Wildland Fire Cycle Product Suite

This document describes the following products used for detecting and monitoring the wildland fire cycle:

- Fire Danger Rating Product
- NOAA AVHRR NDVI-derived Greenness Maps
- MODIS Active Fire Map, Fire Detection Algorithms and Products
- Geostationary and Polar Animations
- MODIS True Color Product
- MODIS False Color Product
- Smoke Forecasting Products

For more information on the use of satellite data in monitoring the wildland fire cycle as well as the upcoming NPOESS VIIRS instrument, refer to the COMET module "Multispectral Satellite Applications: Monitoring the Wildland Fire Lifecycle" at http://meted.ucar.edu/npoess/multispectral_topics/fire_wx/.

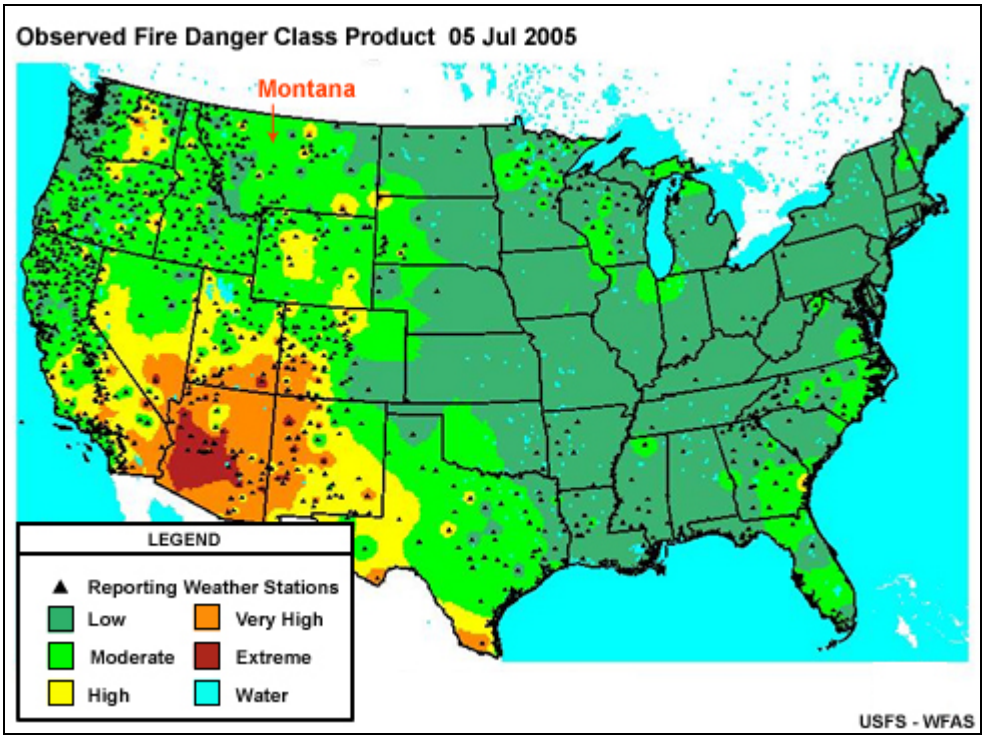
Fire Danger Rating Product

Description: This widely used U.S. Forest Service product is an aid to predicting the potential for wildfires. Based on surface observations of fuels, it can be compared to satellite greenness maps to infer fire susceptibility.

Applications:

- Is a primary product used to assess the risk of fire outbreaks
- Can be supplemented by satellite greenness products in regions devoid of surface reports

Example: The triangles mark the locations of reporting stations used to analyze fire danger. Where they are sparse, for example over Montana, satellite products play an important supplementary role.



Derivation: A Fire Danger Rating level takes into account current and antecedent weather, fuel types, and both live and dead fuel moisture from station reports. It is less valid in regions with fewer reports.

NPOESS VIIRS Improvements: Not applicable

Link: USFS – Wildland Fire Assessment System: http://www.wfas.net/

NOAA AVHRR NDVI-derived Greenness Maps

Description: There are three types of greenness maps, all of which are composited weekly from 1.1 km AVHRR data. The maps are derived from the Normalized Difference Vegetation Index (NDVI), which measures how dense and green plant leaves are. This indicates overall vegetative health and susceptibility to burning.

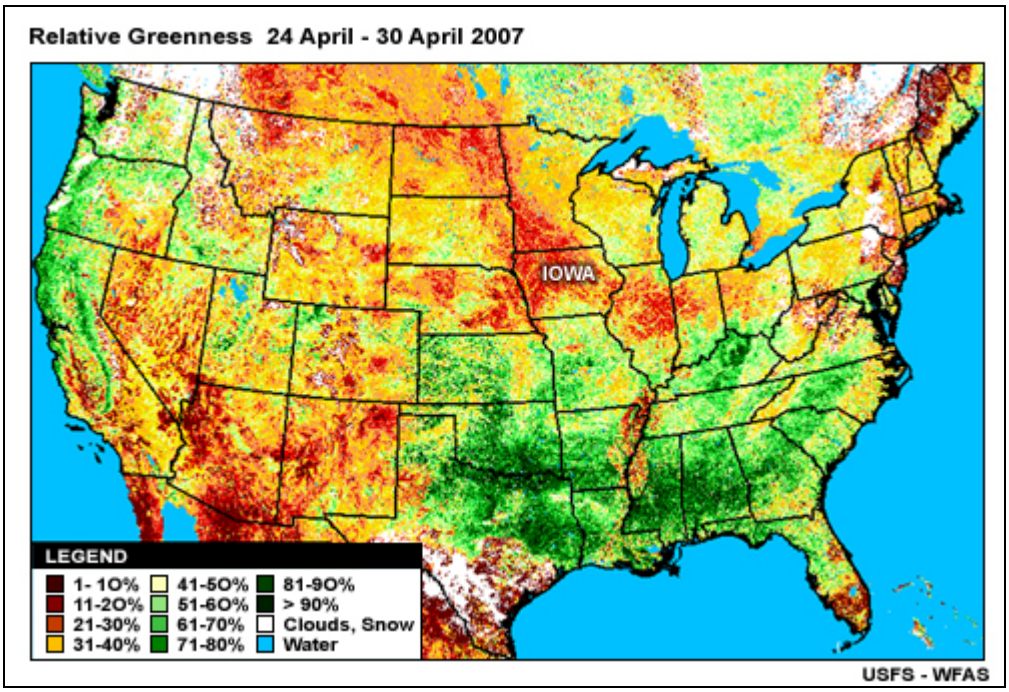
1. Visual greenness maps
    - Portray vegetation greenness compared to a very green reference such as an alfalfa field
    - Are similar to what you would expect to see from the air
    - Normally dry areas are never as green as areas that are typically wetter
2. Relative greenness maps
    - Portray how green vegetation is compared to how green it has been historically over a particular period of time
    - The browner (or less green) the vegetation, the higher the fire risk tends to be
    - Because each pixel is normalized to its own historical range, all areas (dry to wet) can appear fully green at some time during the growing season
    - Are useful indirect measures of fire risk in data-sparse areas
    - Are used for spotting local trends in fire susceptibility
3. Departure from average greenness maps
    - Portray how green each pixel is compared to its average greenness for the current week based on historical weekly data

