Active Fire Monitoring of Thailand and Upper ASEAN by Earth Observation Data: Benefits, Lessons Learned, and What Still Needs to Be Known

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Abstract This paper describes the history of active fire monitoring of Thailand and Upper ASEAN (Cambodia, Lao PDR, Myanmar, and Vietnam) by Earth Observation Data, including benefits, lessons learned, and the unknowns. Satellite remote sensing offers a unique potential for mapping and monitoring fires at large spatial scales. Active fire information from satellites is one of the fundamental data in mitigating the smoke haze effect; therefore, active fire monitoring has become an essential tool for daily fires and smoke haze control, management, and mitigation in Thailand. The three critical sources of active fire hotspot information used in Thailand and elsewhere include (a) NASA's Fire Information for Resource Management System (FIRMS); (b) the National Environmental Satellite, Data, and Information Service (NESDIS), Active Fire Alert System; and (c) the Colorado School of Mines VIIRS NightFire Alert System. On their own, satellite-derived active fire information is insufficient, but the combination of satellite-derived data and traditional fire monitoring from ground-based methods can work well. Adding advanced geostationary fire detection is needed as a next step to enable fire suppression teams to reach fires as quickly as possible, resulting in much more efficient and safer fire control.

Keywords Active fire · Hotspot · Thailand · Upper ASEAN · NASA-FIRMS · VIIRS · NOAA · NightFire

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1 Introduction

In recent years, forest fires and associated haze have become a major environmental problem in the tropical ecosystems of the upper Association of Southeast Asian Nations (ASEAN). Upper ASEAN, or Lower Mekong River Region, consists of five countries: Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam (Biswas et al. 2015; Lasko and Vadrevu 2018; Yu et al. 2017; Albar et al. 2018; Inoue 2018; Hayasaka and Sepriando 2018). Forest fires, open burning, and smoke haze became common environmental issues in this region, specifically, a Lower Mekong River Region that comprises northern Thailand, northeastern-eastern Myanmar, and northern Laos. Smoke haze has long stood out as a significant yearly environmental concern for the region, with its severity varying year-to-year (Adam and Balasubramanian 2021). The term "smoke haze" means atmospheric haze mainly due to smoke from fires or open burning, particularly in forests and agricultural lands. Incomplete burning releases a significant amount of smoke. In Thailand, smoke haze has become a conflict issue between rural and urban people and government authorities in northern Thailand (Marks and Miller 2022).

Moreover, smoke haze affects the tourism industry and causes more respiratory illness, resulting in losing money in all sectors. Humans are known to be the sole player in fires in the region. Farmers want to clear land and eliminate weeds and the remains of previous-cycle crops or seek new ground and resort to burning as an inexpensive tool (Oanh et al. 2018). For forest fires, causes include slash and burn practice, hunting-gathering, and arguably land or personal conflicts (Saharjo and Yungan 2018; Vadrevu et al. 2021a, b). Smoke haze commonly contains tiny and unhealthy particles called Particulate Matter 2.5 or PM2.5 (Phairuang 2021). The smoke haze transboundary issue exists, but there needs to be scientifically sound research and studies to confirm the smoke haze movement and behavior on a small scale. Simply looking only at active fire hotspot information will not address the smoke haze transboundary issue, as the transport depends on various parameters. Active fire information from satellites is one of the fundamental data in mitigating the smoke haze effect (Elvidge et al. 2021); therefore, active fire monitoring has become an essential monitoring tool for daily fires and smoke haze control, management, and mitigation in Thailand and Upper ASEAN.

2 Study Area

Upper ASEAN is located in the Indochina Peninsula at 9.0 and 25.0 north latitudes, 92.5 and 110 east longitudes. Thailand is centrally located in the Indochina Peninsula between 5 40 and 20 30 north latitudes and 90 70 and 105 45 east longitudes, covering an area of 513,115 km^2 characterized by a monsoon climate (Fig. 1). It has two dominant vegetation types: evergreen and deciduous. The evergreen forest contains a significant proportion of non-leaf shedding species and covers about 40% of the area. It can be further classified into tropical rainforests, dry evergreen, hill evergreen, coniferous, mangrove, swamp, and beach forests. The remaining 60% belongs to the deciduous forest, which comprises species with leafless periods. Trees growing in this latter type of forest tend to develop growth or annual rings that cannot be found in the evergreen forest species. The deciduous forest, prone to surface fires during dry seasons, can be categorized into mixed deciduous, dry dipterocarp, and savanna. Though fires in the mixed deciduous forest have great potential to be severe and damaging, if bamboo constitutes a majority of this forest, they play a vital role in its regeneration (Charuppat 2001).

