

# Satellite-Based Fire Products: Methods, Data Access, and Applications

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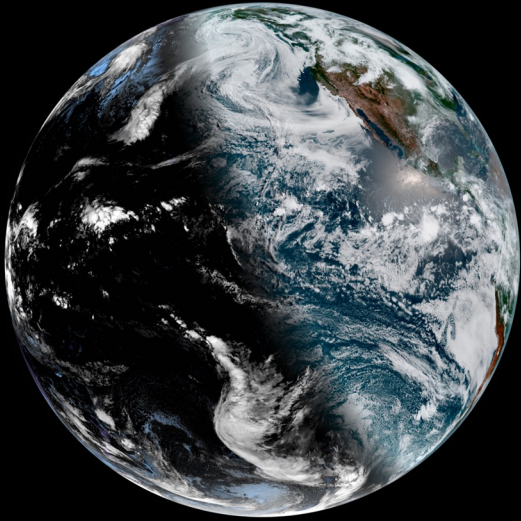


# Several Satellite Instruments Observe Fire Detections

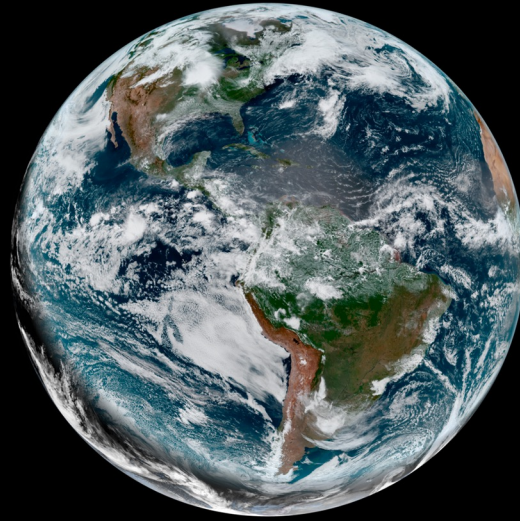
	<b>MODIS</b>	<b>VIIRS</b>	<b>ABI</b>
Platform	Terra , Aqua	Suomi NPP, NOAA-20, NOAA-21	GOES 16, 17, 18
Launched	Dec 1999, May 2002	Oct 2011, Nov 2017, Nov 2022	Nov 2016, Mar 2018, Mar 2022
Swath	2,330 km	3,040 km	---
Equator Crossing Time	10:30 am (des), 1:30 pm (asc)	1:30 pm (asc), 1:30 pm (asc)	Geostationary
Spatial Resolution	250 m, 500 m, 1 km	375 m, 750 m	500 m, 1km, 2km
Temporal Resolution	Global Coverage: 1-2 days	Global Coverage: Daily	Full Disk: 15 min CONUS: 5 min
Spectral Coverage	36 bands (VIS, IR, NIR, MIR) Band 1-2: 250 m Band 3-7: 500 m Band 8-36: 1 km	22 bands (VIS, IR, NIR, MIR) I-Bands (1-4): 375 m M-Bands (1-16): 750 m Day/Night Band: 750 m	16 bands (VIS, IR, NIR, MIR) 500 m – 2 km



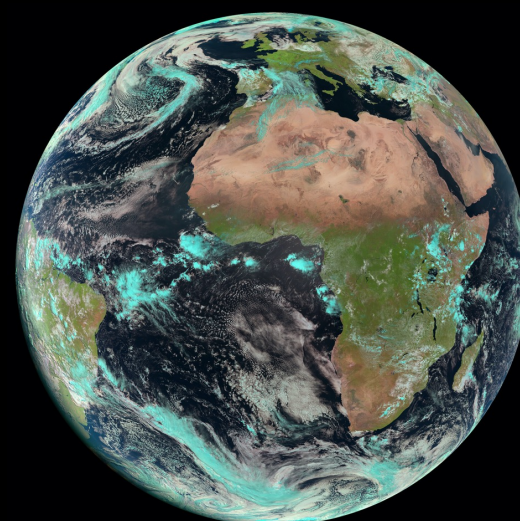
# Geostationary Observations of Active Fires