Applications:

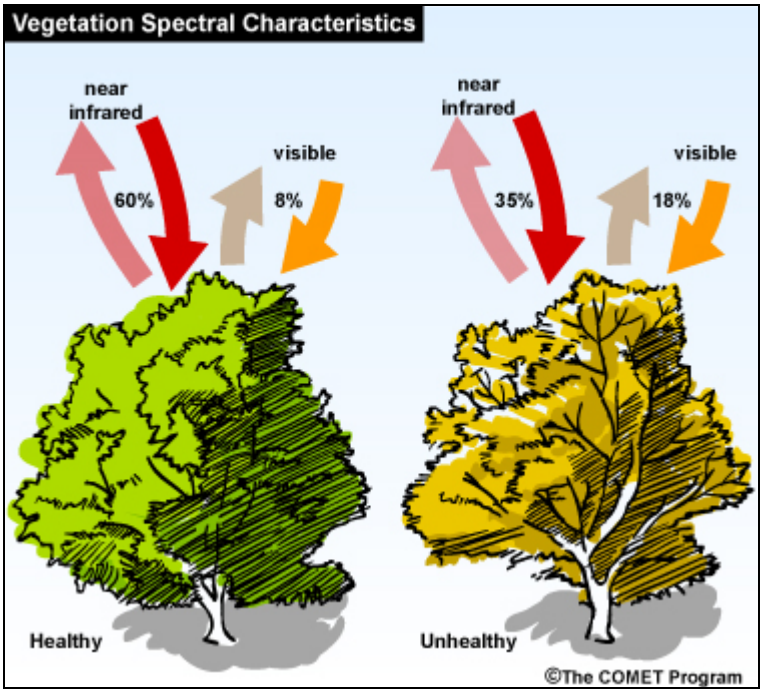
- Are used to detect areas with possible susceptibility to fires (areas appear red or yellow)
- Are useful in regions without surface observations
- Can supplement surface-derived products in data-sparse areas

Example: Relative greenness maps

Red shades indicate low levels of greenness compared to historical greenness, whereas greens indicate high levels. In this example, we see low values of relative greenness over Iowa, and high values over much of the Deep South.



Derivation: The greenness products are based on the NDVI, which is derived from NOAA AVHRR satellite observations. NDVI is an indicator of the amount of photosynthetically active radiation being reflected by a plant's chlorophyll pigment within the green portion of the visible spectrum.



NDVI is calculated as a difference between visible (red wavelength region) and near-infrared light reflected by vegetation. Healthy vegetation absorbs most of the visible light and reflects a large portion of the near-infrared light that it receives. In contrast, unhealthy and/or sparse vegetated surfaces reflect more visible light and less near-infrared light. Note that the data on the graphic are representative of conditions within a satellite footprint, but that real vegetation is, of course, far more varied.

NPOESS VIIRS Improvements: Compared to NOAA AVHRR, NPOESS VIIRS will have higher spatial resolution and more spectral channels for an improved characterization of vegetation greenness and perhaps vegetation moisture.

Links:

- USFS Wildland Fire Assessment System, http://www.wfas.net/
- NDVI tutorial, http://earthobservatory.nasa.gov/Library/MeasuringVegetation/

MODIS Active Fire Map

Description: An easy-to-interpret map of the location of fires and burned areas along with highways, cities, and other geographical markers. The map represents the fire extent as detected by MODIS over the last 12 to 24 hours.

Applications:

- Serves as a briefing tool for non-satellite experts who want an accurate summary of fire conditions
- Is appropriate for inclusion in briefings and reports
- An online archive makes past data accessible

Example: Product loops, such as this one from southern California in 2003, make it easy to see the progression of fires. Yellow indicates recently burned areas; red indicates active fires.

Derivation: This product is compiled at the USDA Forest Service (USFS) Remote Sensing Applications Center in cooperation with NASA Goddard Space Flight Center, the University of Maryland, the National Interagency Fire Center, and the USFS Missoula Fire Sciences Lab. Each set of maps contains MODIS active fire detections for the 24-hour period proceeding the specified time. The maps are produced daily at 3:00 AM and 3:00 PM local time in the Mountain Time Zone.

NPOESS VIIRS Improvements: With decreased data latency, products will be available sooner in emergency situations.

Link: USDA Forest Service MODIS Active Fire Mapping Program
http://activefiremaps.fs.fed.us/activefiremaps.php

Fire Detection Algorithms and Products

Description: Several algorithms are available to identify fire locations from satellite observations. None are completely accurate; sometimes they fail to detect fires or detect too many fires. Most are fully automated, although some involve human input for better quality control.