Forest fires are common in Thailand as wildland fires and are caused by humans (Akaakara 2001). Forest fires fall into six general categories in Thailand: surface, crown, ground fires, semi-crown, and semi-ground fires. First, a surface fire burns

Fig. 1 Upper ASEAN and Thailand (https://www.google.co.th/)

organic materials in soil layers and often the surface litter, loose derbies such as leaves and fallen branches, low-growing vegetation, and other fire fuels on the forest floor. Surface fires occur in the dry dipterocarp, mixed deciduous plantations, dry evergreen, hill evergreen, and some parts of the tropical rainforests. Second, a crown fire is a fire that burns primarily in the leaves and needles of trees, spreading from tree to tree above the ground. It occurs in the coniferous forest and pine plantations in the country's northern region. Third, a ground fire is a fire that burns primarily under the forest floor, spreading underground from tree to tree and usually lasting a long time. It occurs only in the peat forest in the southern region of Thailand (Plodpail et al. 1987; Akaakara 2001). Three additional types of fires occur in the transition, which are semi-crown fires, semi-ground fires, and spot fires which recently happened in southern Thailand in a degraded peat forest where paperbark trees dominated. Surface fire is a common fire type in Thailand and this region. Forest fires in Thailand occur annually during the dry season from late December to early May, with the most occurring in March (Akaakara 2001; Tanpipat et al. 2009). The relationships between the forest fires and the forest types are summarized in Table 1.

Table 1 Relationships between the forest fires and the forest types in Thailand

	Surface fire	Ground fire	Crown fire	Semi-ground fire	Semi-ground fire	Spot fire
Tropical rainforest	X					
Dry evergreen forest	X					
Hill evergreen forest	X					
Coniferous forest	X	X	X	X	X	X
Mangrove forest	X					
Peat forest	X	X	X	X	X	X
Beach forest	X					
Mixed deciduous forest	X					
Dry dipterocarp forest	X					
Savanna	X					X

The forest fire situation in Upper ASEAN has been widely reported in the media, with increasing access to information through the rapid development of cyber-technologies. Satellite monitoring of active fires has led to greater transparency, and the number of fires detected since 2003 has decreased (Copernicus 2020), but the forest fire, open burning, and smoke haze continue to be a problem every dry season. From AFoCO's Forest Fire Management Training Course's discussions among AFoCO's member states in 2019 and 2020, just for Upper ASEAN participants, the causes and needs can be listed. Those causes are all related to human activities by the country in Table 2 (AFoCO 2019, 2020).

Fires are essential for tree regeneration in dry dipterocarp and deciduous forest and usually occur annually during the dry season. There can be natural causes, such as lightning strikes, but not in this region. In the case of Thailand or the Upper ASEAN or tropical zone, lighting occurs during thunderstorms (wet lighting), so such a fire does not spread from where it occurs. Unfortunately, the major causes of forest fires are related to activities of those who live in rural areas, not the natural; they are incendiary fires ignited by people for the gathering of forest non-timber products, agricultural land preparation, political conflict, hunting, timber, cattle grazing, agricultural land expansion, and carelessness to say a few. The officially recorded statistics collected since 1980 by Thailand's Forest Fires Control Division of the National Park, Wildlife, and Plant Conservation Department, Ministry of Natural Resources and Environment (a former division in the Thai Royal Forest Department) clearly showed a very insignificantly small number of fires were of natural causes and they were not spread

Table 2 Fire causes of Upper ASEAN countries

	Cambodia	Lao PDR	Myanmar	Thailand	Vietnam
Firewood utilization	X	X	X	X	
Slash and burn	X	X	X	X	
Cash mono-crop		X	X	X	X
Hunting		X	X	X	
Cattle			X	X	
Plantation project		X			
Harvesting honey					X
Carelessness	X				X
Resin collection	X				
Concessions	X				
Burn after logging	X				
New settlement	X				
Conflicts				X	
Timber				X	
Land encroachment				X	

Source AFoCO's Country Report during Forest Fire Management Short Training Course's discussions among AFoCO's member states in 2019 and 2020 out (DNP 2020). Therefore, in this context, it is safe to conclude that all forest fires in Thailand are man-made. And their major causes are directly related to the activities of the inhabitants in the rural areas who live near or within the forests.