GOES-West/ABI



GOES-East/ABI



MSG/SEVIRI



Himawari/AHI



# Active Fire Products

- The Thermal Anomalies/Active Fire products deliver actively burning locations in NRT at 2 km (ABI), 1 km (MODIS), or 375 m (VIIRS) resolution.
- Provides snapshots of active burning fires

## Fire Detections NOAA-20 VIIRS

9/1/2022 – 9/31/2022



## Sensors and Product Names

MODIS	MOD04A1 (Terra) MYD04A1 (Aqua)
VIIRS	VNP14IMGTDL_NRT (SNPP) VJ114IMGTDL_NRT (N20)
ABI	FDC



# What are thermal anomalies?

- Significant increase in absolute radiance at  $\sim 4 \mu\text{m}$  and  $\sim 11 \mu\text{m}$ 
  - Measured as Brightness Temperature (BT) (K)
- All algorithms are similar.
  - Cloud masks applied
  - Use other wavelength bands to filter out sun glint and coastal regions



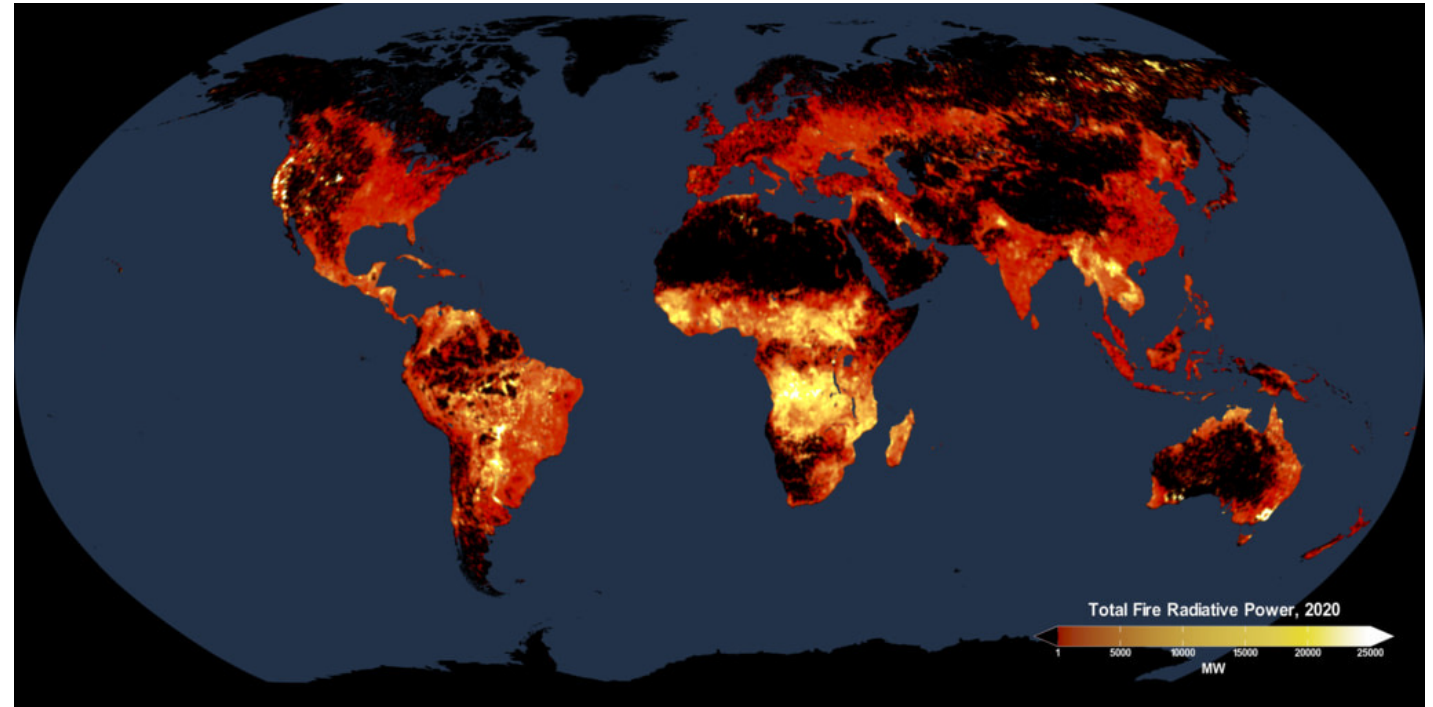
VIIRS Fire Detections, NASA Worldview



# Fire Radiative Power (FRP)

- Rate of emitted radiative energy by a fire
  - Usually expressed in units of power (W, MW, or J/s)
- Fire Radiative Energy (FRE)
  - Time integrated FRP, usually expressed as (J)
  - Correlation between FRE and fire emissions

## VIIRS 375m Cumulative FRP for 2020



<https://svs.gsfc.nasa.gov/4899>



# VIIRS Active Fires, Jan-Sep 2021



<https://svs.gsfc.nasa.gov/4945>

# Active Fire Detection Algorithm

## Classify Cloud and Water Pixels

- Use thresholds in brightness temperature (BT) and reflectance in particular bands
- Different thresholds for day and night

## Active Fire Detection

- Use fixed or dynamic (moving window) thresholds to identify potential fire pixels
- Use complementary data from other channels

## Are you sure it's a fire?

- Characterize background
- Check for bright fire-free targets (glint, coastal regions, deserts, cleared forests)





# VIIRS Algorithm

Band	Wavelength Range	
I4	3.55 – 3.93 $\mu\text{m}$	Fire Detection
