4.3 THE HAZARD MAPPING SYSTEM (HMS) - NOAA'S MULTI-SENSOR FIRE AND SMOKE DETECTION PROGRAM USING ENVIRONMENTAL SATELLITES

Donna McNamara*, George Stephens, and Mark Ruminski
NOAA/NESDIS, Satellite Services Division
Camp Springs, MD

Tim Kasheta
RS Information Systems, Inc.
Camp Springs, MD

1. INTRODUCTION

The Hazard Mapping System (HMS) (figure 1) is an operational system that capitalizes on existing sensors on the current suite of environmental satellites to create a daily fire and smoke analysis over the US and adjacent areas of Canada and Mexico. Automated fire detections are incorporated into the system from Geostationary Operational Environmental Satellite (GOES), Advanced Very High Resolution Radiometer (AVHRR) and Moderate Resolution Imaging Spectroradiometer (MODIS). A key component is the quality control performed by an analyst who inspects all available imagery and automated fire detects, deletes those detects believed to be false alarms and adds additional fires that the automated routines have not detected. Nighttime lights imagery from Defense Meteorological Satellite Program Operational Linescan System (DMSP/OLS) and a variety of ancillary static layers are available to assist the analyst. HMS products are available in ASCII, graphical and Geographic Information System (GIS) formats. Use of GIS has increased the use of National Environmental Satellite, Data, and Information Service products among non-traditional users. Future plans include operationally running several of the automated algorithms on global imagery.

Figure 1 - Hazard Mapping System Overview

* Corresponding author address: Donna P. McNamara, NOAA/NESDIS/OSDPD/SSD, 5200 Auth Rd, Rm. 510, Camp Springs MD 20746; email donna.mcnamara@noaa.gov

2. BACKGROUND

Biomass burning has tremendous impact on the Earth's ecosystems and climate, for it drastically alters the landscape and biologic structure, and emits large amounts of greenhouse gases and aerosol particles. Smoke aerosols may interact with cloud droplets and alter considerably the earth's radiation budget. Remote sensing is the most efficient and economical means of monitoring fires over large areas on a routine basis, despite some limitations. Satellite observations can provide timely information on both fire development and fire damage following fire. Remote sensing of fires also has the potential to help authorities make decisions regarding fire fighting and reducing the impact of fires on the human population.

Investigations into the capability to detect fires from space using environmental satellites have been conducted at National Environmental Satellite, Data and Information Service (NESDIS) for over twenty years. Matson and Dozier (1981) demonstrated the ability to detect and characterize sub-pixel resolution fires. Matson et al. (1984) correlated satellite derived hot spots with confirmed ground observations, and Matson et al. (1987) presented a summary of satellite detection capabilities. Satellite images of fires and smoke have been produced routinely within the NESDIS's Satellite Services Division (SSD) since then to demonstrate detection capabilities.

In the summer and autumn of 1997, NESDIS for a period of several months provided routine imagery of wildfires and smoke in Indonesia in response to requests from United Nations aid organizations prompted by concern over pollution from the extensive smoke plumes. In the spring of 1998, massive fires burned across large tracts of Florida, Mexico and other parts of Central America. The resultant large smoke plumes brought a pall to a large section of the US that extended from Texas to the Mid Atlantic states. The Florida fires caused considerable damage, destroying a number of homes and closing portions of Interstate highways.

In response to this emergency, SSD began producing a regular analysis of smoke plumes and fire hotspots over the Gulf Coast states, Mexico, Central America and the Gulf of Mexico during the 1998 fire season. Subsequently, an ad hoc regional graphic product covering situation dependent areas was produced twice per day and made available to users via the internet, and development was begun on an operational smoke and fire monitoring system covering all of North America.

3. THE HAZARD MAPPING SYSTEM

The initial fire and smoke product was phased out in June 2002 as the HMS, became operational. The HMS is an interactive processing system that allows trained satellite analysts to manually integrate fire detects from various automated algorithms with imagery from geostationary and polar orbiting satellites. The result is a quality controlled display of the locations of fires and major smoke plumes in the 50 United States. The ability to include all of Mexico and Canada, when smoke from these countries affects the U.S., was added in 2004.

The HMS product relies heavily on satellite imagery from NOAA's Geostationary Operational Environmental Satellite (GOES) series, which allows for at least half-hourly detection of these hazards over the U.S. The frequent temporal updates allow for detection of fairly short lived fires as well as fires that have intermittent cloud cover over them. The primary satellite bands employed are 3.9 microns for sensing fires and visible wavelengths for smoke detection (figure 2a, b). The resolution of the GOES sensor is 1km at satellite subpoint for the visible channel and 4 km at subpoint for the 3.9 micron channel (and all other thermal bands). However, resolution gradually decreases as satellite viewing angle increases such that the effective resolution over large parts of the US is actually 5 to 6 km.

