SATELLITE-BASED FIRE DETECTION AND MAPPING FOR THE EASTERN UNITED STATES

Brad Quayle
USDA Forest Service – Remote Sensing Applications Center
Salt Lake City, Utah

1. INTRODUCTION

The USDA Forest Service Moderate Resolution Imaging Spectroradiometer (MODIS) Active Fire Mapping Program (http://activefiremaps.fed.us) provides daily operational fire detection data and mapping products for the continental United States and Alaska. This effort is a result of a partnership between the Forest Service Remote Sensing Applications Center (RSAC), NASA Goddard Space Flight Center (GSFC), the University of Maryland, and a network of MODIS ground stations operated by various institutions throughout the country. The objective of the program is to leverage synoptic view, high temporal remote sensing imagery and fire detection locations observed by MODIS to produce a suite of fire-related geospatial products. Products and information provided by the program are valuable for monitoring the current location and extent of fire activity throughout all geographic areas of the United States.

The rationale for the MODIS Active Fire Mapping Program grew from experience gained by the Forest Service and other federal land management agencies during the catastrophic western United States fire season in 2000. Initiated in 2001, the original program focus was to monitor the fire activity that occurs annually in the western states. Annually, however, the Eastern and Southern Geographic Areas (Figure 1) collectively comprise nearly 21% of the wildland fire acreage in the United States and 66% of the prescribed fire acreage (National Interagency Coordination Center, 2005). As a result, in 2002, the MODIS Active Fire Mapping Program expanded to provide operational fire detection and monitoring coverage for the eastern United States.

2. MODIS ACTIVE FIRE DETECTION FOR THE EASTERN UNITED STATES

The MODIS instrument is onboard two polar-orbiting NASA Earth Observing System (EOS) platforms, Terra and Aqua. MODIS collects high temporal image data for 36 co-registered spectral bands at one of three spatial resolutions -

Figure 1- Extent of the Eastern and Southern Geographic Areas as designated by the interagency wildland fire community. These areas comprise 21% of the annual 4.4 million wildland fire acreage in the United States and 66% of the annual 1.9 million prescribed fire acreage.

250 meters, 500 meters and 1 kilometer. Designed to monitor a host of Earth's land, ocean and atmospheric processes, MODIS has several technical attributes that facilitate global fire detection multiple times daily at a spatial resolution of 1 kilometer (Table 1).

The combination of both MODIS sensors provides at least four daily thermal observations at latitudes greater than 30°. For the area of the United States east of the 90th meridian, daytime MODIS thermal observations are acquired at approximately 1500 - 1700 UTC (Terra) and 1700 - 1900 UTC (Aqua). Evening MODIS observations take place at approximately 0200 – 0400 UTC (Terra) and 0600 - 0800 UTC (Aqua). The timing of the MODIS thermal observations provide for diurnal monitoring of fire activity.

Fire detections are gleaned from MODIS image data by measuring the response of potential fire pixels in the 4 μm and 11 μm bands and by applying subsequent absolute thresholds and contextual analyses to determine the presence of a fire for a given pixel (Giglio et al., 2003). Specific algorithm modifications are applied to address different atmospheric and land surface conditions

Table 1 - MODIS technical specifications (Source: NASA)

INSTRUMENT	
Type	Multi-spectral cross track scanning radiometer
View Angle	110° (+/- 55° from nadir)
Swath	2,330 KM swath (cross track), 10 KM (along track)
Spectral Resolution	36 bands (0.4 μm to 14.4 μm, Visible to Thermal Infrared)
Spatial Resolution	2 @ 250 meters, Red/NIR (Bands 1 & 2) 5 @ 500 meters, Visible to MIR (Bands 3 – 7) 29 @ 1 KM, Visible to TIR (Bands 8 – 36)
Temporal Resolution	Once daily for collection of solar reflective bands; Twice daily for collection of thermal bands (at latitudes greater than 30 degrees)
Quantization	12 bits
ORBIT	
Type	Sun-synchronous, near polar orbit
Altitude	705 KM
Inclination	98.2° degrees
Equatorial Crossing	10:30 a.m. descending node (Terra); 1:30 p.m. ascending node (Aqua)
GENERAL	
Launch Date	December 18, 1999 (Terra); May 4, 2002 (Aqua)
Design Life	6 years

present on daytime versus nighttime observations (Giglio et al., 2003).

Immediate access to MODIS imagery and derived fire detection locations is facilitated by the Rapid Response System (Descloitres et al., 2002) developed by GSFC and the University of Maryland. The Rapid Response System is an automated image processing system that processes MODIS imagery and extracts fire detection locations and associated fire characteristics. Fire detection processing in the Rapid Response System uses the same algorithm utilized by the MODIS Adaptive Processing System (MODAPS) to produce the MOD14 Fire and Thermal Anomalies product (National Aeronautics and Space Administration, 2005). The MOD14 product is available from the Land Processes Distributed Active Archive Center (LP-DAAC) within days of MODIS image data acquisition; however, this delay minimizes its use for operational fire detection and monitoring.