Smog and haze from wildfires can have a profound impact on health and everyday life. It is a transboundary issue that will require an international effort to solve. The latest examples are peat fires at South Sumatra in 2015 and 2019 (Ismi 2019).

Active fire information is the most common fire information that has been used in Upper Southeast Asia and Thailand in almost the past 2 decades since the AVHRR World Fire Web, DMSP-OLS NOAA System, FIRMS University of Maryland, etc. These systems gradually become an important part and much needed information for wildland fire and smoke haze control and management from the top to the bottom and vice versa in Thailand. The information on the active fires has become the most important information for addressing fire and smoke haze for daily operations.

3 History of Active Fires Monitoring in Thailand and Upper ASEAN

Satellite-derived active fire information has been used in Upper ASEAN or Southeast Asia and Thailand for over two decades. In 1999, the Asian Center for Research on Remote Sensing (ACRoRS), Asia Institute Technology (AIT) began using The Advanced Very-High-Resolution Radiometer (AVHRR) World Fire Web, which was started in 1998 (GFMC 2020). With informal Committee of Earth Observation System (CEOS) Working Group on Information Systems and Services (WGISS) meeting in Bangkok, Thailand, in 1999 and WGISS/GOFC (Global Observation of Forest Cover) Demonstration in 2000 meetings (Cahoon et al. 2000), the Global Observation Information Network (GOIN) 1999 by NASA Research and Education Network was demonstrated to show the Global Internet capabilities through Asia Pacific Advanced Network (APAN) and the possibility of utilizing Earth Observation Satellite (EOS) information to support a daily fire control was feasible through NOAA-AVHRR's fire products. In 1999, launching the Terra Satellite and later the Afternoon Train proved useful. EOS later became essential information supporting fire control and smoke haze management. The expansion of active fire detection from the NOAA-AVHRR-World Fire Web system (Li et al. 2000) by The Defense Meteorological Program (DMSP) Operational Line-Scan System (OLS) NOAA System was set up at Asian Center for Research on Remote Sensing (ACRoRS), Asian Institute of Technology (AIT) in 2003. Later in 2006, the Department of National Park Wildlife and Plants Conservation requested support from the Fire Information for Resource Management System (FIRMS) at the Department of Geography, University of Maryland; it has been using FIRMS (http://earthdata.nasa.gov/firms) ever since. Initially, FIRMS provided data from MODIS onboard the Aqua and Terra satellites; VIIRS 375 m active fire data (Schroeder et al. 2014) were added when it became available from Suomi-NPP and NOAA-20. FIRMS was transitioned to

NASA's Land and Atmosphere Near-real-time Capability for EOS (LANCE) in 2012. In 2017, the collaboration with NOAA-National Centers for Environmental Information [NCEI, Formal National Geophysical Data Center (NGDC)] was started, and the VIIRS NightFire alert system for Southeast Asia was established. Later in 2019, the system was moved to the Colorado School of Mines. In March 2019, following Thailand's National Forest Fire and Smoke Haze meeting, the Royal Forest Department requested official support from NOAA-National Environmental Satellite, Data and Information Service (NESDIS) to obtain quicker VIIRS active fire products to Thailand and later the whole Southeast Asia.

