Rapid Mapping of Active Wildland Fires: Integrating Satellite Remote Sensing, GIS, and Internet Technologies

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Abstract

The U.S. Department of Agriculture (USDA) Forest Service Remote Sensing Applications Center (RSAC), in collaboration with the National Aeronautics and Space Administration (NASA)-Goddard Space Flight Center (GSFC) the University of Maryland, and the USDA Forest Service Fire Sciences Laboratory in Missoula, MT, acquires and processes Moderate Resolution Imaging Spectroradiometer (MODIS) data to produce active fire map and information products. MODIS imagery is processed to identify where fires have been detected and to produce active fire maps for the entire United States twice daily via the Internet along with further geospatial analysis and image processing to create associated fire information and image products. The MODIS active fire maps provide a daily synoptic view of the wildfire situation at the national and regional levels for interagency fire community use in strategic planning and for general public information.

Introduction

Annually, more than 135,000 wildland fire ignitions in the United States burn more than 4 million acres of land (National Interagency Fire Center 2002). If a wildland fire escalates to a large fire incident, the responsible Geographic Area Coordination Center (GACC) allocates appropriate firefighters, support personnel, and equipment. The National Interagency Fire Center (NIFC) National Multi-Agency Coordination (NMAC) group may also allocate fire suppression assets at the national level to a large incident. Regional and national use of remote sensing technologies to detect and monitor wildland fires is important for strategic planning. The finite number of traditional airborne and satellite remote sensing platforms such as Landsat, SPOT, AVHRR, and others, however, cannot continuously detect and monitor the numerous current and new wildland fires occurring daily throughout particular regions, or the entire country. Traditionally, airborne platforms are used to map fire activity at a large scale on a limited number of individual incidents for tactical purposes. Factors relating to temporal resolution, spectral resolution, or geolocational accuracy may further limit the application of the satellite remote sensing platforms in daily fire monitoring and mapping over large areas.

Since 2001 the USDA RSAC, NASA-GSFC, the University of Maryland, and the USDA Forest Service Missoula Fire Sciences Laboratory have collaborated to provide a synoptic view of active fire data and daily information from a

consistent sensor. The partners agreed to develop a rapid response fire-detection system and active fire-mapping process to provide daily active fire maps and associated image and information products for the entire United States via the Internet by using MODIS. The MODIS sensor, rapid response fire-detection system, and active fire-mapping process work together to provide daily geospatial products and information to the interagency fire community and the general public. The partners continue to improve the quality of the data products, increase the frequency of product delivery, and enhance access to the data products via the Internet.

Why Use MODIS for Active Wildfire Mapping?

Two recently launched NASA Earth Observing System (EOS) satellites–Terra and Aqua–carry the MODIS sensor. Terra was launched in December 1999 and Aqua was launched in May 2002. Terra, formerly known as AM-1, follows a sun-synchronous, descending polar orbit at an altitude of approximately 705 kilometers crossing the equator at 10:30 a.m. local time. Aqua, formerly known as EOS PM, is also on a sun-synchronous, polar orbit at the same altitude; however, it follows an ascending path, crossing the equator at 1:30 p.m. local time. **The final Aqua engineering adjustments have been implemented now and its data can be fully utilized.** The MODIS sensor is designed to map Earth's land, ocean, and atmospheric characteristics, with several unique characteristics that support daily wildfire detection and mapping.

<u>Temporal Resolution</u>. Both Terra and Aqua orbit the Earth approximately 14 times daily. Each MODIS sensor has a 2,330-kilometer (1,400-mile) view during a single pass that enables it to image any location twice daily in the mid to high latitudes, for one daytime and one nighttime pass. The location of the orbits, which move slightly from day to day, and the wide view, allow the contiguous 48 States to be imaged by a single MODIS sensor with 3 orbit passes (figures 1 and 2). The temporal offset of the orbits of the two satellites allows for fire monitoring throughout the day. For example, Terra's daytime and nighttime passes over the Central and Western United States are approximately 1,800 UTC (Coordinated Universal Time, or Greenwich Mean Time—GMT) and 500 UTC (2,300 MDT, Mountain Daylight Time), respectively. Aqua passes over the same area approximately 2 hours later. Daily fire monitoring is impractical with higher-resolution satellite sensors such as Landsat and SPOT, because they can image any location only every several days.

