Wildfire Report Series

Investigation of MODIS-Detected Fires in NFIRS

Executive summary

Moderate Resolution Imaging Spectroradiometer (MODIS)[1] is a satellite-based instrument used to collect data about features on the Earth's surface. Scientists have developed algorithms to analyze that data to detect active fires. Researchers David T. Butry and Douglas S. Thomas published a paper in 2017[2] that compared the MODIS active fire data for California from 2003 to 2014 to wildfire incident data collected by the U.S. Fire Administration's (USFA's) National Fire Incident Reporting System (NFIRS) and found that only 32% of the MODIS-detected fires could be matched to an NFIRS incident. (Butry and Thomas' criteria for identifying wildfires in NFIRS and for matching them to MODIS active fire data are discussed on page 2.)

In conducting this analysis, USFA's goal was to apply a variation of Butry and Thomas' MODIS/NFIRS fire incident matching process at the national level to determine if the same proportion of data could be matched in the rest of the U.S. Additionally, as a path to improving NFIRS reporting, it was thought that this could be a first step in determining the feasibility of using MODIS data as a means for identifying wildfire incidents that may be missing from NFIRS.

Using geocoded 2017 NFIRS data for all fire incidents in the U.S., USFA found that only 1.1% of the MODIS observations (or 1.6% of MODIS-identified incidents) occurred within 1 kilometer and 24 hours of any NFIRS-reported incident. It was determined that 6.4% of MODIS-identified incidents occurred within national parks and national forests, grasslands, and wilderness areas, but only a handful of these incidents appear in NFIRS data. As for the remaining unmatched MODIS-identified incidents, it is uncertain whether they occurred in other public lands; were small, controlled unreported fires; or were false positives.

MODIS

MODIS is an observational instrument operated by the National Aeronautics and Space Administration. It is the name of the sensor aboard two satellites, Terra and Aqua, that were launched in 1999 and 2002 respectively. Terra and Aqua follow a sun-synchronous near polar orbit, approximately 705 kilometers above the surface of the Earth. Collectively, the satellites observe each point on the Earth's surface three to four times per day, though the interval between passes varies. Instrument data is used to monitor and process trends in land vegetation, ocean phytoplankton, and cloud temperature and altitude, among other features.[3]

One of the uses of MODIS data is the detection of active fires. The fire detection strategy is based on absolute detection of a fire (when the fire strength is sufficient to detect) and on detection relative to its background (to account for variability of the surface temperature and reflection by sunlight).[4] Scientists at the University of Maryland developed the algorithm to identify areas where the infrared radiation being emitted is significantly different from that of surrounding areas. MODIS can routinely detect both flaming and smoldering fires

[1]National Aeronautics and Space Administration (NASA). (n.d.). *About.* MODIS: Moderate Resolution Imaging Spectroradiometer. Retrieved December 16, 2020 from https://modis.gsfc.nasa.gov/about/index.php

[2]Butry, D. T., & Thomas, D. S. (2017, August 8). Underreporting of wildland fires in the US Fire Reporting System NFIRS: California. *International Journal of Wildland Fire, 26*(8), 732–743. https://doi.org/10.1071/WF17004

[3]NASA. (n.d.). *Data.* MODIS: Moderate Resolution Imaging Spectroradiometer. Retrieved December 16, 2020 from https://modis.gsfc.nasa.gov/data/

[4]NASA. (n.d.). *MODIS thermal anomalies/fire.* MODIS: Moderate Resolution Imaging Spectroradiometer. Retrieved December 16, 2020 from https://modis.gsfc.nasa.gov/data/dataprod/mod14.php

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approximately 1,000 square meters in size. Under very good observing conditions (e.g., near nadir, little or no smoke, relatively homogeneous land surface, etc.), flaming fires one-tenth this size can be detected. Under pristine (and extremely rare) observing conditions, even smaller flaming fires approximately 50 square meters can be detected.[5]

The Butry/Thomas analysis: Matching selected NFIRS fires to MODIS observations by county and date in California

Summary of approach and findings

Butry and Thomas examined MODIS-detected fires within areas of local jurisdiction in California from 2003 to 2014 and found that only 32% of them were present in NFIRS. However, their analysis did not use geocoded NFIRS data, and they were only able to attempt to match NFIRS fires with MODIS-detected fires by county and date. In addition, the criteria they used to select NFIRS incidents may have omitted some fires that may have been detected by MODIS.

It should be noted that NFIRS is not a census of all fire department-responded incidents, and it is not based on a statistically derived sample. Among other issues that prevent the NFIRS from being a complete source for fire department incident data are reporting deadlines, data access and budgetary considerations. For fire incidents, as with other NFIRS fire department-responded incidents, the NFIRS raw totals do not reflect the whole of the U.S. fire problem; NFIRS contains incident data derived from voluntary reporting of fire incidents in the U.S.