Active fire information has become a key component of forest fires, open burning, and smoke haze control monitoring programs in Thailand. All levels of management routinely use it for daily fire and smoke haze operations across the country. During the 2007 fire season, satellite-derived active fire data became part of the National Forest Fire Control Operation through the Forest Fire Control Division, Forest Protection, and Fire Control Office, Department of National Park, Wildlife and Plants Conservation, and Ministry of Natural Resources and Environment to the National Ad hoc Committees under the Deputy Prime Minister. To build confidence in the satellite-derived fire products, the Forest Fire Control Division carried out a field validation campaign to determine the accuracy of the MODIS active fire product; the results showed good accuracy, where burned areas were found near active fire hotspots reported at 91.84%, 95.60%, and 97.53% for 2007, 2008, and 2009 (Tanpipat et al. 2009). The Forest Fire Control Division continues this field validation task until today, and the information is used for the routine suppression task. Later in 2016, the VIIRS active fire product had 98% verification accuracy with the smallest burned area found at four m^2 (unpublished DNP report 2016), which is the same burned area's size as what found by Schroeder et al. (2014) in Brazil. With very high accuracy results, it later became a Key Performance Index (KPI) of many government agencies until today. Nowadays, the number of active fires detected inside and outside protected areas comparison has been a key statistic for people involved in daily fires and smoke haze control and management. A reliance on statistics in the past few years has led to conflicts between local people and government authorities, resulting in increasing numbers of arsonists setting fires in the deeper forested and mountainous areas where firefighters hardly reach to control them. Moreover, during the past five years of The Asian Forest Cooperation Organization's (AFoCO) 15 member states training and Disaster Mitigation Working Group of Asia Pacific Advanced Network, active fire information is always mentioned to educate participants about existing technology that can be used to a part of their forest fire control within their country.

Since 2003, there has been a gradual reduction in active fires detected using MODIS data. However, air quality is still a major concern. According to the Pollution Control Department of Thailand, the number of bad-quality air days increased from 60 days in 2017 to 112 days in 2020. The smoke haze from fires has become a national issue and is pushing the People's Clean Air Act into Thailand Parliament, hopefully again by the end of 2021 because the Prime Minister of Thailand just rejected the first "People's Clean Air Act" proposal in late March 2021 resulting in another rolling motion to collect 10,000 Thai's signatures to put it through the Thai parliament again.

At a regional level, the use of active fire information systems is taught as one of the Forest Fire Management topics in an annual five-day training course organized by the Asian Forest Cooperation Organization (AFoCO, http://afocosec.org/) for its member states. The three active fire information systems have been introduced to participants, so they can be used in their countries. For example, Cambodia used active fire information from NASA-FIRMS after the training in 2015.

All three systems have an email alert with a KML file which can be easily used on a smartphone. Representatives of forestry government agencies from Thailand, Lao PDR, Cambodia, Myanmar, and Vietnam who participated in AFoCO's Forest Fire Management training course are the people who receive those email alerts and distribute them to responsible people in the country. Only Thailand has used such information extensively, as mentioned. Web Map Service of FIRMS is also commonly used by active Thai citizens and NGOs who would like to follow fire situations closely.

4 Description of Main Existing Fire Monitoring Systems and Sources Using in Upper ASEAN

4.1 FIRMS NASA

NASA's Fire Information for Resource Management System (FIRMS, Figs. 2 and 3) delivers global active fire information, derived from MODIS (Aqua and Terra) and VIIRS (S-NPP and NOAA-20), in easy-to-use formats, within 3 h of satellite observation, as well as the full archive of active fire data. FIRMS has users in over 160 countries with over 12,000 users registered for near-real-time, daily or weekly, active fire email alerts. The Fire Map interface enables users to view and query active fires by time since detection, as well as view corrected reflectance imagery (from MODIS and VIIRS), Aerosol Index from the Ozone Mapping Profiler Suite (OMPS) and historic burned areas (derived from MODIS). Originally developed by the University of Maryland, with funds from NASA's Applied Sciences and the United Nations Food and Agriculture Organization (UN FAO), FIRMS is now part of NASA's Land, Atmosphere Near-real-time Capability for Earth Observing System (EOS) (LANCE, Fig. 4), which is managed by NASA's Earth Observing System Data and Information System (EOSDIS).