As the data source for the MODIS Active Fire Mapping Program, Rapid Response operates as a distributed system. The main Rapid Response System is located at GSFC and processes near real-time MODIS data (2-4 hours post-acquisition) for the entire United States. This raw image data is made available to the GSFC Rapid Response System via a bent pipe feed from the NOAA MODIS Near Real Time Processing System. In addition to the main Rapid Response System, there are several instances of the Rapid Response System residing at MODIS direct readout ground stations throughout the United States. MODIS direct readout ground stations collect daily real-time MODIS data for substantial portions of the country. MODIS image data are continuously broadcast directly from both MODIS sensors as they orbit overhead. Ground stations can collect raw image data broadcast by MODIS while maintaining line of sight visibility to the sensor. These real-time MODIS data are immediately processed to extract fire locations using the Rapid Response System on site.

For the MODIS Active Fire Mapping Program, real-time MODIS fire detection data coverage for the eastern as well as the western United States is facilitated by MODIS direct readout ground stations managed by RSAC in Salt Lake City, Utah and the Space Science and Engineering Center (SSEC) at the University of Wisconsin in Madison, Wisconsin. Raw fire detection data produced by the Rapid Response System at GSFC and RSAC and SSEC ground station facilities are continuously integrated into the MODIS Active Fire Mapping Program at RSAC. The near real-time fire detection data provided by GSFC augments the real-time data provided by the MODIS ground stations and serves as a alternative data source when necessary.

3. MODIS ACTIVE FIRE MAPPING PRODUCTS FOR THE EASTERN UNITED STATES

Raw fire detection data are compiled and processed by the MODIS Active Fire Mapping Program to provide several value-added geospatial products 24 hours daily, year round. The operational products provide a comprehensive assessment of the current fire activity and extent for the eastern United States, and the rest of the country, based on the most recent MODIS observations.

MODIS Active Fire Mapping products are intended for use at regional and national scales. The products can also be used with local fire information (e.g. Incident Status Summary Database (ICS209), National Fire Plan Operations and Reporting System, etc.) to provide contextual

information. The integration of MODIS fire mapping products with various sources of ancillary information facilitates an integrated decision support system for the management of wildfire and prescribed fire activity. Notable MODIS Active Fire Mapping Program geospatial products provided for the eastern United States include the following:

Hardcopy Fire Detection Maps- Digital versions of regional scale hardcopy maps displaying cumulative and recent MODIS fire detection activity (Figure 2). 21 poster-size maps – including nine maps covering the area of the United States east of the Mississippi River - are updated up to four times daily after local MODIS observations as fire conditions warrant.

Interactive Fire Detection Map- Web-based, interactive fire detection mapping application for the continental United States. Users can pan/zoom to a user-specified scale and integrate current MODIS fire detection data with various map layers (Figure 3). MODIS fire detection data are updated hourly and are provided in conjunction with fire detection data provided by NOAA NESDIS from other high temporal sensors (McNamara et al., 2002). MODIS fire detection data compiled and processed by the MODIS Active Fire Mapping Program are also relayed to other web-based, fire support mapping services including GeoMAC (http://geomac.usgs.gov).

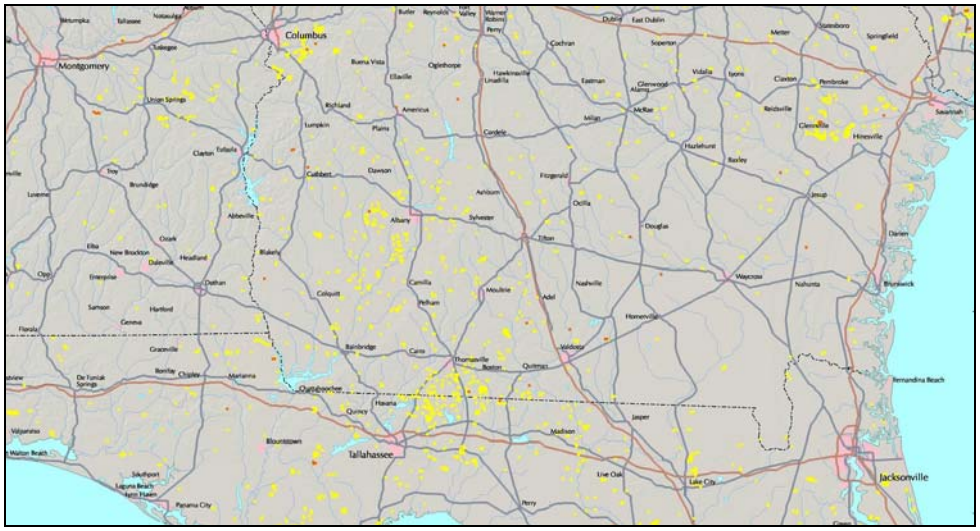

Figure 2 - Recent and cumulative year 2005 MODIS fire detection activity for southern Georgia and Alabama and northern Florida on April 21, 2005. MODIS fire detections in the last 12 hours are depicted in red; last 24 hours in orange, and previous detections in yellow.

