

SPACE-BASED SENSORWEB MONITORING OF WILDFIRES IN THAILAND

*Steve Chien^a, Joshua Doubleday^a, David McLaren^a, Ashley Davies^a, Daniel Tran^a
Veerachai Tanpipat^b, Siri Akaakara^b, Anuchit Ratanasuwan^b, Daniel Mandl^c*

^aJet Propulsion Laboratory, California Institute of Technology, USA

^bNational Park, Wildlife and Plant Conservation Department of Thailand

^cNASA Goddard Space Flight Center, USA

ABSTRACT

We describe efforts to apply sensorweb technologies to the monitoring of forest fires in Thailand. In this approach, satellite data and ground reports are assimilated to assess the current state of the forest system in terms of forest fire risk, active fires, and likely progression of fires and smoke plumes. This current and projected assessment can then be used to actively direct sensors and assets to best acquire further information. This process operates continually with new data updating models of fire activity leading to further sensing and updating of models. As the fire activity is tracked, products such as active fire maps, burn scar severity maps, and alerts are automatically delivered to relevant parties.

We describe the current state of the Thailand Fire Sensorweb which utilizes the MODIS-based FIRMS system to track active fires and trigger Earth Observing One / Advanced Land Imager to acquire imagery and produce active fire maps, burn scar severity maps, and alerts. We describe ongoing work to integrate additional sensor sources and generate additional products.

Index Terms— Forest fires, Active Fire Mapping, Burn Scar Assessment, Carbon Cycle, Sensorweb

1. INTRODUCTION

Forest fire is a major cause of not only global deforestation, but also the reduction of carbon stored in forests. The forest fire season in Thailand is observed during the dry season, from the beginning of November to the end of April, with its peak in March. The majority of the forest fires are ground fires in the dry dipterocarp and mixed deciduous forests consuming surface litter and small vegetation. These fires may spread to the upper levels of the canopy in mixed deciduous forest with bamboo or pine plantations.

Almost all forest fires in Thailand are man-made, primarily started by rural settlers who live in or adjacent to the forests (Akaakara 2001). The main activities that cause forest fires in Thailand include the gathering of forest

non-timber products, spreading of agricultural debris burning, hunting, and carelessness. In certain extremely dry sites, double burning in one season is also common



Figure 1: Active forest fires with smoke plumes in Thailand

(Akaakara 2001 and Csiszar et al. 2006). Figure 1 shows



Figure 2: Burn scar from forest fire in Thailand

active forest fires with smoke plumes in Thailand. Figure 2 shows a post fire burn scar in Thailand.

Thailand forests are comprised of two dominant vegetation types: evergreen forests and deciduous forests. The evergreen forest is composed of a great proportion of the non-leaf shedding species and covers about 40% of the

total forested area. This family of forest contains the tropical rain forest, dry evergreen forest, hill evergreen forest, coniferous forest, mangrove forest, swamp peat forest, and beach forest. On the other hand, the deciduous forest, which covers the remaining 60%, is comprised of species with leafless periods. Trees growing in this type of forest tend to develop growth or annual rings that cannot be found in the evergreen forest species. The deciduous forest, prone to ground fires during the dry season, can be divided into the mixed deciduous forest, dry dipterocarp forest, and savanna forest. Fires in the mixed deciduous forest have a potential to be severe if the main vegetation is bamboo. In Thailand, fire is an essential phenomenon in the deciduous forest's ecology due to its central role in forest regeneration (Akaakara 2001 and Plodpail et al. 1987).

In Thailand, the National Park, Wildlife and Plant Conservation Department (NPWPCD; <http://www.dnp.go.th>) is responsible for forest fire control and management. The Forest Fire Control Division (FFCD; <http://www.dnp.go.th/forestfire>) consists of 21 regional centers, 64 provincial offices, and 138 forest fire stations. Areas of interest are monitored using ground patrols (on-foot and with patrol vehicles) as well as by fire towers and aircraft and satellite monitoring (Akaakara 2001).

2. USE OF REMOTE SENSING TO MONITOR FIRES IN THAILAND

Though the traditional methods are still being used in daily operation, satellite remote sensing is becoming more common in forest fire management. The Moderate Resolution Imaging Spectroradiometer (MODIS) is a multi-spectral remote sensing device. The collected data is available in near real time. It is therefore a promising data source for use in tracking both active fires and burned areas during the forest fire season (Li et al. 2001 and Menzel et al. 1996). MODIS is one of the sensors in the Earth Observing System (EOS). There is a large body of prior work using Advanced Very High Resolution Radiometer (AVHRR) of the National Oceanic and Atmospheric Administration (NOAA) in polar orbiting platforms (POES) satellites, the Geostationary Operational Environmental Satellite (GOES), the Defense Meteorological Satellite Program Operational Linescan System (DMSP-OLS), the Along Track Scanning Radiometer (ATSR), and the Tropical Rainfall Measuring Mission Visible and Infrared Scanner (TRMM-VIRS).