I5	10.5 – 12.4 $\mu\text{m}$	Compared with I4 to separate active fire from background
I1	0.6 – 0.68 $\mu\text{m}$	Cloud Sun glint Water Discrimination
I2	0.846 – 0.885 $\mu\text{m}$	
I3	1.58 – 1.64 $\mu\text{m}$	

## Data Artifacts:

Pixel Saturation

South Atlantic Magnetic Anomaly  
(SAMA)

## Candidate Fire Pixel Identification

- $BT_4 > BT_{4S}$  OR  $\Delta BT_{45} > 25K$  (daytime)
- $BT_4 > 295K$  OR  $\Delta BT_{45} > 10K$  (nighttime)

$BT_{4S} = 501 \times 501$  background BT window

$$BT_{45} = BT_4 - BT_5$$

## Validation

- Error rate: 0 – 1.2% (China)



# VIIRS – File Contents

<https://www.earthdata.nasa.gov/learn/find-data/near-real-time/firms/viirs-i-band-375-m-active-fire-data>

Attribute	Description	
Latitude	Latitude	Center of nominal 375 m fire pixel
Longitude	Longitude	Center of nominal 375 m fire pixel
Bright_ti4	Brightness Temperature I-4	VIIRS I-4 channel brightness temperature of the fire pixel (K)
Scan	Along Scan Pixel Size	Actual pixel size
Track	Along Track Pixel Size	Actual pixel size
Acq_Date	Acquisition Date	Date of VIIRS acquisition
Acq_Time	Acquisition Time	Time of acquisition/overpass of the satellite (in UTC)
Satellite	Satellite	N= Suomi NPP, I=NOAA-20
Confidence	Confidence	Low - Areas of sun glint and lower relative temperature anomaly Nominal - Free of potential sun glint contamination during the day and strong temperature anomaly in either day or nighttime data High - Day or nighttime saturated pixels
Version	Version (Collection and Source)	"1.0NRT" - Collection 1 NRT processing "1.0" - Collection 1 Standard processing
Bright_ti5	Brightness Temperature I-5	I-5 Channel brightness temperature of the fire pixel measured in Kelvin
FRP	Fire Radiative Power	FRP depicts the pixel-integrated fire radiative power in MW (megawatts).
DayNight	Day or Night	D= Daytime Fire, N= Nighttime Fire