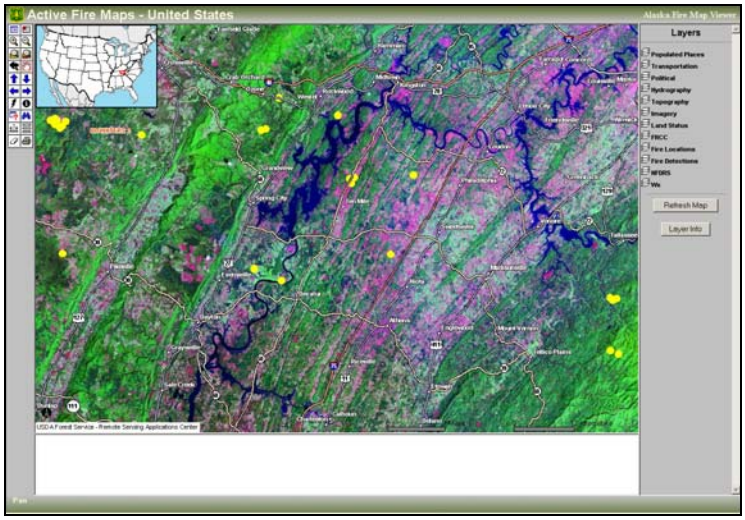

Figure 3 - Web-based, interactive MODIS fire detection maps display fire detection data with user-selected map layers at user-defined map extents and scales.

Fire Detection GIS Data – Hourly updates of cumulative 1 kilometer MODIS fire detection datasets for the entire United States. Current and historical GIS datasets include attribute fields describing fire characteristics and are compiled from MODIS Rapid Response output at GSFC and MODIS ground stations. These MODIS fire detection GIS datasets are also mirrored at the Geospatial One Stop (http://www.geodata.gov).

Fire Detection Summaries – Cursory map and tabular summaries describing the most recent individual MODIS fire detection locations for the United States.

4. FUTURE OF THE PROGRAM

In preparation for the post-MODIS era, the MODIS Active Fire Mapping Program is preparing to leverage the next generation of moderate resolution sensors capable of fire detection and monitoring. It is anticipated that future sensors will provide fire detection data at relatively higher spatial resolution and assess additional characteristics about observed fire activity.

Currently, RSAC is making preparations to leverage the Visible/Infrared Imager/Radiometer Suite (VIIRS) in the near future. VIIRS is a follow-on sensor to the Advanced Very High Resolution Radiometer (AVHRR) and will fly on the National Polar-Orbiting Environmental Satellite System (NPOESS). The first NPOESS satellite will be launched in 2009 preceded by the launch of an EOS-NPOESS bridging mission, the NPOESS Preparatory Project (NPP), in late 2006. The VIIRS instrument onboard NPP and NPOESS is anticipated to collect global fire detection data at a spatial resolution of 750 meters. With a planned constellation of three NPOESS satellites orbiting the Earth by 2013, VIIRS will provide six daily thermal observations for fire detection and monitoring.

5. ACKNOWLEDGEMENTS

The author wishes to acknowledge several entities that help make the USDA Forest Service MODIS Active Fire Mapping Program possible. These entities include NASA Goddard Space Flight Center and the University of Maryland for the development and implementation of the Rapid Response System; the NOAA MODIS Near Real Time Processing System for providing access to the near real-time MODIS data stream; and, the University of Wisconsin Space Science and Engineering Center and the University of Alaska-Fairbanks Geographic Information Network of Alaska (GINA) for providing access to real-time MODIS imagery and fire location data.

6. REFERENCES

Descloitres J., R. Sohlberg, J. Owens, L. Giglio, C. Justice, M. Carroll, J. Seaton, M. Crisologo, M. Finco, K. Lannom, and T. Bobbe, 2002: The MODIS Land Rapid Response project. *IGARSS: IEEE International Geoscience and Remote Sensing Symposium Proceedings*, Toronto, 2002.

Giglio, L., Descloitres, J., Justice, C. O., and Kaufman, Y. J., 2003: An enhanced contextual fire detection algorithm for MODIS. *Remote Sensing of the Environment*, 87, 273-282.

McNamara, D., G. Stephens, B. Ramsay, E. Prins, I. Csiszar, C. Elvidge, R. Hobson, and C. Schmidt, 2002: Fire Detection and Monitoring Products at the National Oceanic and Atmospheric Administration. *Photogrammetric Engineering and Remote Sensing* 68, 774-775.

National Aeronautics and Space Administration, 2005: MODIS Fire and Thermal Anomalies Guide. Online technical reference, accessed April 18, 2005. URL: http://modis-fire.umd.edu.

National Interagency Coordination Center, 2005: National Interagency Coordination Center 2004 Statistics and Summary. Accessed April 15, 2005. URL: http://www.nifc.gov/news/2004_statssumm/2004Stats&Summ.html.

7. AUTHOR BIOGRAPHY

Brad Quayle is a remote sensing/geographic information system specialist in the Operations Program of the USDA Forest Service Remote Sensing Applications Center in Salt Lake City, Utah. At RSAC, he manages the MODIS Active Fire Mapping Program and utilizes MODIS and other satellite sensors to support other aspects of wildfire management, and resource inventory and assessment objectives.