Figure 1. An example of a Terra MODIS orbit track over the United States. Daytime passes are in blue; nighttime passes are in red.

Figure 2. An example of a MODIS field of view.

Spectral/Spatial Resolution. MODIS has a broad spectral resolution with 36 coregistered bands covering 0.4 to 14.4 micrometers (visible to thermal infrared) collected at one of three spatial resolutions (250, 500, and 1,000 meters). The bands have a narrow spectral width and a radiometric resolution of 12 bits (4,096 brightness values). MODIS can maintain and recalibrate the proper sensor calibration by pointing the sensor at view objects of consistent radiances (e.g., the moon and deep space) (Justice et al. 2002). MODIS data is used according to the fire and thermal anomalies algorithm to detect fires (Giglio et al. 2000). The algorithm uses three of MODIS' 1-kilometer thermal bands (two at 4 micrometers and one at 11 micrometers) in conjunction with techniques to minimize the occurrence of false detections (Giglio et al. 2000). The higher saturation threshold of MODIS thermal

bands, compared to other sensors, enables the sensor to detect bright, hot fires both at night and in the daylight without being oversaturated by the brightness of the fire signature (Herring 1998).

Geolocation. MODIS offers superior geolocational accuracy to other moderate-resolution satellites. For example, errors in the AVHRR ephemeris can result in geolocation errors of several kilometers. Using the definitive ephemeris, constantly generated by GSFC and uploaded to Terra, minimizes MODIS geolocational errors. The unique onboard calibration process enables the MODIS sensor to crosscheck its geolocational accuracy against known physical Earth features that have been mapped at a very high level of accuracy (Wolfe et al. 2002). This process ensures +/-50-meter accuracy for Terra MODIS 1-kilometer bands. In other words, the positional accuracy of the center of the 1-kilometer pixel is within 50 meters in any direction.

Rapid Response System. Free downloading of MODIS data and MODIS-derived products is available 2 to 3 weeks after data acquisition from the U.S. Geological Survey (USGS) Earth Resources Observation Systems (EROS) Distributed Active Archive Center (DAAC). The Rapid Response System developed by RSAC, GSFC, the University of Maryland, and the Missoula Fire Sciences Laboratory acquires and processes MODIS data in real time and further processes data for mapping and monitoring wildfires. Worldwide MODIS data is transferred to the Tracking and Data Relay Satellite System (TDRSS) network and relayed to the EOS Data and Operations System (EDOS) in White Sands, NM, and then forwarded to GSFC in Greenbelt, MD, within 4 to 6 hours. In addition, a MODIS direct broadcast receiving station installed and managed by RSAC in Salt Lake City, UT, receives data for the western two-thirds of the United States in real time as the sensor passes overhead and disseminates the data to national forests and other field units within a few hours of acquisition. Once the MODIS data is acquired at both locations, it is automatically atmospherically corrected, calibrated, and georeferenced, and further processed for fire detections within 1 hour. Each fire detection contains the latitude/longitude centroid coordinates of the 1-kilometer cell, UTC time of detection, and detected brightness temperature, and is output into a raw, fixed-text file format for continued data processing. Several factors can limit the fire-detection capabilities of MODIS: (1) MODIS thermal bands cannot detect fires through heavy cloud cover; (2) to be detected, a fire must be at least 100 square meters in size, burning at 1,500 degrees Fahrenheit at the moment MODIS passes overhead; and (3) fires occurring on particular types of terrain may be obscured from MODIS' view (e.g., on steep slopes or in narrow canyons).

MODIS Wildfire Maps and Related Products

Raw fire detection data from RSAC and GSFC are continually compiled at RSAC in Salt Lake City and automatically processed into ArcInfo Geographic Information System (GIS) coverages for mapping and analysis twice daily (3:00 a.m. and 3:00 p.m. Mountain Daylight Time). The processed MODIS fire-detection data are used to automatically produce poster-size active fire maps covering each of the 11 interagency-designated geographic areas throughout the country, in addition to 2 smaller-scale maps produced for the Western and Eastern United States. Maps are produced at the prescribed times to ensure availability to the interagency wildfire community for

strategic planning at the beginning and end of each day, as well as for disseminating timely general public information. The maps are produced in a variety of formats (.jpeg, pdf, and HP-RTL) and are posted on RSAC's Rapid Response Web page (www.fs.fed.us/eng/rsac/fire_maps.html). Maps for the current day and archived maps for the current calendar year are also accessible.