The FFCD in Thailand uses the MODIS active fire detection capability available from the Fire Information for Resources Management System (FIRMS; <http://maps.geog.umd.edu/firms>) at the University of Maryland). This monitoring system has been used in daily operations beginning in December 2006 through a collaboration between FFCD (Thailand) and FIRMS (USA). Since 2007, the delivery time of data from FIRMS

to FFCD has been reduced from once a day to every 4 to 5 hours.

Within Thailand, the FFCD monitors sites of particular interest. The selected monitoring sites are the World Heritage Huai-Kha-Khaeng (HKK) Wildlife Sanctuary, the World Heritage Khao Yai (KY) National Park, Hua Ham Dang (HND) National Park, Salak Phra Wildlife Sanctuary, Salawin National Park, and Doi Suthep Pui (DSP) National Park (Table 1 lists the sites and Figure 3 shows them on a map of southeast Asia).

Table 1: Selected Fire Monitoring Sites

Site	Location	Size (Sq.Km.)	Notes
Huai Kha Khaeng	Central West	2,574.00	Trend to have big forest fire deep inside every year
Huay Nam Dang	North	1,256.12	Tourist attraction and many hill tribes' slash and burn agricultural practice
Doi Suthep-Pui	North	261.06	Very near urban area
Khao Yai	Central East	2,168.00	Near rapid resort and resident development



Figure 3: Study Sites

Salawin	Northwest	721.52	Adjacent to Myanmar
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Salak Phra	West	858.55	Part of Western Forest
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3. REMOTE SENSING OF FOREST FIRES

The MODIS sensor has been used to track wildfires via the FIRMS (<http://maps.geog.umd.edu/firms/>) system. The MODIS sensors flying on the Terra and Aqua spacecraft provide excellent temporal coverage (at least 2x per day daylight overflights), spectral range (0.62-14.3 μ m), and spatial coverage (coverage of the majority of Thailand each overflight). However the MODIS sensor has limited spatial resolution (250m-1000m per pixel), hampering its use in precise estimation of fire intensity and burn severity.

The Landsat series of spacecraft have been used in fire monitoring both for active fire detection and burn severity measurement. Landsat offers higher resolution (30 m per pixel) imagery but has a limited revisit rate (approximately every 2 weeks). Thailand currently utilizes Landsat-5 data when overflights are available and is able to download data to local ground communications stations for rapid data usage. The ASTER instrument has also been applied to forest fire applications such as active fire mapping and burn severity measurement.

The Earth Observing One (EO-1) Advanced Land Imager (ALI) Instrument provides higher spatial resolution data (30km wide swath, 30m spatial resolution multispectral, 9 bands 0.4-2.4 μ spectral range). While EO-1 also has nadir overflights only every 15 days, because EO-1 can be pointed at targets off nadir it can provide 5 day and 5 night overflights every 15 days. ALI imagery is automatically processed to derive hotspot detection onboard (originally developed for volcanic thermal emission estimation but also applicable to wildfire hotspot detection) [Davies et al. 2006]. ALI also supports generation of burn severity products [Van Wagendonk et al. 2004]. Figure 4 shows EO-1/ALI data acquired in September 2009 to track the Station Fire in Southern California.

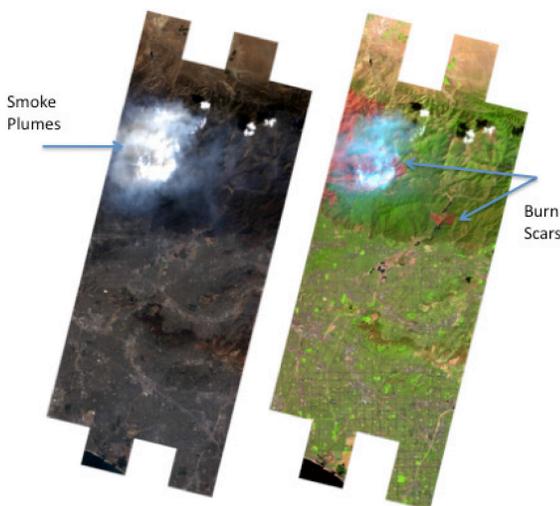


Figure 4: Visible and burn scar enhanced images from ALI instrument on EO-1 of Station Fire near Los Angeles 03 September 2009
Images courtesy EO-1 Mission NASA GSFC

4. A FIRE SENSORWEB FOR IMPROVED FIRE MONITORING IN THAILAND

Sensorweb technologies offer the promise of improved monitoring by integrating multiple types of sensor data to direct assets to better track the phenomena of interest. In the general sensorweb concept, a cycle of data acquisition, modeling, and redirection and reconfiguration of sensors to acquire further data is operated continuously. In the context of the Thailand Fire Sensorweb the data being acquired consists of ground-based reports (fire patrols, watch towers), aerial data (from helicopters and aircraft), and space-based sensors (MODIS, Landsat, ALI). Modeling consists of forest fuel loading and weather models to estimate burn hazard and progression for fires and for associated smoke. Response and retargeting would consist of tasking space, ground, and aerial assets to better track fire events. As part of this sensorweb cycle, relevant data products are generated, including: active fire maps, burn scar estimation products, and fire alerts.