4.2 VIIRS NOAA-NESDIS

The ground segment serving VIIRS onboard S-NPP and JPSS (e.g., NOAA-20) spacecrafts includes primary 300 Mbps Ka-band receiving stations located in the

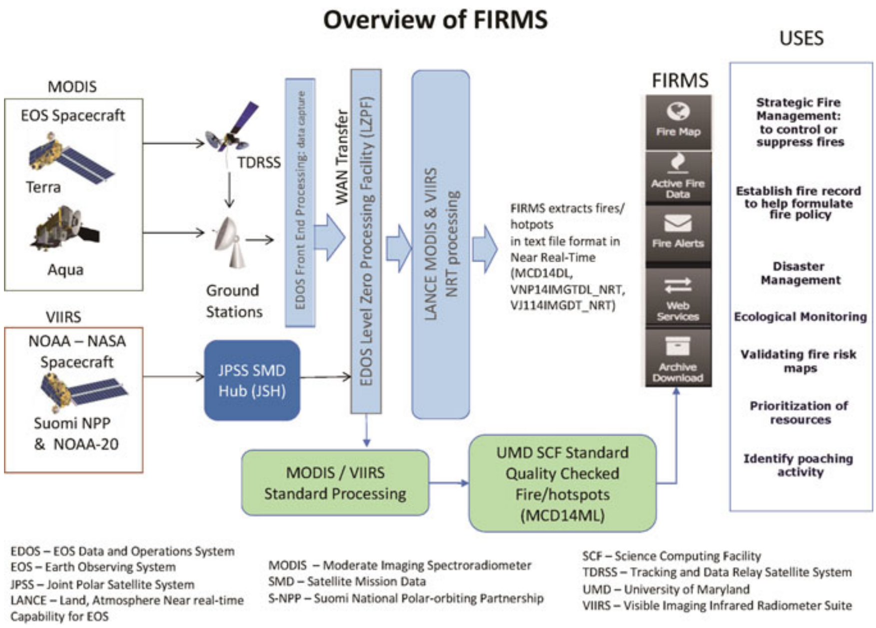

Fig. 2 Overview of FIRMS (Diane Davies, NASA-LANCE Operation Manager)

Fig. 3 FIRMS fire map showing VIIRS 375 m active fire detections (in red) from NOAA-20 (https://go.nasa.gov/3sRsP3b)

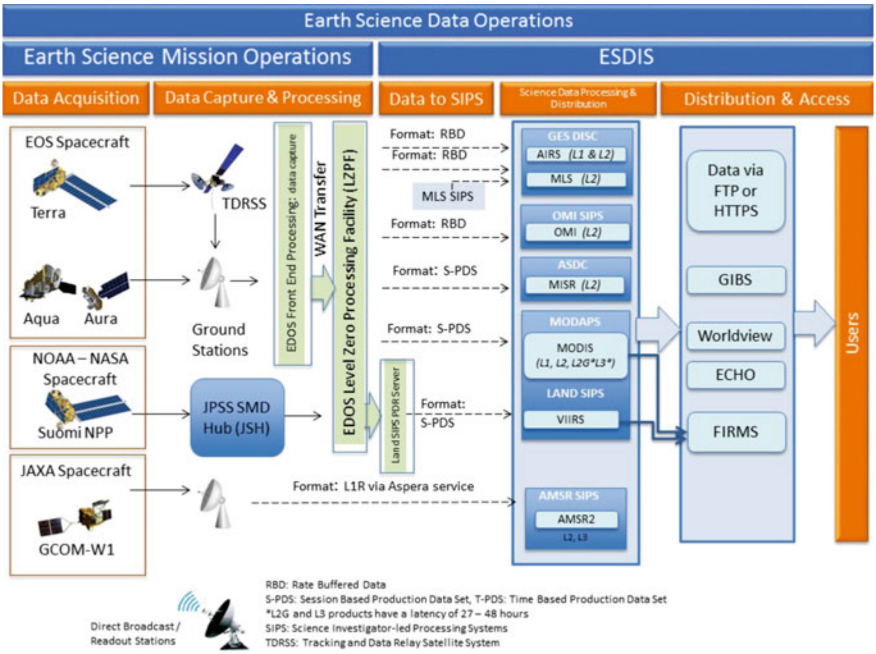

Fig. 4 Overview of LANCE (Diane Davies, NASA-LANCE Operation Manager)

northern (Svalbard/Norway and Fairbanks/Alaska) and southern (McMurdo and Troll/Antarctica) hemispheres, providing Stored Mission Data (SMD) downlink capabilities in addition to telemetry and commanding operations. From the receiving stations, data are relayed to a primary processing node located at the NOAA Satellite Operations Facility (NSOF) in Suitland/Maryland—USA, where mission data are converted into raw, sensor, and environmental products for distribution and archival. A more stringent 80-min data latency makes the JPSS mission particularly well-suited for near-real-time forest fire detection applications. In comparison, S-NPP data latency requirements are set at a somewhat higher 140-min. Data quality monitoring and calibration are performed continuously ensuring that products remain within specifications throughout the mission's lifetime. In addition to NOAA's primary ground system, a network of 15 Mbps X-band ground receiving stations found in all five continents provides access to direct broadcasting data used in support of local and regional applications.