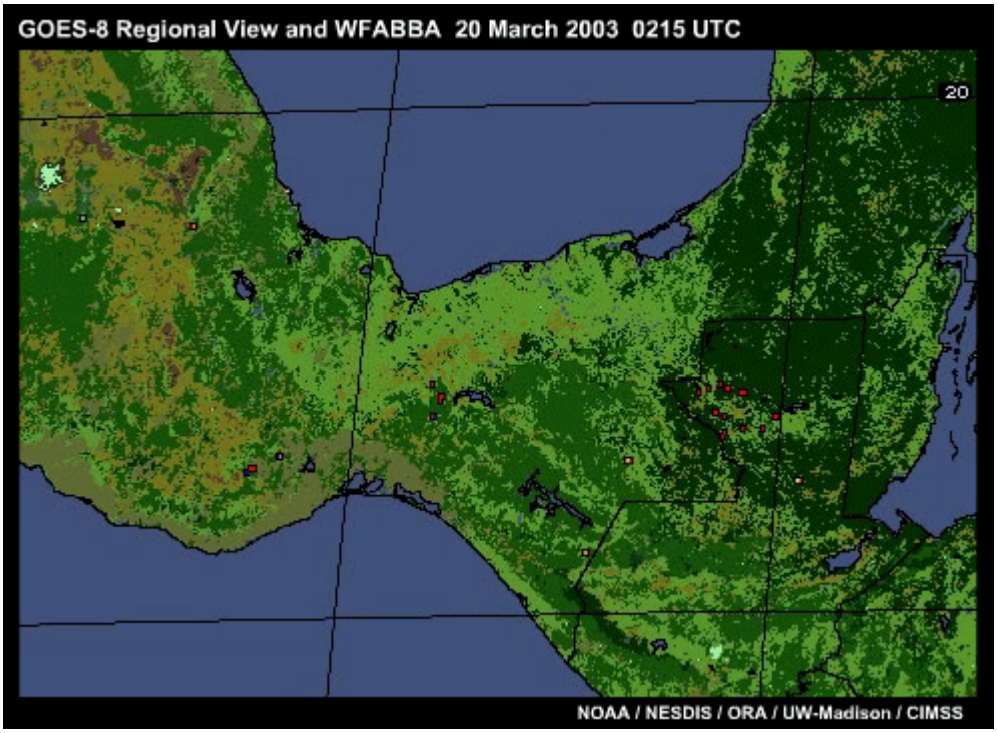
- Wildfire Automated Biomass Burning Algorithm (WFABBA): Automated fire detections from GOES satellites, developed by the Cooperative Institute for Meteorological Satellite Studies (CIMSS)
- MODIS Rapid Response System: Provides rapid access to MODIS fire data globally
- Fire Identification Mapping and Monitoring Algorithms (FIMMA): Automated fire detections from NOAA polar-orbiting weather satellites
- NOAA-NESDIS Hazard Mapping System (HMS): Analyst quality controlled fire and smoke products that utilize the three automated fire detection algorithms listed above. Analysts can specify additional fires; the products are used by government agencies, private companies, and universities

Applications:

- Fire locations are overlaid on images or maps, such as MODIS true and false color images, and distributed to government users, etc.
- Fire detections are used to estimate smoke emissions for smoke transport forecasts

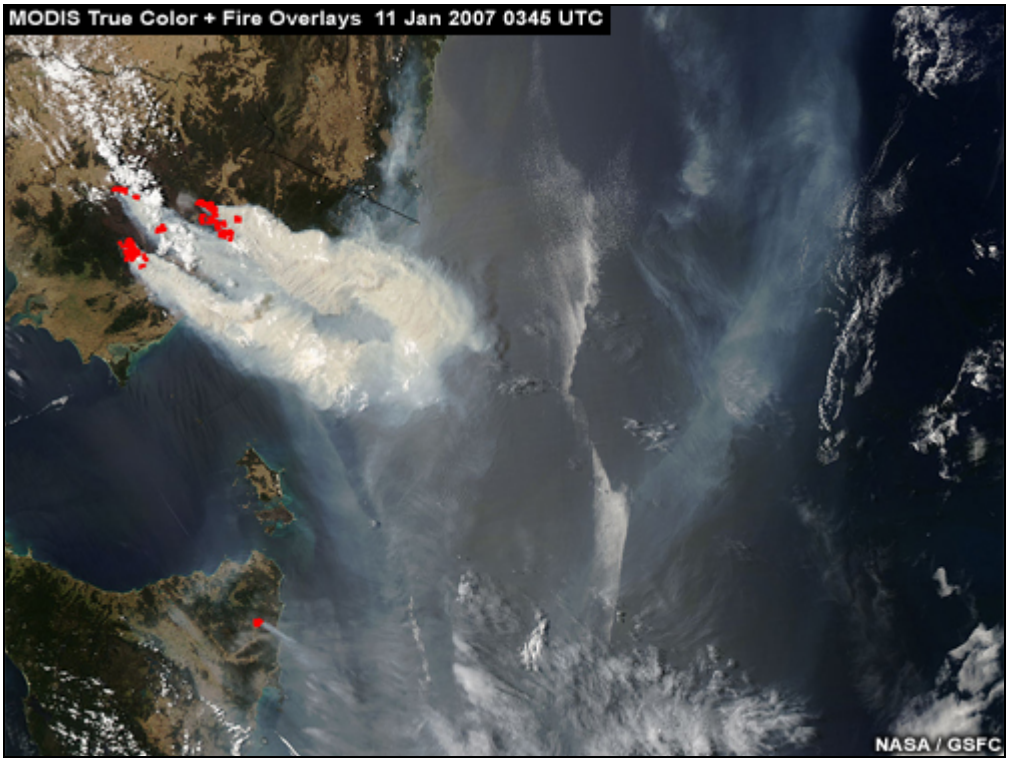
Example: WFABBA

Detections are shown as red dots in this loop of Central America.