The state of California is divided into distinct areas where either the local fire department, CAL FIRE or the agencies of the federal government have primary responsibility for wildfire incident management. The authors first identified MODIS-detected fires that occurred within local direct protection areas. They then retrieved a subset of California NFIRS incidents by selecting incidents where any of the following criteria was present:

- ❯ Incident Type = 141: Forest, woods or wildland fire.
- ❯ Incident Type in 100 series (Fire) or 561 (Unauthorized burning), 631 (Authorized controlled burning), or 632 (Prescribed fire), and:
  - ▸ Actions Taken includes 13: Establish fire lines (wildfire), or
  - ▸ Actions Taken includes 14: Contain fire (wildland), or
  - ▸ Actions Taken includes 15: Confine fire (wildland), or
  - ▸ Actions Taken includes 16: Control fire (wildland).
- ❯ Incident Type in 100 series (Fire), and:
  - ▸ Area of Fire Origin = 95: Wildland, woods, or
  - ▸ Suppression Factor includes 775: Urban-wildland interface area.
- ❯ Wildland Fire Module: Was used for incidents where Incident Type was not 632 (Prescribed fire).

Finally, they found those NFIRS fires that occurred in the same county (using the county of the reporting fire department) and on the same day as any MODIS-detected fire in local direct protection areas (Figure 1).

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[5]University of Maryland. (n.d.). *Active fire products.* MODIS Active Fire and Burned Area Products. Retrieved November 6, 2019 from http://modis-fire.umd.edu/af.html; Giglio, L., Schroeder, W., Hall, J. V., & Justice, C. O. (2018, December). *MODIS collection 6 active fire product user's guide revision B.* NASA. http://modis-fire.umd.edu/files/MODIS_C6_Fire_User_Guide_B.pdf

Figure 1: Subset of MODIS and NFIRS data examined for county-date matching

MODIS observations — NFIRS incidents

Selected NFIRS
incidents in Local
Direct Protection
Areas
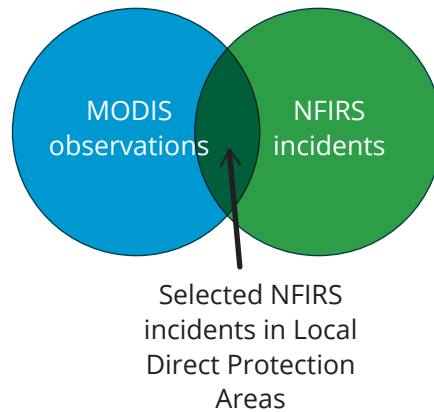
Butry and Thomas found that 32% of the MODIS-detected fires in areas of local responsibility occurred in the same county and on the same day as an NFIRS-reported fire that met the criteria defined in the study to describe wildfires.

Discussion of approach

It is possible that some of the methods and assumptions used in this analysis are problematic. Butry and Thomas make an implicit assumption that all fires detected by MODIS are wildfires, but MODIS can on rare occasions detect fires as small as 50 square meters (4-meter radius) and routinely detects fires 1000 square meters in size (18-meter radius). The criteria Butry and Thomas used to identify wildfires in the NFIRS data potentially omits many other kinds of incidents that could match the MODIS observation. Moreover, the criteria used omits other factors that could identify additional wildland fires. Notably, the criteria do not include other outdoor incident types:

- ❯ 140: Natural vegetation fire, other.
- ❯ 142: Brush or brush-and-grass mixture fire.
- ❯ 143: Grass fire.
- ❯ 170: Cultivated vegetation, crop fire, other.
- ❯ 171: Cultivated grain or crop fire.
- ❯ 172: Cultivated orchard or vineyard fire.
- ❯ 173: Cultivated trees or nursery stock fire.
- ❯ 561: Unauthorized burning.
- ❯ 631: Authorized controlled burning.
- ❯ 632: Prescribed fire.

The criteria do not consider property use:

- ❯ 655: Crops or orchard.
- ❯ 659: Livestock production.
- ❯ 669: Forest, timberland, woodland.
- ❯ 931: Open land or field.

The criteria omit certain areas of origin:

- ❯ 94: Open area, outside; included are farmland, field.

Last, the criteria do not include other possible suppression factors:

- ❯ 434: Poor or no access for fire department apparatus.
- ❯ 760: Unusual vegetation fuel loading.

Incidents defined under these categories would not be included in the analysis unless they also meet the criteria specified by Butry and Thomas.

The criteria Butry and Thomas use to identify potential wildfires rely upon values in the Basic, Fire and Wildland Fire Modules. Of these, only the first Action Taken value is required and is populated with useable data nearly all of the time (Table 1). Area of Fire Origin, in the Fire Module, contains usable data in 81% of the reports where a Fire Module is completed (Table 2). Suppression Factors, also in the Fire Module, are optional fields and are sparsely populated (Table 3). Finally, Butry and Thomas use the presence of the Wildland Fire Module to infer a wildfire, but the Wildland Fire Module is only used for 23% of the incidents where it is allowed (Table 4).

Action Taken is recorded in the NFIRS Basic Incident Module. In this module, up to three values may be entered. The first one is required for all values of aid, and the others are optional.