Building on the SMD source data, NOAA/NESDIS Office of Satellite and Product Operations provides on-demand VIIRS fire detection email alerts to various users in Thailand as well as neighboring Upper ASEAN member states. Users receive country-specific fire detection data every 12 h or less, including location, timing, and intensity (fire radiative power [FRP]) information packaged in a GIS-friendly format (comma-separated value [csv], KML). Both S-NPP and NOAA-20 data were being served at the time of writing.

4.3 VIIRS NightFires (VNF)

VIIRS NightFires (VNF) is a multispectral global fire detection product developed by the Earth Observation Group (EOG) in 2012 (Elvidge et al. 2013). EOG produces VNF at Colorado School Mines, and nightly global data are made accessible in near real time for nightly global detection of infrared emitters such as wildfire and natural gas flaring. In 2012, NASA and NOAA began collecting data with the Visible Infrared Imaging Radiometer Suite (VIIRS) from a polar orbit. The VIIRS collects a complete set of orbital strips covering the globe daytime and nighttime at near 1 km^2 resolution every 24 h over a wide range of spectral channels. The sensor specifications came from the meteorological community. Traditional satellite fire detection is performed with mid-wave infrared (MWIR) channels, and VIIRS collects that in two channels. EOG reviewed nighttime VIIRS data in April 2012 were surprised by the large number of infrared emitter detections present in daytime channels designed for measurement of reflected sunlight. This includes bands M7 and M8 in the near infrared and M10 in the shortwave infrared. These spectral bands are typical for earth observation sensors, but usually the nighttime data are not collected. The decision to collect the NIR and SWIR at night originated with a VIIRS design engineer who added them to the nighttime collection mode to mitigate for mid-wave infrared (MWIR) signal saturation anticipated for large fires. EOG realized that with the detections spread across the NIR, SWIR, and MWIR, it may be possible to analyze fire temperatures via Planck curve fitting. The original development of VNF was funded by NOAA's Joint Polar Satellite System (JPSS) proving ground program. For pixels with IR emitter detection in two or more channels, the VNF algorithm calculates temperature, source size, and radiant heat using Planck's Law and its derivatives, including Wien's displacement law and the Stefan–Boltzmann law. VNF traces its roots back to methods pioneered by Dozier (1981).

The importance of the NIR and SWIR data in VNF's success turns out to be crucial. With sunlight eliminated, the VIIRS NIR and SWIR band data act as super-detectors for sub-pixel infrared emitters. These wavelengths have some advantage over mid-wave (MWIR) and long-wave infrared (LWIR) channels used in that all the energy measured in the NIR and SWIR at night can be attributed to emitting sources present on the ground. In addition, the SWIR detection limits are quite low due to the low levels of incoming solar radiation and the signal-to-noise requirements for daytime imaging. It turns out that the SWIR data are particularly important for the detection and monitoring of gas flares as they coincide with the peak of radiant emissions from flares due to their high temperature. It has been shown that the inclusion of the shorter wavelength channels extends the IR emitter detection limits as compared to the MWIR fire products (Elvidge et al. 2019). EOG provides near-real-time VNF detection alerts for the Upper ASEAN region by email.

5 Benefits, Lessons Learned, and What Still Needs to Be Known

5.1 Benefits

The active fire monitoring systems described above are useful for daily fire and smoke haze control, management, and mitigation. They provide an overview, in near real time, of where fires occur, and the information is being used to empower citizens to monitor the government's work in fire control and funded low-cost air quality networks, which are expanding due to public concern about air quality. As mentioned earlier, air quality is a key concern that has led to the 2021 People's Clean Air Act being taken to the House of Representatives in the Thai Government.