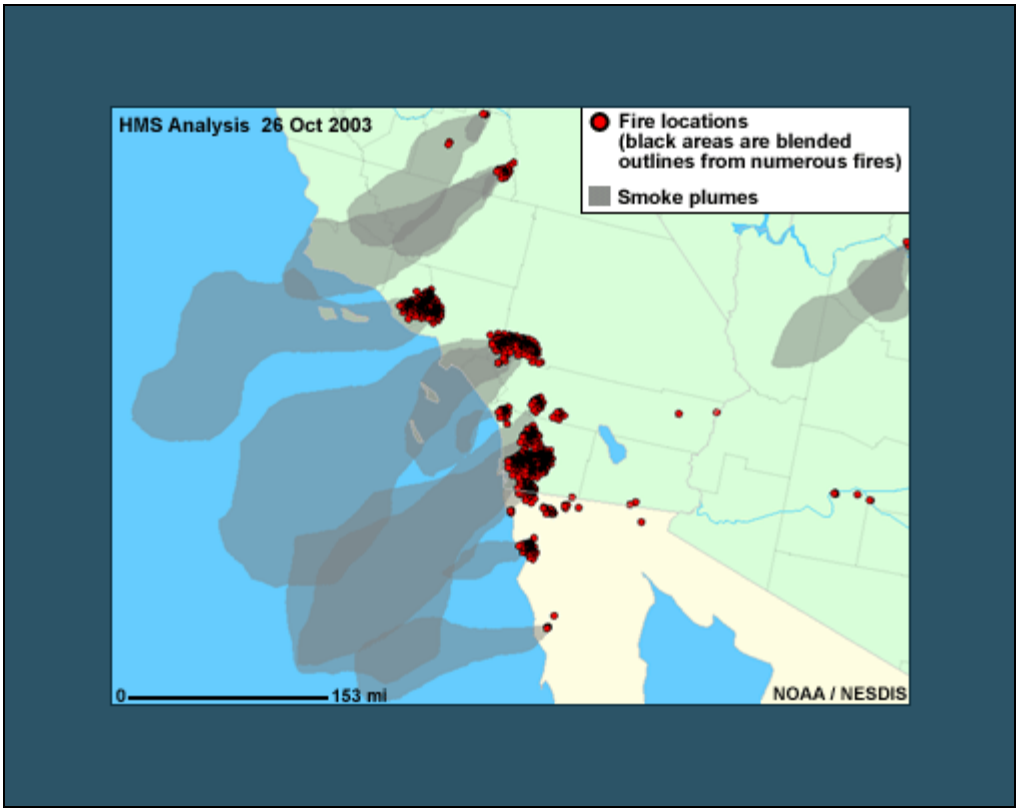
Example: MODIS Rapid Response System

Detections appear in red on this MODIS true color imagery over Australia.



Example: HMS fire detections

Detections are shown in red on this map of fires in southern California.



Derivation: The automated processing of digital multispectral satellite data is key to creating these products. Note that the NOAA-NESDIS HMS system output is quality controlled by a person.

NPOESS VIIRS Improvements: In addition to the traditional shortwave fire channels carried by NOAA AVHRR and MODIS, VIIRS will have the Day/Night Band (DNB), which will significantly enhance satellite detection of nighttime fires.

Links:

- WFABBA (GOES Fire Detects from the Wildfire Automated Biomass Burning Algorithm): http://www.ssd.noaa.gov/PS/FIRE/Layers/ABBA/abba.html
- MODIS Rapid Response System: http://rapidfire.sci.gsfc.nasa.gov/
- FIMMA (Fire Identification Mapping and Monitoring Algorithms): http://www.ssd.noaa.gov/PS/FIRE/Layers/FIMMA/fimma.html
- HMS (NOAA-NESDIS Hazard Mapping System): http://www.ssd.noaa.gov/PS/FIRE

Geostationary and Polar-orbiting Animations

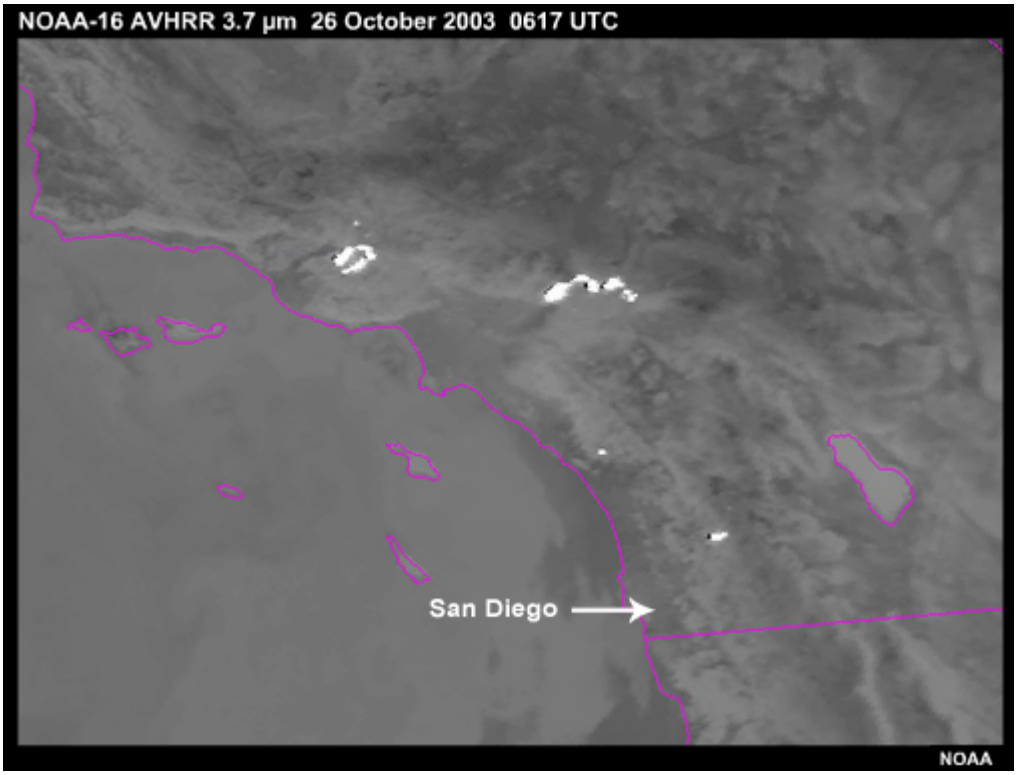
Description: Sequences of images showing fire hotspots and smoke

Applications:

- Helping to locate new fires
- Viewing trends in fire hotspots
- Watching the evolution of smoke plumes