Each active fire map displays active fire detections within the last 24 hours of the specified time and date on the map, as well as the cumulative detections from January 1st of the current year. The maps are rendered on a shaded relief base with other geospatial data for reference, such as political boundaries, cities, roads, and hydrographic features (figures 3 and 4).

Twice daily, RSAC's Rapid Response Web page provides reports of additional GIS analysis of current MODIS detection data detections and other spatial data for detailed geospatial information. The reports list all fire detections for the last 24-hour period with their latitude/longitude coordinate, time, and date of detection, and intersections of national forests, counties, States, and nearest towns.

Daily MODIS image data is also available from the Rapid Response Web site. MODIS "Quick-Looks"—true-color .jpegs of MODIS imagery with fire detections collected at the RSAC's direct broadcast receiving station—are available at varying resolutions for each daytime MODIS pass over the Central and Western United States. MODIS data for selected current large fires are processed daily and presented as true-color and false-color composite .jpeg images. These images portray the current burn extent, active fire areas, and smoke plumes for the duration of the fire.

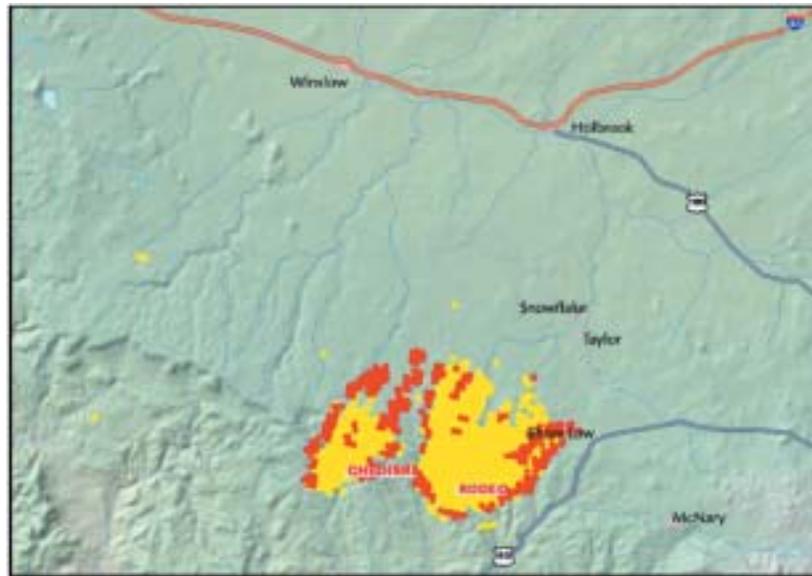Figure 3. An example of a MODIS active fire map for the Southwestern Geographic Area.

Figure 4. A subset of an active fire map. Red areas represent detections within the last 24 hours; yellow areas represent previous detections.

Summary

The design and development of the Rapid Response System for mapping and monitoring wildfires with MODIS are a result of a collaborative effort by the USDA Forest Service Remote Sensing Application Center, NASA-Goddard Space Flight Center, the University of Maryland, and the USDA Forest Service Missoula Fire Sciences Laboratory. The process provides an automated, rapid, and reliable approach for (1) daily acquisition and processing of remotely sensed data for active fire detections; (2) processing, analysis, and mapping of active fire detection data, and the production of other related products; and (3) distributing wildfire mapping products via the Internet. It is an excellent example of successfully integrating remote sensing, GIS, and Internet technologies. The MODIS active fire maps will serve the interagency fire community for strategic planning and provide information for the general public.

Planned future enhancements for the Rapid Response System include (1) integrating Aqua MODIS data to provide an additional view of fire conditions approximately 2 to 3 hours after each Terra MODIS pass; (2) providing cartographic enhancements to current map products; (3) integrating MODIS fire detections and other geospatial data into an interactive Web map interface; and (4) providing additional wildfire geospatial products and information.

Reference

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