# MODIS Algorithm

Channel	Central Wavelength	
21,22	4 $\mu\text{m}$	Active fire detection
31	11 $\mu\text{m}$	Active fire detection, cloud masking, forest clearing rejection
32	12 $\mu\text{m}$	Cloud masking
1	0.65 $\mu\text{m}$	Sun glint and coastal false alarm rejection; cloud masking
2	0.86 $\mu\text{m}$	Bright surface, sun glint, and coastal false alarm rejection; cloud masking
7	2.1 $\mu\text{m}$	Sun glint and coastal false alarm rejection

## Potential Fire Pixel Identification

- 0.86 Reflectance < 0.35 (daytime only)
- $BT4 > BT4^*$
- $BT4 - BT11 > \Delta BT^*$

$BT4^*$  and  $\Delta BT^*$  are dynamic thresholds calculated using a  $\sim 301 \times 30$  moving window centered on the pixel of interest.

## Validation

- Global Commission Error (false alarms) 1.2%

Giglio et al., 2016

<https://www.sciencedirect.com/science/article/pii/S0034425716300827>

NASA's Applied Remote Sensing Training Program



# MODIS – File Contents

<https://www.earthdata.nasa.gov/learn/find-data/near-real-time/firms/mcd14dl-nrt>

Attribute	Description	Description
Latitude, Longitude	Latitude, Longitude	Center of 1 km fire pixel
Brightness	Brightness Temperature 21 (K)	Channel 21/22 brightness temperature of the fire pixel (K)
Scan	Along Scan Pixel Size	Actual pixel size
Track	Along Track Pixel Size	Actual pixel size
Acq_Date	Acquisition Date	Data of MODIS acquisition
Acq_Time	Acquisition Time	Time of acquisition/overpass of the satellite (in UTC)
Satellite	Satellite	A = Aqua and T = Terra
Confidence	Confidence (0-100%)	Confidence estimates range between 0 and 100% and are assigned one of the three fire classes (low-confidence fire, nominal-confidence fire, or high-confidence fire).
Version	Version (Collection and Source)	Version identifies the collection and source of data processing, for example: "6.1URT" - Collection 6.1 Ultra Real-Time processing. "6.1NRT" - Collection 61 Near Real-Time processing. "6.1" - Collection 61 Standard processing.
Bright_T31	Brightness Temperature 31 (K)	Channel 31 brightness temperature of the fire pixel (K)
FRP	Fire Radiative Power	Pixel-integrated FRP in MW (megawatts)
Type*	Inferred Hot Spot Type	0 = Presumed Vegetation Fire, 1 = Active Volcano, 2 = Other Static Land Source, 3 = Offshore
DayNight	Day or Night	D= Daytime fire, N= Nighttime fire



# ABI Algorithm

Channel	Central Wavelength	
2	0.64 $\mu\text{m}$	Cloud screening, surface albedo
7	3.9 $\mu\text{m}$	Hot spot location and characterization
14	11.2 $\mu\text{m}$	Hot spot location and characterization
15	12.3 $\mu\text{m}$	Cloud identification

## Validation

- High false alarm rate

## Fire Pixel Identification

- Part I
  - Loop over all pixels to identify all possible fire pixels
- Part II
  - Threshold tests to refine fire pixel identification and Fire Classification

The GOES algorithm uses spectral, contextual, and temporal tests, the thresholds for which are dynamically determined.



# ABI – File Contents

<https://www.star.nesdis.noaa.gov/goesr/docs/ATBD/Fire.pdf>

Attribute	Dimension	
Fire Mask Codes	Grid (xsize, ysize)	Codes indicating final disposition of pixels (including fire flags if so determined)
Subpixel Fire Size	Grid (xsize, ysize)	Subpixel fire size for processed fires (codes 10 and 30) (km <sup>2</sup> ) This is set to -9 if the subpixel fire temperature is less than 400 K at the end of the algorithm.
Subpixel Fire Temp	Grid (xsize, ysize)	Subpixel fire temperature for processed fires (codes 10 and 30) (K) This is set to -9 if the subpixel fire temperature is less than 400 K at the end of the algorithm.
Subpixel FRP	Grid (xsize, ysize)	Subpixel fire radiative power for processed fires (codes 10, 13, 14, 30, 33, and 34) (MW)
Previous Fire Mask	ABI Full Disk Grid	ABI full disk mask of seconds since 1 January 2001 when a fire was last detected in that fixed grid pixel.
QA Flags	Grid (xsize, ysize)	QA flags where 0 indicates a fire and nonzero indicates non-fire pixels (see table)
Metadata	27 values, 12 strings	<ul style="list-style-type: none"> <li>a. Number of fire categories</li> <li>b. Definition of each fire category</li> <li>c. Percent of pixels for each fire category</li> <li>d. Number of QA flag values</li> <li>e. Definition of each QA flag value</li> <li>f. Percent of retrievals with each QA flag value</li> <li>g. Total number of fires</li> </ul>