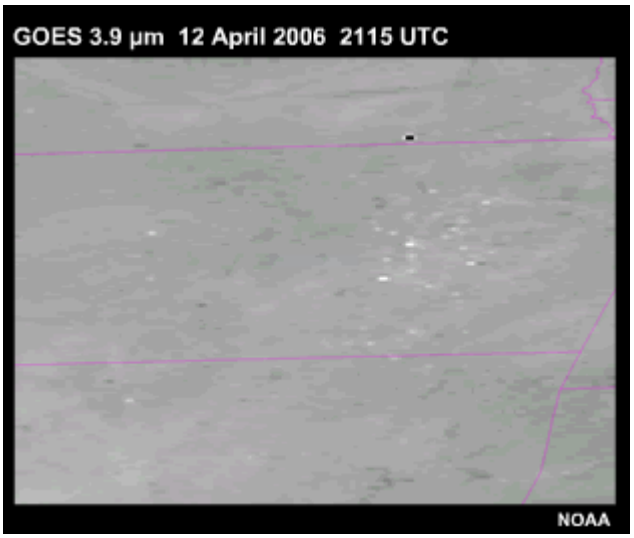
Example: Polar-orbiting loops

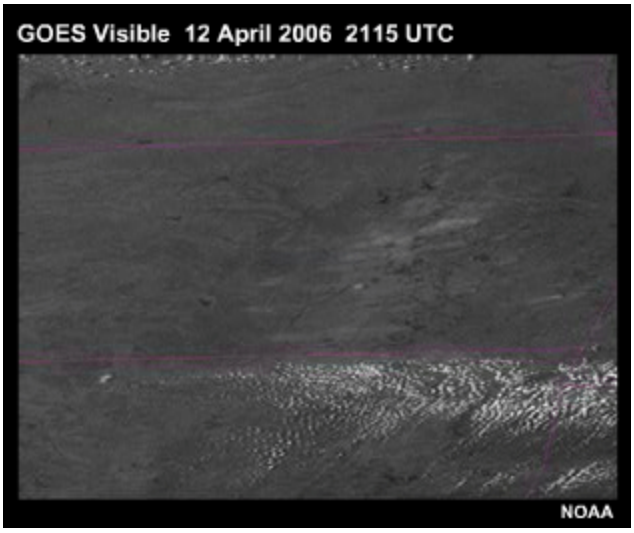
Satellite loops are often made from geostationary images, but polar-orbiting satellite data can provide effective loops as well, particularly at higher latitudes where there can be significant overlap between consecutive orbits. Here is an animation of polar NOAA AVHRR shortwave ('fire' channel) images of thermal hotspots (shown in white) over southern California during a six-day period in October 2003, day and night. Even though there are significant time gaps between the images, the sequence tells an important story of how the fires spread. Notice how the strong offshore wind shapes the fires near San Diego into a bow-shaped firestorm on 26 and 27 October.



Example: Polar-orbiting and geostationary imagery loops

Images from geostationary satellites produce smoother animations than those from polar-orbiting satellites due to the shorter time interval between scans. The animation on the top is of GOES fire channel imagery from 12 April 2006. The flickering bright spots are fires, most or all of which are agricultural or prescribed burns. The animation on the bottom is of visible GOES imagery, which shows the smoke generated from these fires.





NPOESS VIIRS Improvements: With decreased data latency, VIIRS imagery will be available more quickly to forecasters, and loops can be constructed with channels of higher spatial resolution.

Links: WFABBA (GOES Fire Detections from the Wildfire Automated Biomass Burning Algorithm)

- http://www.ssd.noaa.gov/PS/FIRE/Layers/ABBA/abba.html
- http://cimss.ssec.wisc.edu/goes/burn/abba.html

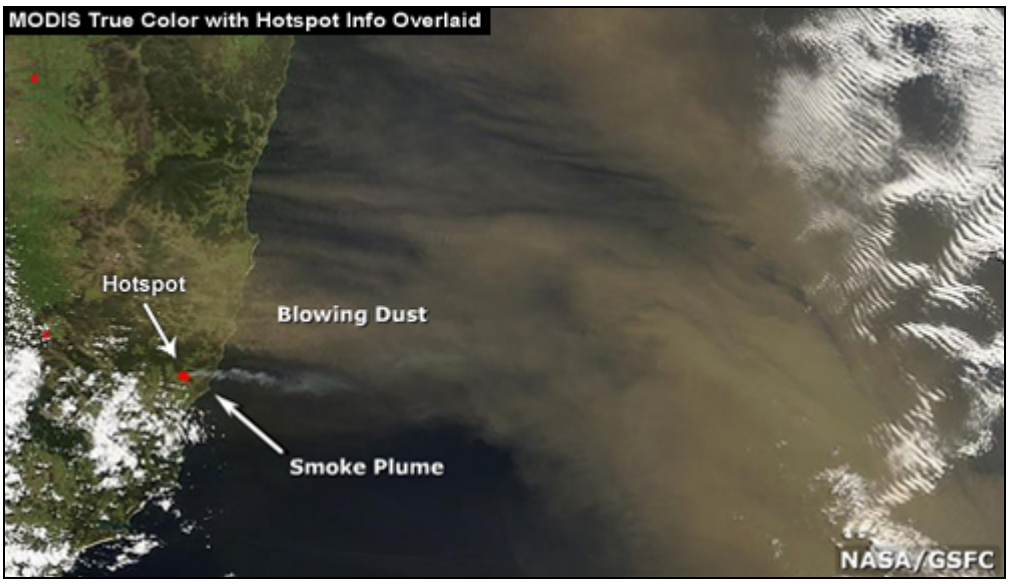
MODIS True Color Product

Description: A color combination image that combines channels corresponding to the red, blue, and green wavelengths (MODIS channels 1, 4, 3). The realistic color combination on these products resembles what the human eye would see given the same scene.

Applications:

- Is the optimal satellite product for the general interpretation of smoke and other large aerosols
- Often reveals smoke where it cannot be seen on other products
- Reveals information about the landscape (mountains, chaparral, vegetation coverage, snow cover, water bodies, etc.), which adds important context for those forecasting or studying fires
- Red spots or red perimeters are often added, marking the location of likely fires based on thermal anomaly information derived from shortwave and longwave infrared channels