Table 1: Usability of primary actions taken (Basic Incident Module)

	Action Taken 1			Action Taken 2			Action Taken 3		
	Primary[1]	Aid Given	Total	Primary	Aid Given	Total	Primary	Aid Given	Total
Total basic incidents	1,073,284	227,128	1,300,412	1,073,284	227,128	1,300,412	1,073,284	227,128	1,300,412
Invalid values[2]	11,975	7,538	19,513	2,337	854	3,191	1,080	154	1,234
Null values	1	0	1	730,701	157,477	888,178	944,352	199,607	1,143,959
Usable values	1,061,308	219,590	1,280,898	340,246	68,797	409,043	127,852	27,367	155,219
Percent of incidents	99	97	98	32	30	31	12	12	12

[1]Primary refers to incidents where Aid = 1 (Mutual Aid Received), 2 (Automatic Aid Received), 5 (Other Aid Given), or N (No Aid). Aid Given refers to incidents where Aid = 3 (Mutual Aid Given) or 4 (Automatic Aid Given).
[2]Invalid Values are entered values that are not listed in the NFIRS Complete Reference Guide, including "-", "00", "0", "6", "18", "25", "59", "68", "95", and "N."

Area of Fire Origin and Suppression Factors are recorded in the NFIRS Fire Module, which is only required for certain incident types where the reporting department (primary) is not giving aid. Area of Fire Origin is required. Suppression Factors are optional, and up to three values may be recorded.

Table 2: Usability of area of fire origin (Fire Module)

	Area of origin		
	Primary[1]	Aid Given	Total
Total Fire Module reports	598,828	5,803	604,631
Null values	448	274	722
Undetermined (UU)	94,464	2,020	96,484
Other (0)	18,751	192	18,943
Usable values	485,165	3,317	488,482
Percent of incidents with Fire Module	81	57	81

[1]Primary refers to incidents where Aid = 1, 2, 5, or N. Aid Given refers to incidents where Aid = 3 or 4.

Table 3: Usability of suppression factors (Fire Module)

	Suppression factor 1			Suppression factor 2			Suppression factor 3		
	Primary[1]	Aid Given	Total	Primary	Aid Given	Total	Primary	Aid Given	Total
Total Fire Module reports	598,828	5,803	604,631	598,828	5,803	604,631	598,828	5,803	604,631
Null values	426,033	3,900	429,933	595,107	5,709	600,816	597,467	5,765	603,232
Undetermined (UUU)	1	0	1	2	0	2	0	0	0
Other (0)	1,567	28	1,595	55	2	57	31	0	31
None (NNN)	154,590	1,536	156,126	0	0	0	0	0	0
Usable values	16,637	339	16,976	3,664	92	3,756	1,330	38	1,368
Percent of incidents with Fire Module	4	9	4	1	2	1	0	1	0

[1]Primary refers to incidents where Aid = 1, 2, 5, or N. Aid Given refers to incidents where Aid = 3 or 4.

The Fire Module is required for most incident types but may be substituted with the Wildland Fire Module for certain kinds of fires. The Fire Module is optional for certain incident types in the 100 series (fire incidents) but is not available for other kinds of incidents. Neither module is required if the department is assisting another department (where Aid = 3 or 4).

Table 4: Presence of Fire and Wildland Fire Module by module requirement[1]

	Primary[2]			Aid Given			Total		
	Incidents	% Using Fire	% Using Wildland	Incidents	% Using Fire	% Using Wildland	Incidents	% Using Fire	% Using Wildland
Fire or Wildland required	216,979	73	27	45,852	3	3	262,831	61	23
Fire required	365,130	100		156,146	3		521,276	71	
Fire optional	328,130	23		21,459	1		349,589	21	
Wildland optional	163,045		1	3,671		1	166,716		1
Total	1,073,284	56	6	227,128	3	1	1,300,412	46	5

[1]Either the Fire Module or the Wildland Fire Module is required for incident types 140-143, 160, and 170-173. The Fire Module is required for incident types 100, 111-112, 120-123, 130-138, and 161-164. The Fire Module is optional for all other fire incident types, and the Wildland Fire Module is optional for incident types 561, 631, and 632. Both modules are optional for Aid Given.
[2]Primary refers to incidents where Aid = 1, 2, 5, or N. Aid Given refers to incidents where Aid = 3 or 4.

Butry and Thomas did not have geocoded NFIRS incident data and matched selected NFIRS and MODIS incidents based on county and date. In practice, this means that any qualifying NFIRS incident in the county could be matched to any MODIS observation in the local direct protection area, regardless of the actual distance between the points. Also, matching incidents solely by date does not allow the researchers to identify possible matches where the NFIRS and MODIS reports occurred on adjacent dates.

USFA analysis: Matching a broader base of more precisely located NFIRS fires to MODIS observations within 1 kilometer and 24 hours at the national level

Summary of approach and findings

In an attempt to reproduce Butry and Thomas' results at the national level, this analysis used NFIRS and MODIS[6] data from 2017 covering the entire U.S. The 2017 NFIRS data was geocoded, so it was possible to find matches at a much more granular level than by county. All fire incident types were included (rather than attempting to define "wildfires" with NFIRS criteria), as well as authorized and unauthorized fires (Incident Types 631 and 561) and prescribed fires (Incident Type 632). To eliminate issues related to time zones and to be able to compare incidents within a 24-hour window, date and time of all NFIRS incidents was standardized by converting the alarm time to Universal Coordinated Time. Nationwide, we found that about 1.1% of the MODIS observations and 1.6% of the MODIS incidents occurred within 1 kilometer and 24 hours of an NFIRS incident.