As a preliminary step towards this fire sensorweb vision, we have developed a pilot system using MODIS and Earth Observing One. The Thailand Fire Sensorweb currently processes alerts from FIRMS which are delivered by email to the Thailand Wildfire Sensorweb Agent at the Jet Propulsion Laboratory. This agent then categorizes the alerts based on the study regions defined above weighted by the confidence of the alert. Each area is assigned a weighted importance factor and combined with the alert confidences and weights to produce an ordered priority of regions. Then for the highest scoring region we compute the priority-confidence weighted centroid of the alerts and request further imaging of that target.

The Earth Observing One spacecraft has automated tasking capability [Chien et al. 2005] and is integrated with this alert system to automatically task imaging the highest scoring wildfire area determined above. When the new data is acquired it is automatically processed for hotspot and burn severity data. These products are then automatically delivered to the relevant Thailand authorities (e.g. FFCD) via FTP.

Calculating burn severity requires some additional processing. In order to be most useful, we develop a Difference Normalized Burn Ratio (Δ NBR) product using baseline ALI imagery collected for the 6 sites outlined above. Because the burn scar may cover areas that are part of several baseline pre-burn images, we first compute a mosaic of pre-burn NBR that covers the post burn image area (note that this may require data from multiple pre-burn baseline images). Next a post burn NBR product is derived from the post burn image. These images are aligned using the phase correlation method. The Δ NBR product can then be constructed by computing an image of the difference between the pre and post fire NBR images.

Figure 5 shows the components, assets, and products comprising the current operational Thailand Fire Sensorweb. Modules and products implemented are shown in regular type. Items still being implemented are shown in underline and italics. The current system includes the MODIS, EO-1/ALI, and Landsat-5 satellite data systems and focuses on active fire mapping (AFM) and burn severity (NBR) product generation and delivery.

Future work will focus on four areas: adding additional space sensors, developing and integrating smoke products from satellite data; integrating FFCD in-situ (patrol) and aerial data into the sensorweb; and integrating burn risk, burn progression and smoke models.

5. EXPERIENCE WITH THE THAILAND FIRE SENSORWEB

The Thailand Fire Sensorweb has been operating to cover the current (2011) fire season. While the 2011 fire season has seen limited fire activity due to moderate temperatures and rainfall, the fire sensorweb has successfully detected, responded, and delivered products on several occasions. Figure 6 shows EO-1/ALI imagery acquired 04 March 2011 and post-fire NBR products for a fire in the Huay Nam Dang area.

7. CONCLUSIONS

We have described a sensorweb in implementation to monitor and track fires in Thailand. The current system integrates MODIS/FIRMS-based active fire mapping with EO-1/ALI response imagery and burn severity products. Ongoing work targets: integrating additional satellite systems; generation of smoke products from satellite data; integrating patrol, aircraft, and fire tower information; and integrating models of fire risk, progression, and smoke.

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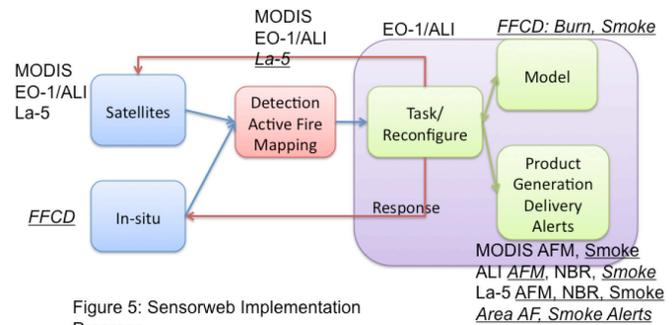


Figure 5: Sensorweb Implementation Progress
Regular Type – Implemented
Italics and Underline – In Progress

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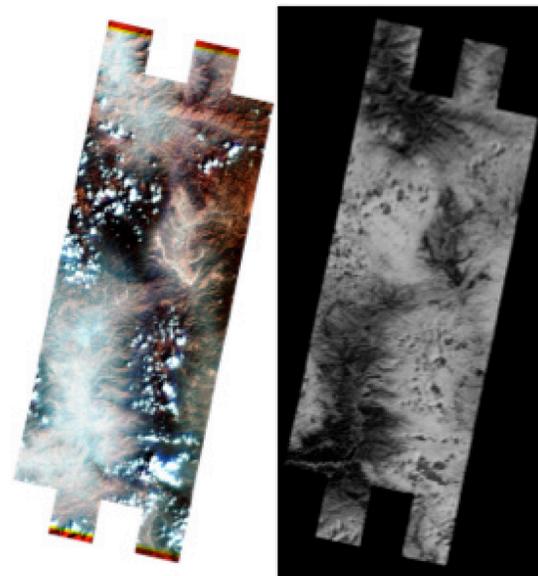


Figure 6: EO-1/ALI Color image (L) and Normalized Burn Ratio (R) product of Huay Nam Dang acquired 4 March 2011 in response to active fire alert
Images courtesy EO-1 mission/GSFC

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