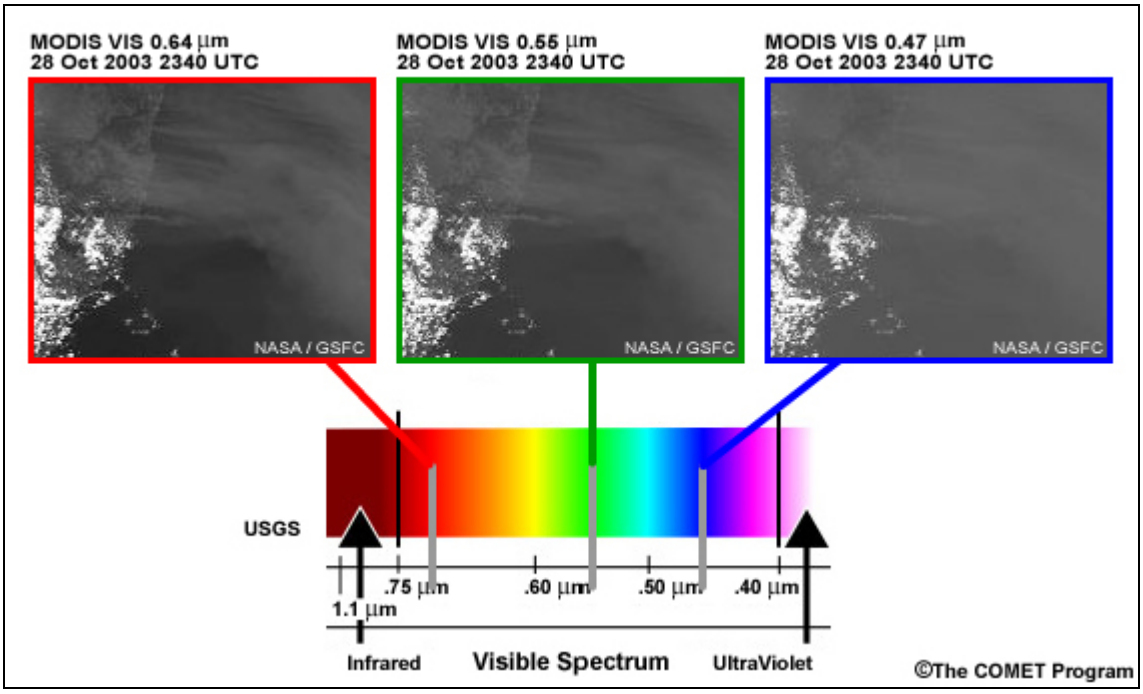
Example: This true color image shows blowing dust and smoke from the east coast of Australia. It is easy to distinguish the smoke plume from the large area of blowing dust.



In contrast, smoke from burning vegetation appears relatively white, reflecting the red, green, and blue components of visible light in relatively equal amounts. Clouds are easily separated from the suspended dust in true color imagery and appear white for much the same reason.

A small group of red pixels indicating hotspots or fires appears at the western end of the smoke plume. These were inserted after the channel compositing took place, using information from the thermally sensitive shortwave infrared channels on MODIS.

Derivation: Like the upcoming NPOESS VIIRS instrument, the MODIS imager has three visible channels that correspond closely to the red, green, and blue wavelengths within the visible spectrum.



These channels are processed so that one color range is assigned to a particular wavelength region. Combining all of the color ranges produces what is known as true color imagery.

NPOESS VIIRS Improvements: NPOESS VIIRS true color products will arrive at data processing centers less than a half hour after overpass, unlike MODIS images, which often arrive several hours after imaging.

Links:

- MODIS Rapid Response System: http://rapidfire.sci.gsfc.nasa.gov/
- USFS Imagery: http://activefiremaps.fs.fed.us/imagery.php
- NexSat (NRL/NPOPESS Next-Generation Weather Satellite Demonstration Project): http://www.nrlmry.navy.mil/NEXSAT.html

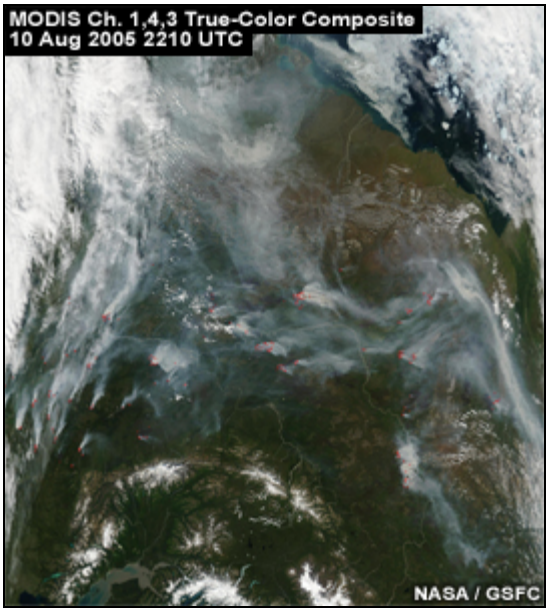
MODIS False Color Product

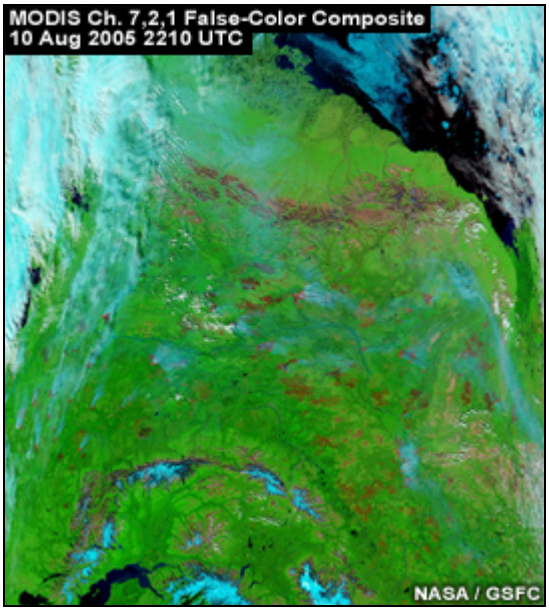
Description: A color combination corresponding to the wavelengths represented by MODIS channels 7, 2, and 1. In this module, we refer to the combination as 'the false color product' even though it is one of many possible false color products.

Applications

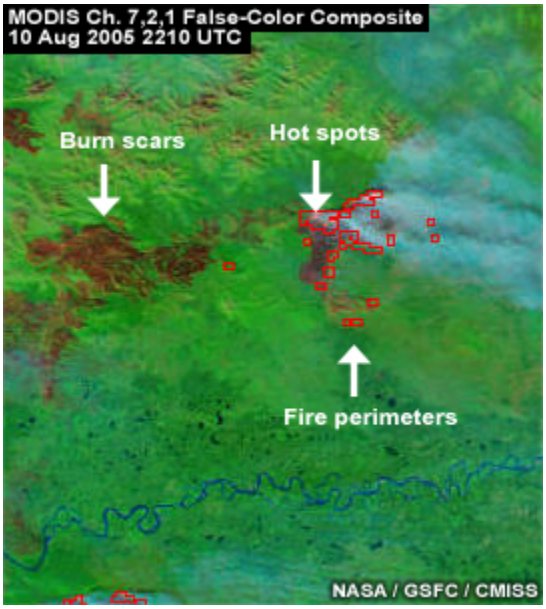
- Shows burn scars in a brownish or brick red color; burn scars are often adjacent to a fire in progress, allowing forecasters to assess the availability of fresh fuel in the vicinity of an advancing fire
- Often conveys fire locations as pink (or other shades of red) or orange spots
- Provides vivid depictions of landscapes and vegetation

Example: Compare this true color image with a false color image during an outbreak of forest fires in Alaska in 2005. The true color composite gives an excellent view of smoke, whereas the false color composite enhances landscape features and individual fire elements.