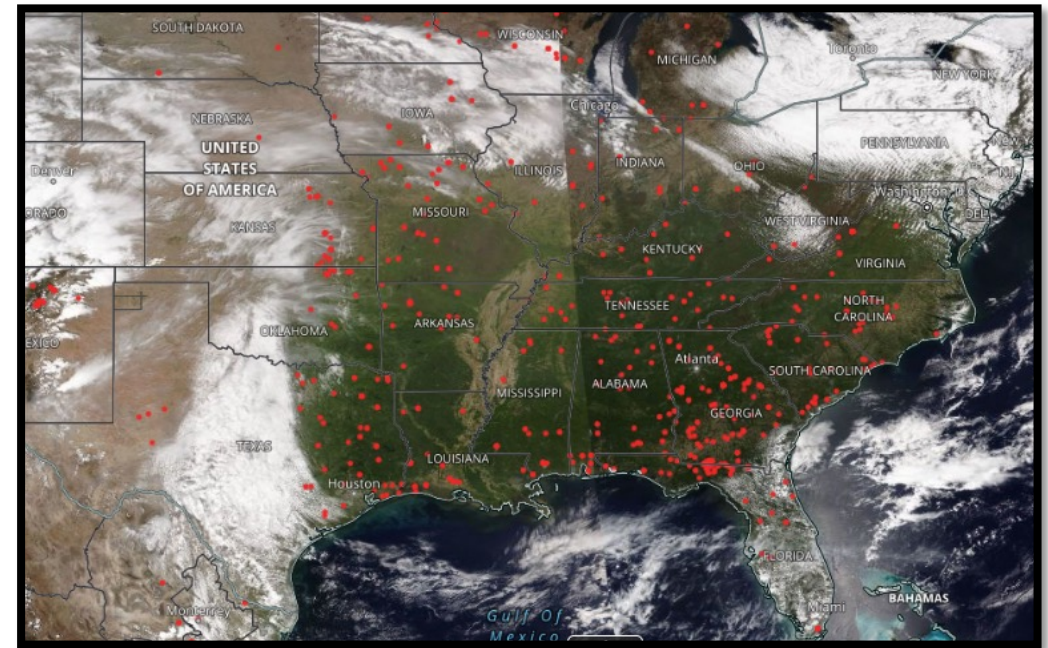
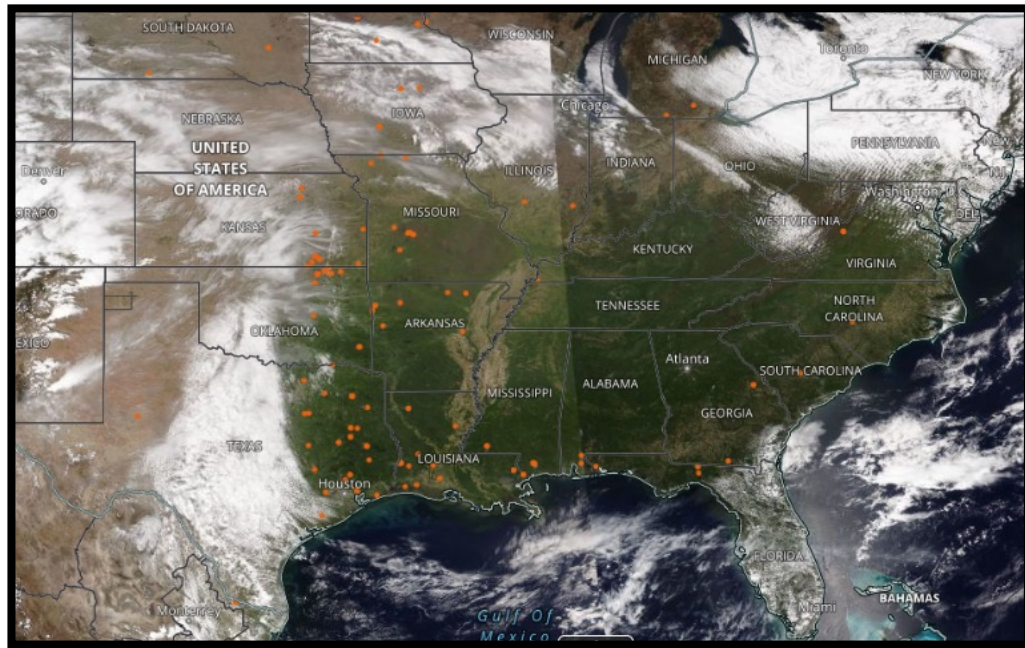
GOES-R ABI WF_ABBA FDCA QA Flags	
QA Code	Fire Mask Code(s) and Definition
0	10-15, 20-25, 30-35 [20-25 not used for ABI currently]: These are the codes for fires, all are considered valid algorithm output.
1	100: Fire-free land pixel that was not otherwise screened out.
2	200, 205, 210, 215, 220, 225, 230, 240, 245: The pixel failed opaque cloud tests.
3	0, 40, 50, 60, 130, 150-153, 155: Pixel unusable due to unusable surface type, sunglint, or being off the disk. Also includes reserved mask values not including 20-25.
4	120-127, 160: Bad input data.
5	170, 180, 182, 185-188: A calculation in the algorithm failed.