The 2017 NFIRS data was geocoded using location information provided by reporting fire departments and the GEOCODE Procedure in SAS 9.4. The precision of geographical coordinates returned by the geocoder is limited by the quality of the input information and the sophistication of the geocoding algorithm. Overall, 72% of the NFIRS incidents examined (where Incident Type was in the 100 series or was equal to 561, 631 or 632) were geomatched to an address, 11% were geomatched to the center point of a named street and 17% were geomatched to the center point of a ZIP code. However, the geocoding precision varied by type of incident. Structure fires (those where Incident Type was between 110 and 123) were geocoded to an address 83% of the time, while fires in forests and grasses (Incident Types 141 and 143) were geocoded to an address only 51% of the time. Some incidents (1,454) lacked sufficient location information to be geocoded and most (953) of these were natural vegetation fires (Incident Types 140-143). Even where the geocoding algorithm provided a geomatched address, it is possible that the location information was incorrectly reported or interpreted. The subsequent analysis is based on identifying NFIRS fires that occurred within 1 kilometer and 24 hours of a MODIS observation; bear in mind that this distance calculation may be based on imprecise NFIRS location information. A summary of the geocoding precision by NFIRS incident type is shown in Table 5.

Table 5. Geocoding precision of 2017 NFIRS data fire locations by fire incident type										
	Address	**%**	**Street**	**%**	**ZIP**	**%**	**City**	**%**	**None**	**%**
Structure	405,952	83	14,264	3	66,125	14	13	0	247	0
Vehicle	87,615	55	31,747	20	40,733	25	9	0	78	0
Natural	18,881	66	4,673	16	5,204	18	1	0	48	0
Forest	13,694	51	5,185	19	7,569	28	6	0	297	1
Brush	58,860	60	17,133	17	21,900	22	5	0	295	0
Grass	45,726	51	17,863	20	25,803	29	3	0	313	0
Authorized, unauthorized, prescribed	127,998	77	18,940	11	19,730	12	3	0	45	0
Other	172,647	71	36,128	15	34,540	14	8	0	131	0
Total	931,373	72	145,933	11	221,604	17	48	0	1,454	0

We were unable to identify shapefiles designating local direct protection areas for all states, but shapefiles for national parks and national forests, grasslands, and wilderness areas to examine MODIS incidents in areas of federal control were used. This omits land under the management of the Bureau of Land Management, Bureau of Reclamation, Bureau of Indian Affairs, and Fish and Wildlife Service as well as state parks and state forests. However, we found that 6.4% of MODIS incidents occurred within national parks and national forests, grasslands, and wilderness areas.

[6] https://fsapps.nwcg.gov/afm/gisdata.php

Consolidating MODIS observations to incidents

Since the Terra and Aqua satellites both pass each point on Earth multiple times per day and since wildfires can have long durations, rules were developed to consolidate multiple MODIS **observations** to single MODIS **incidents**. MODIS observations within 24 hours and 1 kilometer (0.62 miles) of any other MODIS observation were grouped together as a single incident. This technique may overestimate the number of incidents if intervening observations are not captured by the satellites due to cloud or smoke coverage. (For example, if a wildfire lasted three days but was only captured by MODIS on the first and last day, those observations will be classified as separate incidents. Similarly, if a fast-moving wildfire is observed in subsequent satellite passes but the distance between the observations is greater than 1 kilometer, they will be classified as separate incidents.)

As part of this analysis, it was determined there were 162,093 MODIS observations of fire in the U.S. in 2017. Of these, 85,039 observations occurred within 24 hours and 1 kilometer of another observation. There were 77,054 MODIS incidents of fire in the U.S. in 2017, consisting of the groupings shown in Table 6.

Table 6: Consolidation of MODIS observations to MODIS incidents

Number of observations per incident	Number of observations	Number of incidents	Average duration of event (hr)	Average distance (km)
1	56,217	56,217	n/a	n/a
2-5	44,000	17,912	2.8	0.6
6-10	12,209	1,682	12.7	1.8
11-20	9,313	651	27.1	2.9
21-50	11,131	350	49.6	4.6
51-100	9,803	140	90.8	6.8
101-500	21,808	97	165.6	12.0
501+	4,527	5	368.0	25.4

The largest fire, with 1,388 observations between Aug. 16 and Sept. 8, 2017, was the Highline Fire in the Payette National Forest in Idaho. A map depicting the MODIS observations made during this fire is shown below in Figure 2. Figure 2: MODIS Observations in Payette National Forest, Idaho