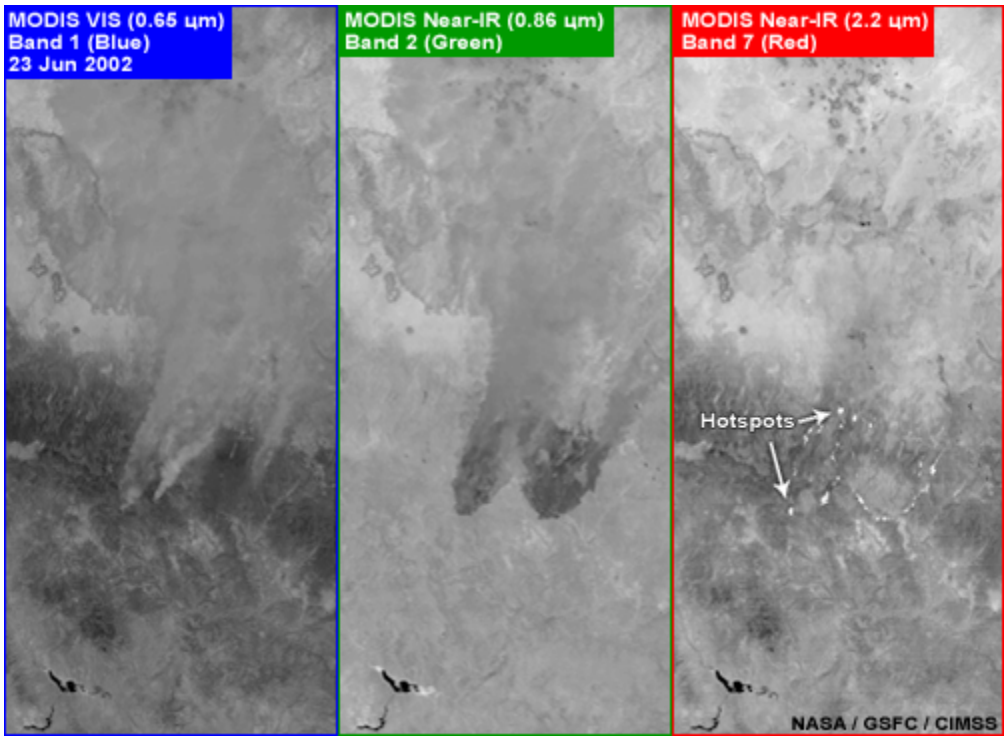


Zooming in on the false color composite, we see burn scars from current and recent fires. In addition, fire perimeters, based on the shortwave fire channel, mark the outer boundaries of hot regions. Individual fires appear in pink or orange.



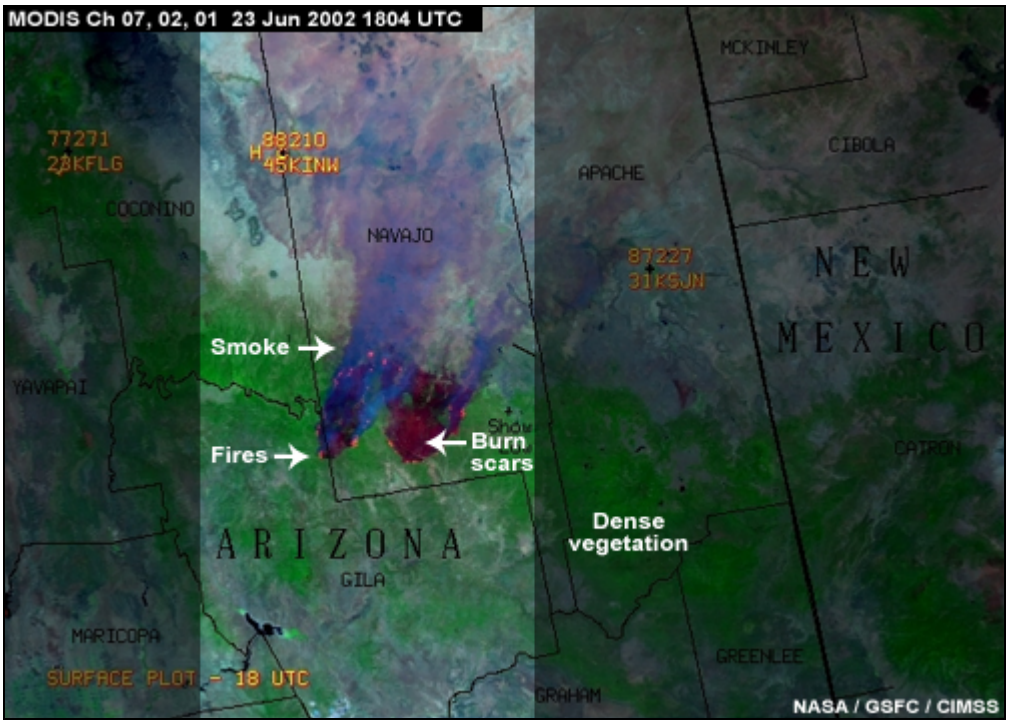
Derivation: The MODIS false color composite is made by combining information from three channels:

- Band 1 (0.65 micrometers assigned to the blue color gun), a visible channel
- Band 2 (0.86 micrometers assigned to the green color gun), a near-infrared channel
- Band 7 (2.2 micrometers assigned to the red color gun), a near-infrared channel capable of showing hot fires



Notice the small white dots on this 2.2 micrometer image, which are hotspots. Although the 4 micrometer region is usually thought of as the fire detection region, fires can also be detected on daytime 2.2 micrometer images, which is a key to making this combination successful.

How do we make these three bands easier to use as a forecasting product? If we combine the images using the red, blue, and green color guns, salient features begin to pop out. Burn scars show up as brick red or brown, smoke appears bluish, and dense vegetation appears green. Fires appear bright red or orange.



NPOESS VIIRS Improvements: Unlike MODIS images, which often arrive several hours after imaging, VIIRS false color products will typically be available less than a half hour after overpass.

Links:

- MODIS Rapid Response System: http://rapidfire.sci.gsfc.nasa.gov/
- USFS Imagery: http://activefiremaps.fs.fed.us/imagery.php

Smoke Forecasting Products

Description: Model-generated forecasts of smoke, which are produced based on the positions of known fires.

