - tactical incident level fire maps and products. Over the past 5 years the MODIS sensor has become an integral part of this effort in that it provides a unique capability to image the U.S. on a daily basis and provide active fire detections at a 1 km spatial resolution (Quayle and Lannom, 2004). National scale, strategic planning fire maps are developed and provided by the USDA Forest Service MODIS Active Fire Mapping Program using the EOS MODIS sensor, direct broadcast capability, and the Rapid Response System. The MODIS Active Fire Mapping Program utilizes near real time data from a network of North American MODIS Direct Broadcast receiving stations augmented by the daily world-wide MODIS data stream provided by NASA Goddard Space Flight Center. The program currently leverages MODIS Direct Broadcast receiving stations located at the USDA Forest Service Remote Sensing Applications Center (RSAC) in Salt Lake City, Utah, the University of Wisconsin Space Science and Engineering Center (SSEC) in Madison, Wisconsin, and the Geographic Information Network of Alaska (GINA) at the University of Alaska-Fairbanks in Fairbanks, Alaska.

Data from the MODIS sensor are used to prepare active fire maps and geospatial data continuously for the entire United States and Canada. These maps and data are made available to fire managers, and the public through the internet at: http://activefiremaps.fs.fed.us. They have proved to be useful for monitoring actively burning fires, assisting in planning, allocating fire suppression resources, and informing the public on current fire activity across the nation.

The Forest Service and other federal land management agencies prepare Burned Area Emergency Response (BAER) plans to mitigate hazards, stabilize soils and restore vegetation cover to the burned areas as soon as possible. Recently, techniques have been developed using airborne and satellite remote sensing imagery to derive base maps to improve the accuracy of the initial burn severity product. These base maps are created using a number of sources such as digital camera and high resolution satellite imagery and MODIS (Bobbe, 2005).

### *2.3 Emissions Monitoring and Modeling Applications*

Biomass burning associated with naturally occurring forest fires, deforestation and other human activities is a major source of trace gases such as NO, CO2, CO, O3, NOx, N2O, NH3, SO2, CH3, and other non-methane hydrocarbons as well at a significant source of aerosols. (Crutzen et al., 1985; Andreae et al., 1988; Crutzen and Andreae, 1990; Levine, 1991). Emissions from biomass burning remain one of the largest unknowns for both climate and air quality monitoring and modeling. In the past 5 years the climate change and air quality modeling communities have increasingly used environmental satellite fire products to augment traditional databases to get a more accurate picture regarding biomass burning emissions.

One example of this is the Fire Locating and Modeling of Burning Emissions program (http://www.nrlmry.navy.mil/flambe/index.html), a joint effort between the Navy, NASA, NOAA, and universities to diagnose and forecast smoke transport (Reid et al., 2004). Since the year 2000, the Naval Research Laboratory in Monterey has been assimilating the GOES WF_ABBA and MODIS fire products (as of 2003) into the NRL Aerosol Analysis and Prediction System (NAAPS) in near real-time to both monitor and predict aerosol loading and subsequent transport around the world. It has successfully projected the movement of large smoke palls regionally and around the globe. The NAAPS is currently being transitioned to the Fleet Numerical Meteorology and Oceanographic Center (FNMOC) as the world's first operational global aerosol model.

Recently, emissions associated with biomass burning have become an important component in regional air quality monitoring and modeling. In response to EPA requirements regarding PM2.5 air quality standards, states are beginning to request biomass burning information to help in determining the cause of regional non-attainment. In areas of non-attainment, states are typically required to implement a plan to achieve attainment, unless they can show transport from other regions. Non-attainment implementation plans are extremely costly for state and local governments. In many cases the government databases for fire activity are incomplete and fire products derived from satellites (GOES, POES, EOS) can help to fill the gap. Over the next 5 years NOAA will be expanding its forecasting mission to include various air quality parameters. Preliminary studies indicate that real-time satellite derived fire products will be an integral part of this new forecasting effort.

## 3. Future Plans

The international environmental monitoring and scientific research communities have stressed the importance of utilizing operational satellites to produce routine fire products and to ensure long-term stable records of fire activity for applications in hazards monitoring, global change research, aerosol and trace gas modeling efforts, land-use and land-cover change detection studies, resource management, and policy and decision-making. This includes better utilization of current systems and long-term plans that ensure the capability to derive similar or improved and enhanced fire products with next generation operational polar orbiting (NPOESS VIIRS, METOP AVHRR) and geostationary (GOES-R, MTG) series.

In the near-term NOAA/NESDIS, UW-Madison CIMSS, and NRL-Monterey are working in association with IGOS GOFC/GOLD to develop and implement a near real-time operational global geostationary fire monitoring network to monitor fires as they occur and capture the diurnal signature (Prins et al. 2001; 2004). Initially the GOES WF_ABBA will be adapted to Meteosat-8 (2006) and MTSAT-1R (2006) and a study will be performed to demonstrate the science and show the benefits and feasibility of a global geostationary fire monitoring network. This study will include the following components: active fire detection, emissions assessment, and numerical model data assimilation. Plans are underway to eventually adapt the WF_ABBA to FY-2C SVISSR (2004), INSAT-3D (2006), and the GOMS Electro N2 (2006). This suite of geostationary sensors will enable nearly global geostationary fire monitoring with significant regions of overlap in Asia.

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