Figure 2: MODIS observations in Payette National Forest, Idaho
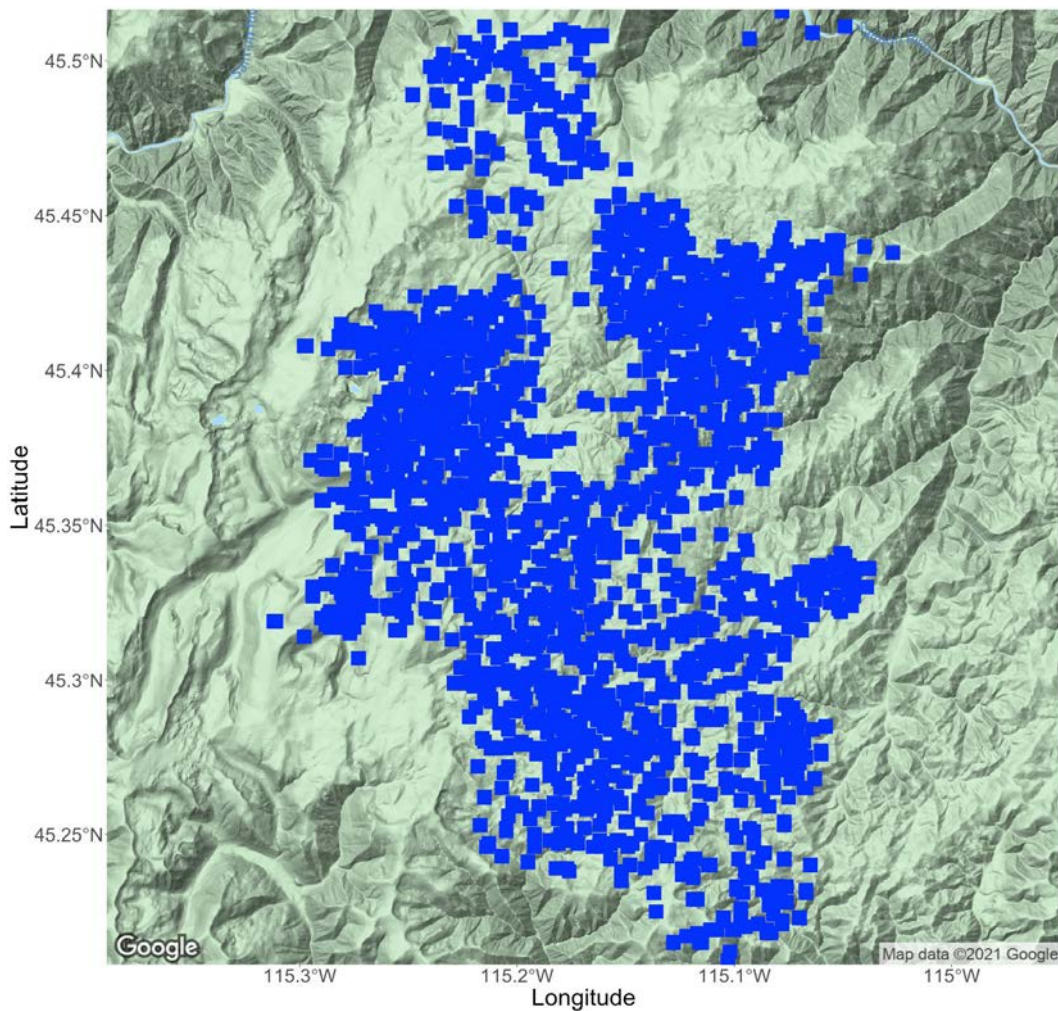
Matching MODIS incidents to NFIRS incidents

Our analysis revealed that 1.1% of MODIS observations and 1.6% of MODIS incidents occurred within 24 hours and 1 kilometer of an NFIRS incident. We grouped MODIS observations and NFIRS incidents and found a total of 1,212 fires consisting of 1,800 MODIS observations and 2,042 NFIRS incidents. Of these fires, 876 included only one MODIS observation apiece, and 1,345 NFIRS incidents in total. The remaining 336 fires included a total of 924 MODIS observations and 697 NFIRS incidents (Table 7).

Table 7: MODIS-NFIRS matches

|	MODIS observations	NFIRS incidents	Total fires
All grouped fires	1,800	2,042	1,212
Fires with a single MODIS observation	876	1,345	876
Fires with multiple MODIS observations	924	697	336

One thousand, eight hundred MODIS observations out of 162,093 matched at least one NFIRS incident, which produces a MODIS observation match rate of 1.1%. Another 1,212 MODIS incidents out of 77,054 matched at least one NFIRS incident, which produces a MODIS incident match rate of 1.6%.

The 2,042 NFIRS incidents that matched at least one MODIS observation (in all grouped fires in Table 7) included several incident types, suggesting that a fire detected by MODIS may be recorded as something other than a wildfire incident. Incident Types 140-143 (Natural vegetation fire, other; Forest, woods or wildland fire; Brush or brush-and-grass mixture fire; Grass fire) and 561, 631 and 632 (Unauthorized burning; Authorized controlled burning; Prescribed fire) were more common among NFIRS incidents that matched MODIS observations than among all NFIRS incidents (Figure 3).