5.2 Troubles

Transboundary smoke and haze can be seen using satellite data under the right conditions; however, as MODIS and VIIRS are both optical instruments, they cannot penetrate clouds or thick smoke, so it is not always possible to determine which fires cause the problem. There are also issues with simply looking at the number of active fire detectors without considering underlying vegetation types and other factors that affect smoke behavior. Apportioning blame can be politically sensitive. Slow delivery of active fire information to the public needs to be improved as well.

5.3 Lessons Learned

Users sometimes need help understanding the caveats and limitations of using satellite-derived active fire information. The MODIS and VIIRS instruments are on polar-orbiting satellites, meaning active fires are only detected as the satellite passes overhead. Because they are optical instruments, clouds, smoke, and thick haze can obscure active fire detection, so using several active fire hotspots detected as a Key Performance Indicator (KPI) will not take into account fires ignited when the satellites are not passing over in the early evening until late night, which will result in creating more smoke haze as fuel on the ground has higher moisture during that time period. To this end, the number of active fire hotspots detected does not reflect the total picture of smoke haze, which affects air quality. More active fires detected in other countries mean additional sources of smoke haze that can be transported long distances to another country. Factors such as wind and air pressure are involved in the movement of smoke haze. Users do not understand what an active fire 'hotspot' is and are sometimes too obsessed with active fire hotspot information, so they depend on it too much. The current active fire delivery platforms need to add reliable geostationary products. So far, The Japan Aerospace Exploration Agency (JAXA) Himawari AHI (Advanced Himawari Imager) active fire products science team is still working on that. There also needs to be culturally competent training extended to mobile applications, including multiple fires and smoke haze products and information ready to use anywhere. The linking to fire emissions such as PM2.5, CO, smoke transport, and modeling in Thailand is not robust yet. There is an ongoing collaboration among the Royal Forest Department, Office of Information Technology Administration for Educational Development (UniNet), Upper ASEAN Wildland Fire Special Research Unit (WFSRU), Forestry Research Center, Faculty of Forestry, Kasetsart University, Webster University Thailand and Chulalongkorn University to deliver fire emissions data from Copernicus Atmosphere Monitoring Service (CAMS) Global Fire Assimilation System (GFAS) to the public in easier to understand ways. The EO APIs need to be improved. Addressing transboundary fire emissions needs a better monitoring system and validation of fire emissions (fuel type, emission variables). Monitoring platforms need to include ancillary data (land cover, land use type, winds, soil moisture, fire weather, etc.). Models need to be integrated into the existing platforms for holistic fire and smoke management. Also, there needs to be a learning process from and expanding on for-profit and non-profit partnerships to address the problem.

5.4 What Still Needs to Be Known

Quicker delivery time of fire information is fundamental to fire control. In the future, additional satellites in the Earth Observing System (EOS) better than VIIRS's capabilities with faster, within 10 min, downlink time onboard are needed for more efficient forest fire control. Faster delivery time of high-quality fire products can help fire managers address the problem quickly with less damage. Improvements in geostationary thermal detection sensors and systems are needed. Further, the estimated size of burned areas (by both optical and microwave data) needs to be delivered faster than the current rate. Fire spread direction, including intensity, is needed for more efficient fire control and suppression. Online analysis tools should be developed where all the statistics of active fire, burned areas, fire emissions, and other related products can be analyzed. Also, the information should be disseminated faster on fire emissions, useful for smoke haze control and air quality management. More international collaborations on forest fire control and smoke haze management can help address the problem effectively.

6 Conclusion

Monitoring wildland fires and smoke haze using Earth Observation Satellite (EOS) has become an integral tool for monitoring active fires and smoke haze in Upper ASEAN. The control, management, and mitigation measures used in Thailand are now expanding to all countries in Upper ASEAN (Lower Mekong River Region). Access to free high-quality active fire information from NASA-FIRMS, VIIRS NightFire Alert System, and VIIRS NOAA Alert System has changed how fires are managed in the region. On their own, satellite-derived active fire information is insufficient, but the combination of satellite-derived data and traditional fire monitoring and detection methods works well. Adding advanced geostationary fire detection is needed as a next step to enable fire control teams to reach fires as quickly as possible.

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