While the high temporal frequency of the GOES satellites allows for detection of many fires, the 4 km pixel resolution limits the size and intensity of fires that can be detected. While some small, but intense fires can saturate the 4 km pixel, the fires cannot be accurately positioned within the pixel. GOES misses small fires that are not burning very hotly compared to the surrounding ground surface temperature. In order to augment the GOES capabilities, NOAA's Polar Orbiting Environmental Satellites (POES) are also employed. They also have visible and 3.9 micron channels, both at 1.1 km resolution. The finer resolution allows for earlier detection of small fires, and shows finer location and detail of the fires. However, the imagery is available only once in 12 hours per satellite at mid latitudes. With 2 to 3 polar orbiting satellites available, these platforms provide a strategic complement to the geostationary satellites.

The primary data source used for the smoke analysis is high resolution visible imagery from the GOES spacecraft, since smoke is normally not observed in the GOES thermal bands. The imagery is viewed in animation, typically using ½ hourly data. However, smoke plumes are most easily observed when there is a low sun angle (in the morning, just after sunrise and in the evening just before sunset).

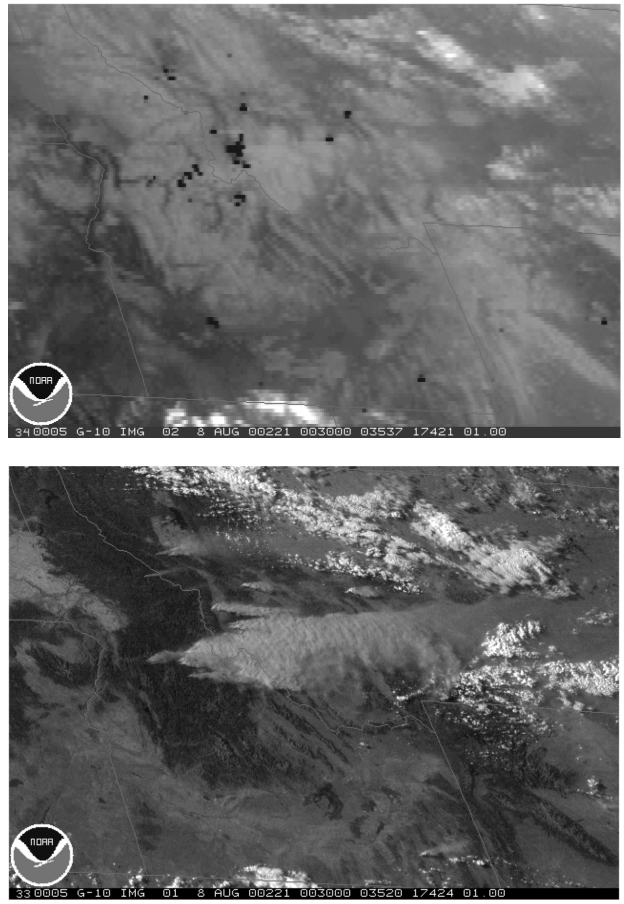

Figure 2 a, b- Fires as seen by GOES; (a) hotspots appear as dark spots on the 4 micron imagery , and smoke is clearly visible in (b) from large fires in Idaho and Montana on August 8, 2000.

While the analyst's eye remains critical, various automated detection algorithms have been developed which can identify hot spots in the satellite imagery. This speeds the process of searching for potential fires.

The Wildfire Automated Biomass Burning Algorithm (WF_ABBA) product was developed by Elaine Prins (NOAA/NESDIS/ORA) at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin. This product, which was implemented operationally within SSD in August 2002, provides coverage over N. America every half hour. The GOES WF_ABBA is a contextual multi-spectral (visible and 3.9 and 10.7 micron) algorithm which uses dynamic local thresholds derived from the GOES satellite imagery and ancillary databases to locate fire pixels and provides identification of fires and estimates of the sub-pixel area and mean temperature of the fires (Prins and Menzel, 1992; Prins et al, 1998; 2001).

The Fire Identification, Mapping and Monitoring Algorithm (FIMMA) product is an automated algorithm to detect fires from Advanced Very High Resolution Radiometer (AVHRR) data from the NOAA polar-orbiting satellites. The FIMMA product was originally developed by Ivan Csiszar while he was a member of the Cooperative Institute for Research in the Atmosphere, working at the NOAA/NESDIS Office of Research and Applications (ORA) in Camp Springs, Maryland. The latest version of FIMMA uses geo-corrected High Resolution Picture Transmission (HRPT) AVHRR data over the US (including Alaska and Hawaii) received from the NOAA/NESDIS CoastWatch group and uses the SeaSpace Terascan software to correct for navigation errors. FIMMA can be run for any pass which has 3.7 micron measurements. The algorithm builds on AVHRR and MODIS algorithms described by Giglio et al (1999) and Li et al (2001). It uses AVHRR channels 2 (.9 micron), 3b (3.7 micron), 4 (10.8 micron) and 5 (12 micron). The algorithm is contextual with additional tests for satellite noise, clouds, hot surfaces, sun glint, and surface type. This product is still considered pre-operational at NOAA; validation and algorithm refinement continues.