Figure 3: Distribution of NFIRS incident types for MODIS matches and for NFIRS, 2017
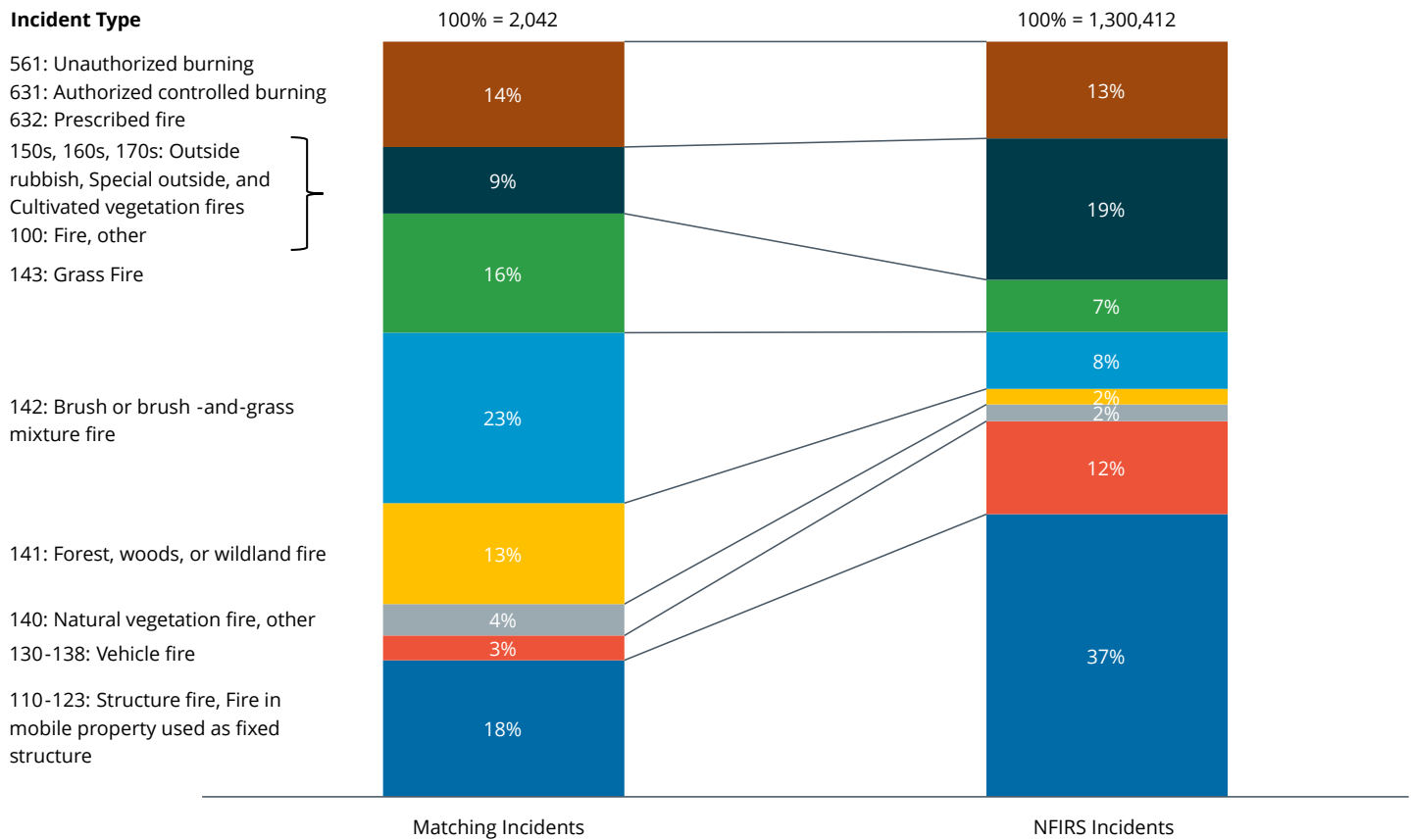
We also compared the NFIRS incidents that matched MODIS observations to the criteria that Butry and Thomas used to select their NFIRS incidents. Overall, only 701 of the 2,042 NFIRS incidents that matched one or more MODIS observations would have been included by Butry and Thomas' criteria. The figure below shows the number of matching NFIRS incidents by each criterion and the total indicates that number of matching NFIRS incidents that match at least one of them (Figure 4). Of the 701 matching incidents, 37 incidents matched three criteria, 224 incidents matched two criteria, and 440 incidents matched one criterion.

Figure 4: Number of matching NFIRS incidents that meet Butry and Thomas' criteria
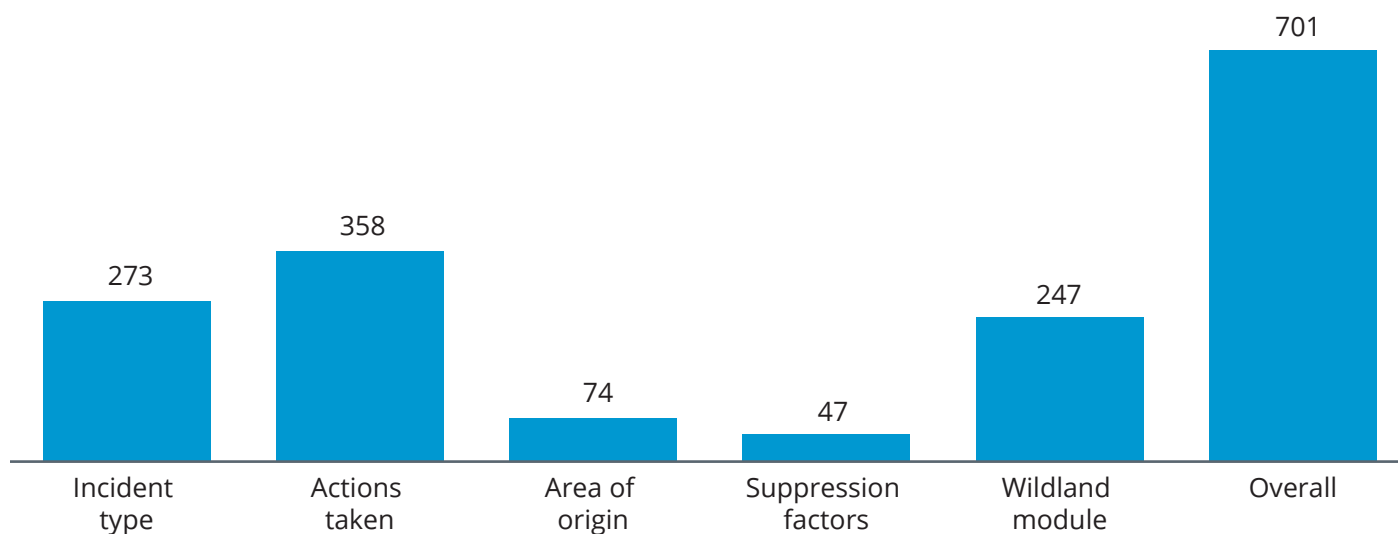
MODIS incidents in selected federal lands
MODIS incidents in selected federal lands