# VIIRS Detects 3-4x More Fires Than MODIS

Daytime Active Fire Detections – 4/27/2022

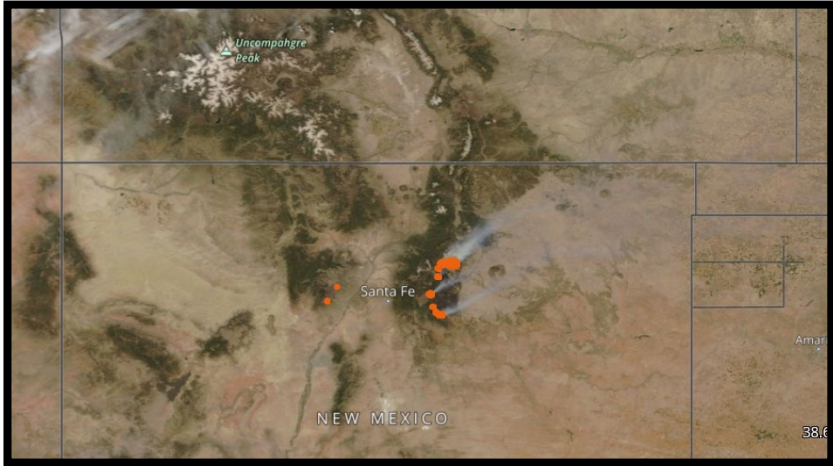
MODIS - Aqua

VIIRS

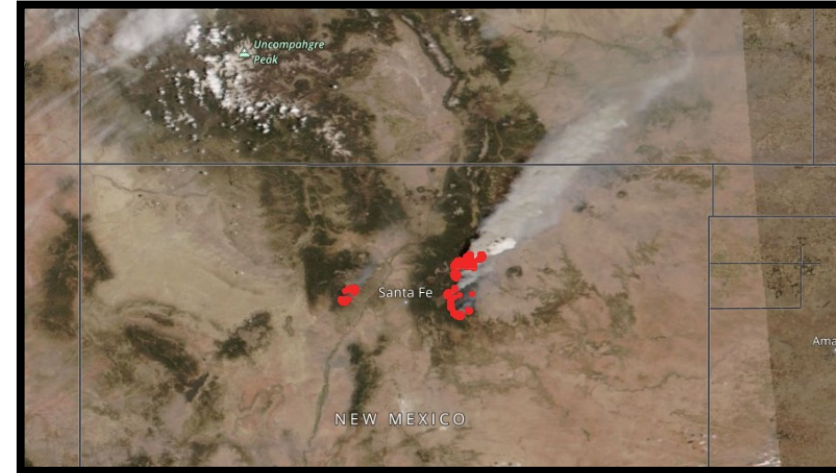


# One Fire, Multiple Views – May 10, 2022

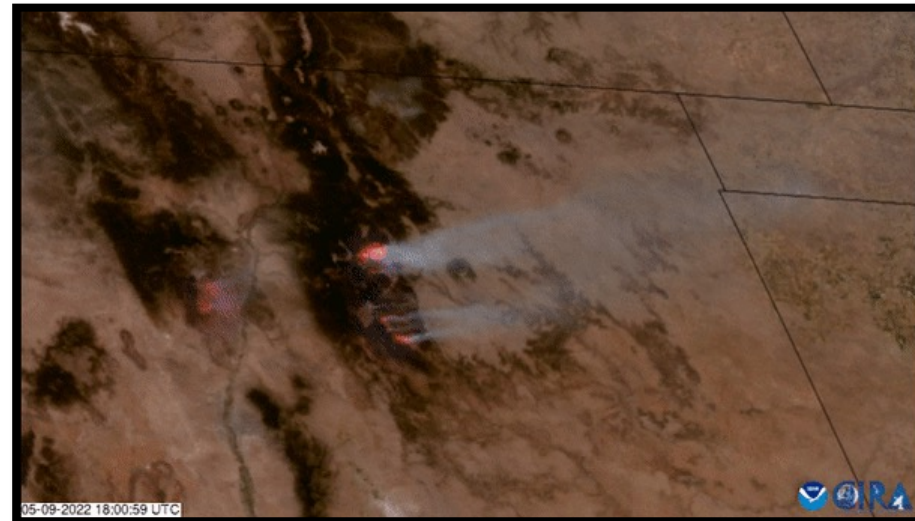
MODIS - Terra



VIIRS



ABI





# Thermal Anomalies Algorithms

- Limitations:
  - False Positives: Small forest clearings (bare soil)
  - Large fire omissions due to thick smoke
  - Larger pixel size of MODIS and ABI can miss small fires
- MODIS Collection 6 (most recent) improves upon these errors.
  - Global commission error of 1.2%
  - Similar error for VIIRS



MODIS Fire Detections, NASA Worldview



# Fire Information for Resource Management System (FIRMS)

<https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms>

- Near real-time (NRT) active fire data within 3 hours of satellite overpass
  - Shorter latency for CONUS (~30 min)
- Global MODIS and VIIRS fire locations, and provisional geostationary observations
- Historical data available
- Available In:
  - Email Alerts
  - Download Shapefile, WMS, KML, or TXT
  - Visualization in **Web Fire Mapper** or **Worldview**
- Video Tutorial: [How to Use NASA's Fire Information for Resource Management System \(FIRMS\)](#)