SSD receives Moderate Resolution Imaging Spectroradiometer (MODIS) data and fire products from NOAA's MODIS Near Real Time Processing System located at NASA Goddard Space Flight Center and run by its sister division -- the Information Processing Division. MODIS instruments fly onboard the NASA TERRA and AQUA polar-orbiting satellites. The MODIS instrument provides 36 discrete spectral channels with resolution ranging from 1/4 to 1 km. This data source has proven to be an important asset in operational fire detection. The fire algorithm (Kaufman et al, 1998; Justice et al, 2002) was developed by the MODIS Fire and Thermal Anomalies team, Chris Justice principal investigator.

The HMS also incorporates nighttime visible data from the Defense Meteorological Satellite Program/ Operational Linescan System (DMSP/OLS). These data are received via the National Geophysical Data Center (NGDC), which also provided the algorithm and processing software (Elvidge 1996). The satellite image is compared to an image of stable lights. Ideally, differences are due to wildfires. This fire product, especially when used in conjunction with infrared data, helps distinguish fires from hot surfaces at night.

These automated detection algorithms, in general do a very good job of identifying potential fires, but false detects can be a problem. For example, heated ground can saturate the 3.9 micron sensor, making it impossible to discriminate fires that may be contained within the area. The current operational NOAA satellites were not designed with fire detection in mind, but future satellites are being designed to have a higher 3.9 micron saturation temperature. The automated algorithms run round the clock, being initiated as soon as data are available. Resultant fire detects are released publicly as soon as possible, for those users who need immediate information and can accept a higher rate of false detects. At 1 pm Eastern time, the fire shift begins. The analyst prepares a preliminary product as the fires begin to develop that day. This preliminary analysis is updated throughout the fire shift (which ends at 11 pm Eastern time). The product for the day before is updated one more time at the start of the next day's shift to ensure the best product is sent to the archive.

There are a number of limitations to the current analysis process:

- There is no way to discriminate between wildfires and agriculture or controlled burns; one can only assume based on duration that the longer lived hotspots are more likely to be wildfires.
- The 3.9 micron imagery can not see through clouds, other than thin cirrus. Multiple looks with different sensors throughout the day help catch fires if there are any breaks in the clouds.
- Small fires, those not burning very hotly and those burning below a thick canopy of overgrowth, may go undetected. At times, smoke plumes are seen without an associated hotspot.
- Smoke is harder to detect in standard visible imagery during the middle of the day with a high sun angle or against a surface with a high albedo.
- Fires, especially in the western US, often are masked by a hot background during the afternoon in the summer. This is due to the high surface temperatures and reflectivity which causes the sensor to saturate.

4. PRODUCT AVAILABILITY

Figure 3 – HMS GIS interface

The primary delivery mechanism for the smoke and fire product is a Geographic Information System (GIS) webpage (figure 3, http://www.firedetect.noaa.gov). This has allowed the fire and smoke products to serve a much large user community than the traditional remote sensing users. Specifically, land and air quality managers have found this system very useful. When users first go to the page they see the latest HMS product, but have the capability to overlay the WF_ABBA, FIMMA and MODIS fire detects. They can also zoom down to the county level to get a closer look at the fires. Ancillary layers, such as geopolitical boundaries, lakes and rivers, major highways, land cover, and fire potential (from NOAA/National Weather Service Storm Prediction Center) are available.

Users can download products directly from an anonymous file transfer protocol (FTP) site gp16.ssd.nesdis.noaa.gov, or via the web at http://gp16.ssd.nesdis.noaa.gov/FIRE/fire.html. Products are available in text (ASCII), graphic or GIS formats.

A new archive of the HMS and WF_ABBA products has been established at NGDC, under the leadership of Ted Habermann. This site can be found at http://map.ngdc.noaa.gov/website/firedetects.

5. FUTURE OF HMS

The HMS, with significant analyst intervention, will continue to be refined for N. America to meet the needs of U.S. land and air quality managers, weather forecaster and emergency planners. A text message describing the fire and smoke situation is under discussion.

Global coverage has been requested by the air quality and aerosol modeling community, and will rely on improvements in the automated algorithms. Efforts have begun (Prins et al 2004) to adapt the WF_ABBA algorithm to Meteosat Second Generation (MSG) and Multi-functional Transport Satellite (MTSAT). With the launch of the Meteorological Operational satellite (METOP) in late 2005, AVHRR data will be available globally at 1 km resolution. MODIS fire detects are already available globally, and MODIS is serving as excellent preparation for the Visible Infrared Imager/Radiometer Suite (VIIRS), which is the replacement for AVHRR on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) satellite. Intensive human intervention to produce a global product appears impossible due to manpower limitations, but analysts' experience will be used to develop methods to integrate all satellite sources, and the analyst will continue to perform quality control.

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