Nearly all MODIS incidents have no counterpart in NFIRS. One explanation for this may be that many MODIS incidents are fires on state or federal lands and the responding departments are not NFIRS reporters. We did not compare MODIS incidents to all public land, but we were able to determine which MODIS incidents occurred in national parks, or in national forests, grasslands and wilderness areas. Overall (Table 8), 37% of MODIS observations occurred in these federal areas. This number only represents 6.4% of MODIS incidents, which suggests that these incidents were large-scale fires and each incident may have been identified separately with multiple satellite observations.

Table 8: MODIS observations and incidents in selected federal lands

	Parks	Forests	Grasslands	Wilderness	Overall
Observations	3,544	55,676	120	24,208	59,755
Incidents	265	4,585	14	1,634	4,931

However, a small number of MODIS observations and incidents in these selected federal lands do match an NFIRS incident. These matches were reported for 20 MODIS incidents (74 observations) by 24 different fire departments (Table 9).

Table 9: MODIS observations and incidents in selected federal lands with NFIRS matches

	Parks	Forests	Grasslands	Wilderness	Overall
Observations	3	71	0	0	74
Incidents	1	19	0	1	20

Hypotheses regarding nonmatching MODIS incidents

There were 77,054 MODIS incidents in 2017. Of the MODIS incidents, 4,931 occurred in national parks or national forests, grasslands, or wilderness areas. Another 1,212 of them occurred within 24 hours and 1 kilometer of a fire that was reported in NFIRS (including 20 that included land in the selected federal areas). That leaves 70,931 MODIS incidents, 92% of the total, that are not accounted for in NFIRS data.

Some of these remaining MODIS incidents may have occurred in other types of public land that we did not examine, such as areas controlled by the Bureau of Land Management or Bureau of Reclamation. Some may have occurred in state parks and forests, and some may have occurred in unpopulated, privately-owned land.

Seventy-three percent of MODIS incidents were observed once and at one location. MODIS generally detects fires that have a radius of 18 meters and can detect fires with a radius as small as 4 meters. These could be examples of authorized or unauthorized fires that are set to clear crop land or burn trash that are quickly extinguished, so no fire department intervention is needed.

We examined three MODIS observations for Frederick County, Maryland, and were surprised to see that they were of solar farms (Figure 5). MODIS' detection algorithm relies on the heat signature emanating from an area, and it is possible that these objects created a false positive under the right conditions.

Figure 5. MODIS observations in Frederick County, Maryland

Umatched MODIS observations, Frederick County, Maryland

10/17/17, 10/20/17[1]