The screenshot displays the NASA Earth Data website interface for the Fire Information for Resource Management System (FIRMS). The page features a blue header with the NASA Earth Data logo and navigation links for 'ABOUT', 'DATA', 'COMMUNITY', and 'RESOURCES'. A search bar is positioned in the top right corner. The main content area is divided into several sections: 'Data' (disciplines), 'Related Content' (listing recent news items), and 'More Resources' (providing links to 'Fire Email Alerts', 'Download Active Fire Data', 'Web Fire Mapper', 'Global Fire Maps', and 'Web Services'). The 'Data' section prominently displays the title 'Fire Information for Resource Management System (FIRMS)' and a brief description: 'FIRMS distributes Near Real-Time (NRT) active fire data within 3 hours of satellite overpass from both MODIS and VIIRS.' Below this, there are two buttons for 'MODIS Active Fire Products' and 'VIIRS Active Fire Products'. The 'Related Content' section lists several news items, including 'EOSDIS Data News - 4/28/2017' and 'Celebrate Earth Day with NASA at Union Station on Thursday, April 20th'. The 'More Resources' section includes a 'Get hotspot/fire locations' heading and a list of options with icons: 'Fire Email Alerts', 'Download Active Fire Data', 'Web Fire Mapper', 'Global Fire Maps', and 'Web Services'.