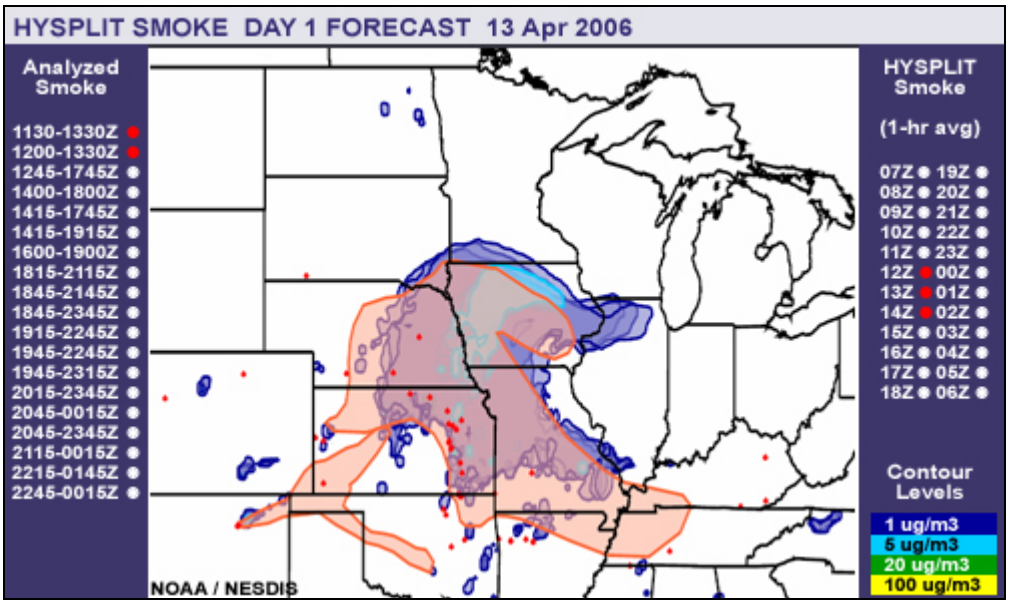
- **U.S. Navy Aerosol and Prediction System (NAAPS):** Forecasts smoke transport and aerosol optical thickness
- **NOAA-NESDIS Hazard Mapping System (HMS):** Determines the locations of fires and smoke using an analyst/algorithm mix; data are used to initialize the HYSPLIT model for smoke forecasting
- **HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) model:** Forecasts smoke dispersion and transport
- **FLAMBE (U.S. Navy Fire Locating and Modeling of Burning Emissions) program:** Estimates smoke output
- **WFABBA (WildFire Automated Biomass Burning Algorithm):** Detects fires, which are assimilated into smoke forecasting schemes
- **NOAA National Weather Service Air Quality Forecast Guidance:** Provides ozone, particulate matter, and other pollutant forecasts

Applications:

- Anticipating hazardous air quality from fires with a lead time of hours to days, enabling the timely issuance of public warnings
- Forecasting degraded visibilities over North America (using the NOAA Interim Smoke Forecast Tool) or globally (using NAAPS)

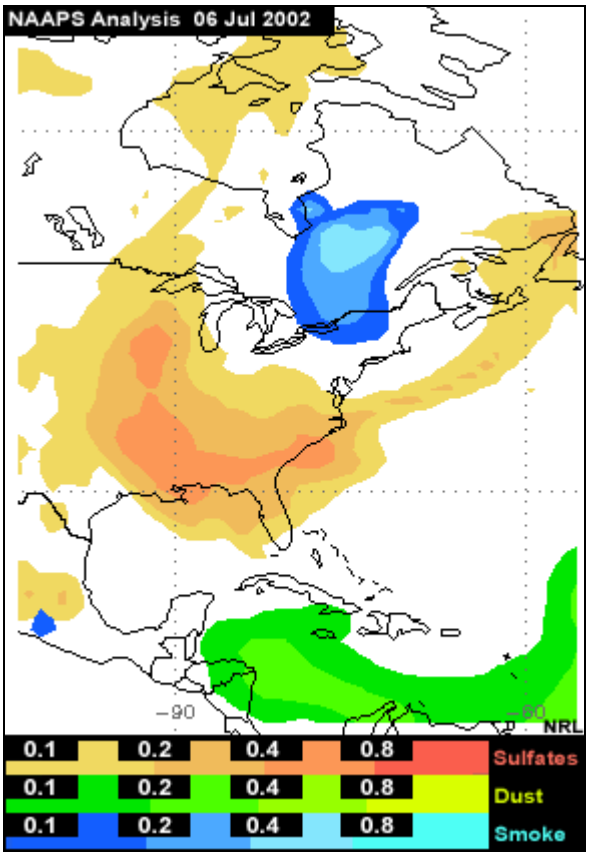
Example: HYSPLIT/HMS

The blue-shaded areas are those forecast by the HYSPLIT model based on fires burning the day before. For comparison, the red-shaded area is the HMS analyst-drawn smoke analysis valid at the forecast time.



Example: NAAPS

This product shows the NAAPS forecast of a smoke plume over the northeastern United States and offshore waters. Smoke magnitudes appear in shades of blue. The units are aerosol optical thickness.



NPOESS VIIRS Improvements: Reduced data latency will mean that satellite detections will be available for assimilation sooner.

Links:

- FLAMBE (U.S. Navy Fire Locating and Modeling of Burning Emissions) program: http://www.nrlmry.navy.mil/flambe/; also viewable in Google™ Earth via that URL
- HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) model: http://www.arl.noaa.gov/ready/hysp_info.html
- MODIS Rapid Response System: http://rapidfire.sci.gsfc.nasa.gov/
- NAAPS (U.S. Navy Aerosol and Prediction System): http://www.nrlmry.navy.mil/aerosol/; also viewable in Google™ Earth at http://www.nrlmry.navy.mil/flambe/
- National Weather Service Air Quality Forecast Guidance: http://www.weather.gov/aq/
- NOAA-NESDIS Hazard Mapping System (HMS): http://www.ssd.noaa.gov/PS/FIRE/hms.html
- NOAA Interim Smoke Forecast Tool: http://www.arl.noaa.gov/smoke/
- WFABBA (Wildfire Automated Biomass Burning): http://www.ssd.noaa.gov/PS/FIRE/Layers/ABBA/abba.html