4/4/17[2]
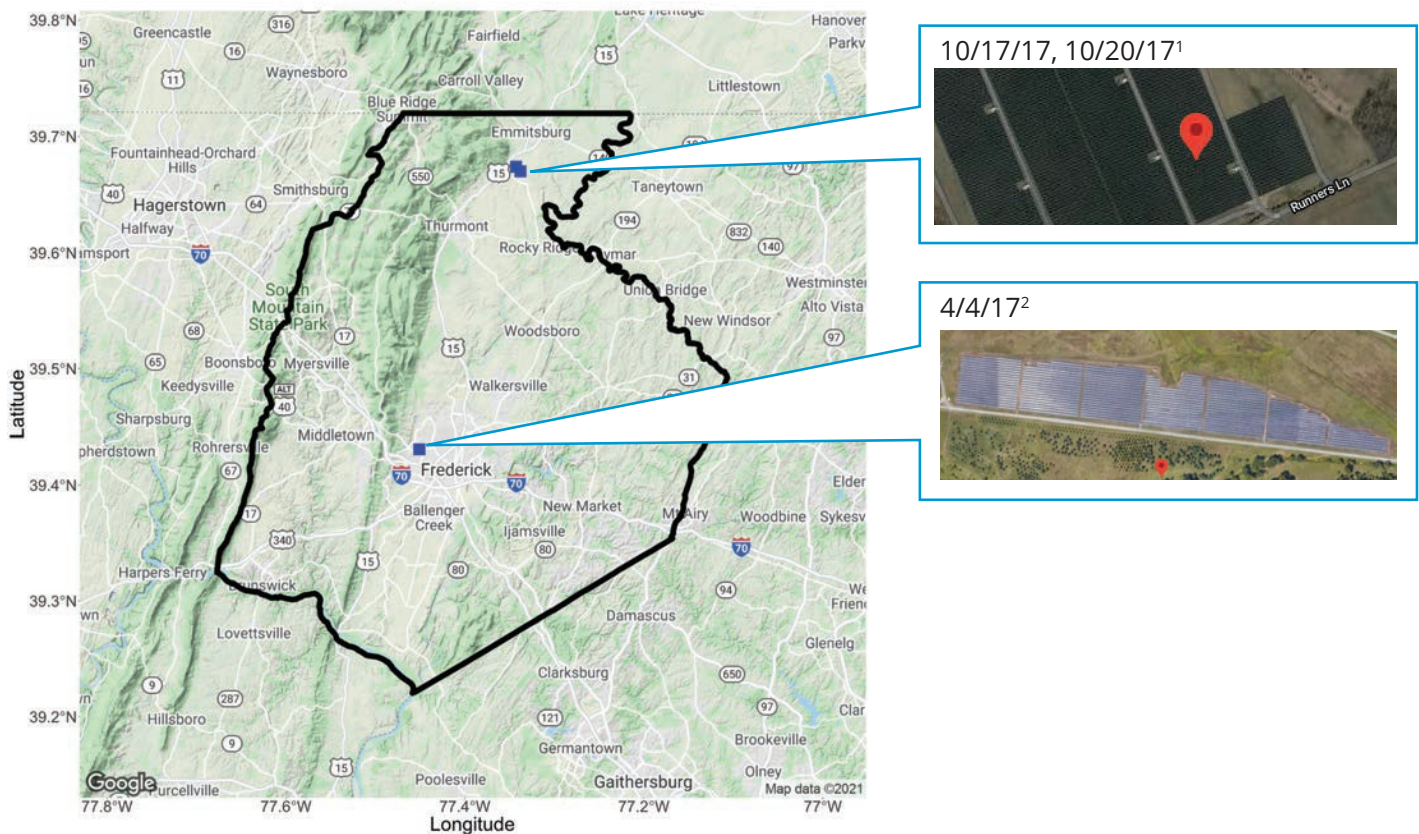
Note: The data for the figure is based on MODIS data retrieved from https://firms2.modaps.eosdis.nasa.gov/download/ and excludes incidents where the Type is "other static land source."
[1]Imagery ©2021 Maxar Technologies, U.S. Geological Survey (USGS), U.S. Department of Agriculture (USDA) Farm Service Agency. Map data ©2021.
[2]Imagery ©2021 Commonwealth of Virginia, Maxar Technologies, USGS, USDA Farm Service Agency. Map data ©2021.

Conclusion

Our examination of MODIS-detected fires supports Butry and Thomas' hypothesis that few of these incidents are reported in NFIRS. Butry and Thomas assumed that MODIS observations were wildfires and those that occurred in local direct protection areas should be recorded in NFIRS as wildfires. Since NFIRS does not have an incident type for "wildfires," Butry and Thomas developed criteria using incident type, actions taken, area of origin and suppression factors to identify NFIRS fires that were candidates for MODIS matching and matched them based on the county

and date. They found that 32% of the MODIS observations occurred on the same date and in the same county as a fire from their NFIRS subset. USFA analysis used geocoded NFIRS data and looked for any NFIRS incident (including unauthorized and prescribed fires) and found that only 1.6% of MODIS incidents occurred within 1 kilometer and 24 hours of any NFIRS incident. A summary is provided in Table 10.

Table 10. Comparison of approaches and conclusions		
Factor	**Butry/Thomas analysis**	**This analysis**
Timeframe	2003-2014	2017
MODIS observations used	Only those located in California Local Direct Protection Areas	Entire U.S.
Consolidated multiple MODIS observations to single incidents	Not done	Grouped MODIS observations within 24 hours and 1 kilometer
NFIRS incidents used for comparison	Incident Type 141 Actions Taken 13-16 Area of Origin 95 Suppression Factor 775 Use of Wildland Module	Incident Type in 100 series or 561, 631, 632
MODIS-NFIRS matching technique	Whether a fire department in the same county as a MODIS observation reported an NFIRS incident (meeting criteria above) on the same day	Whether a MODIS observation occurred within 24 hours and 1 kilometer of an NFIRS incident
Conclusion	32% of MODIS observations are reported in NFIRS	1.6% of MODIS incidents (1.1% of MODIS observations) are reported in NFIRS

We distinguish between individual MODIS observations and MODIS incidents by grouping all MODIS observations that occurred within 1 kilometer and 24 hours together as a single incident. Slightly over half of MODIS observations (52%) can be grouped with another observation to create an incident, which suggests that MODIS can be useful for identifying fires with large burn areas and lengthy durations, likely large named wildfires. We also found that 6.4% of MODIS incidents occur within national parks and national forests, grasslands, and wilderness areas. However, the vast majority of MODIS incidents involve a single observation and most of these are not reported in NFIRS. Additional research should be done to determine whether these are fires in public or nonpublic lands, instances of crop or trash burning, or false positives.