# Where to Obtain MODIS Fire Products

## Archived Data

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Land Process Distributed Active Archive (LPDAAC):  
<http://lpdaac.usgs.gov/>



NASA Earthdata: <https://earthdata.nasa.gov/>

## Near Real Time (NRT)

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Worldview: <http://worldview.earthdata.nasa.gov>



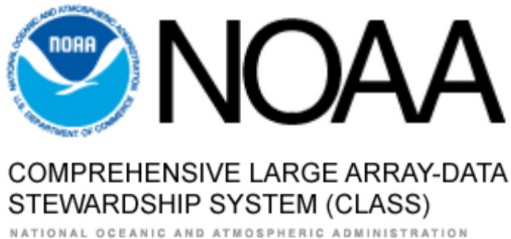
# Where to Obtain VIIRS Products



Worldview: <http://worldview.earthdata.nasa.gov>

VIIRS Active Fire

VIIRS Active Fire: <http://viirsfire.geog.umd.edu>



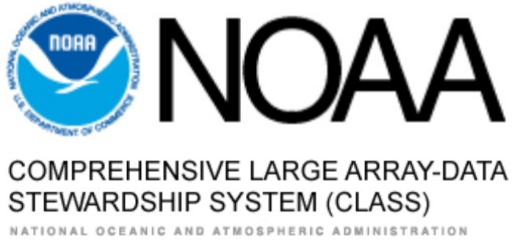
NOAA Comprehensive Large Array-Data Stewardship System (CLASS): <https://www.avl.class.noaa.gov/saa/products/welcome>

LAADS DAAC

Level-1 and Atmosphere Archive & Distribution System:  
<https://ladsweb.modaps.eosdis.nasa.gov/>



# Where to Obtain ABI Products



NOAA Comprehensive Large Array-Data Stewardship System (CLASS): <https://www.avl.class.noaa.gov/saa/products/welcome>



University of Wisconsin GOES Page:  
<http://cimss.ssec.wisc.edu/goes/goesdata.html>



# References

- VIIRS Algorithm
  - Schroeder et al., 2014, Remote Sensing of Environment  
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- VIIRS User Guide
  - [https://viirsland.gsfc.nasa.gov/PDF/VIIRS\\_activefire\\_User\\_Guide.pdf](https://viirsland.gsfc.nasa.gov/PDF/VIIRS_activefire_User_Guide.pdf)
- VIIRS Algorithm Theoretical Basis Document (ATBD)
  - [https://viirsland.gsfc.nasa.gov/PDF/VIIRS\\_activefire\\_375m\\_ATBD.pdf](https://viirsland.gsfc.nasa.gov/PDF/VIIRS_activefire_375m_ATBD.pdf)
- MODIS Collection 6 Algorithm
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- MODIS User Guide
  - [https://modis-fire.umd.edu/files/MODIS\\_C6\\_C6.1\\_Fire\\_User\\_Guide\\_1.0.pdf](https://modis-fire.umd.edu/files/MODIS_C6_C6.1_Fire_User_Guide_1.0.pdf)
- ABI ATBD
  - <https://www.star.nesdis.noaa.gov/goesr/docs/ATBD/Fire.pdf>
- ABI Fire Detection Fact Sheet (with links)
  - [https://www.goes-r.gov/education/docs/fs\\_fire.pdf](https://www.goes-r.gov/education/docs/fs_fire.pdf)
- ABI and VIIRS ADP and AOD Documents
  - <https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/documents.php>



# Questions & Discussion Prompts

- Changes in what retrieved quantity are used to detect fires?
- What is a source of uncertainty for fire detection?

