N5 Sensors

HOW SATELLITES ARE USED TO DETECT AND TRACK WILDFIRES IN THE US

Objective – To identify the main satellites, instruments, and methods essential for detection of wildfires in the United States. Discussion of limits of detection both in fire size and time to detect are discussed from the standpoint of satellite flight path, and instrumental and data processing limitations.

Section 1 – How Satellite-Based Detection of Wildfires Works

Use of satellites in detection of hotspots was documented by Michael Matson and Jeff Dozier, in their paper "Identification of Subresolution High Temperature Sources Using a Thermal IR Sensor" in the journal Photogrammetric Engineering and Remote Sensing Vol 47, September 1981, pp.1311 published by American Society of Photogrammetry. In their paper, they described the approach where simultaneous use of 3.8 micron and 11 micron thermal infrared channels on board a NOAA-6 environmental satellite provided estimates of the size and temperature of the hot spots on the ground. Authors mentioned the detection of active burning forest fires using multichannel measurement from Advanced Very High-Resolution Radiometer (AVHRR) instrument onboard the satellite. We have come a long way since then, now advanced satellite imagery along with data processing can produce high resolution images of forest fires as seen in the image below.

Figure 1: Active fire pixels in processed satellite image.

Principles of Infrared (IR) based Detection of Wildfires from Space.

Active or smoldering fires emit IR energy with the spectral radiance distribution shown below. However, our atmosphere absorbs specific wavelength IR energy quite efficiently mostly by water and carbon dioxide molecules. In other words, the atmosphere around earth selectively transmits IR energy of certain wavelengths described as atmospheric transmission windows (shown in the figure below). So, active fires and burnt areas can be differentiated by looking at different IR bands that fall in the atmospheric windows.

Most of the imaging instruments utilize detection of multiple bands of IR (channels) for active and burned area determination.

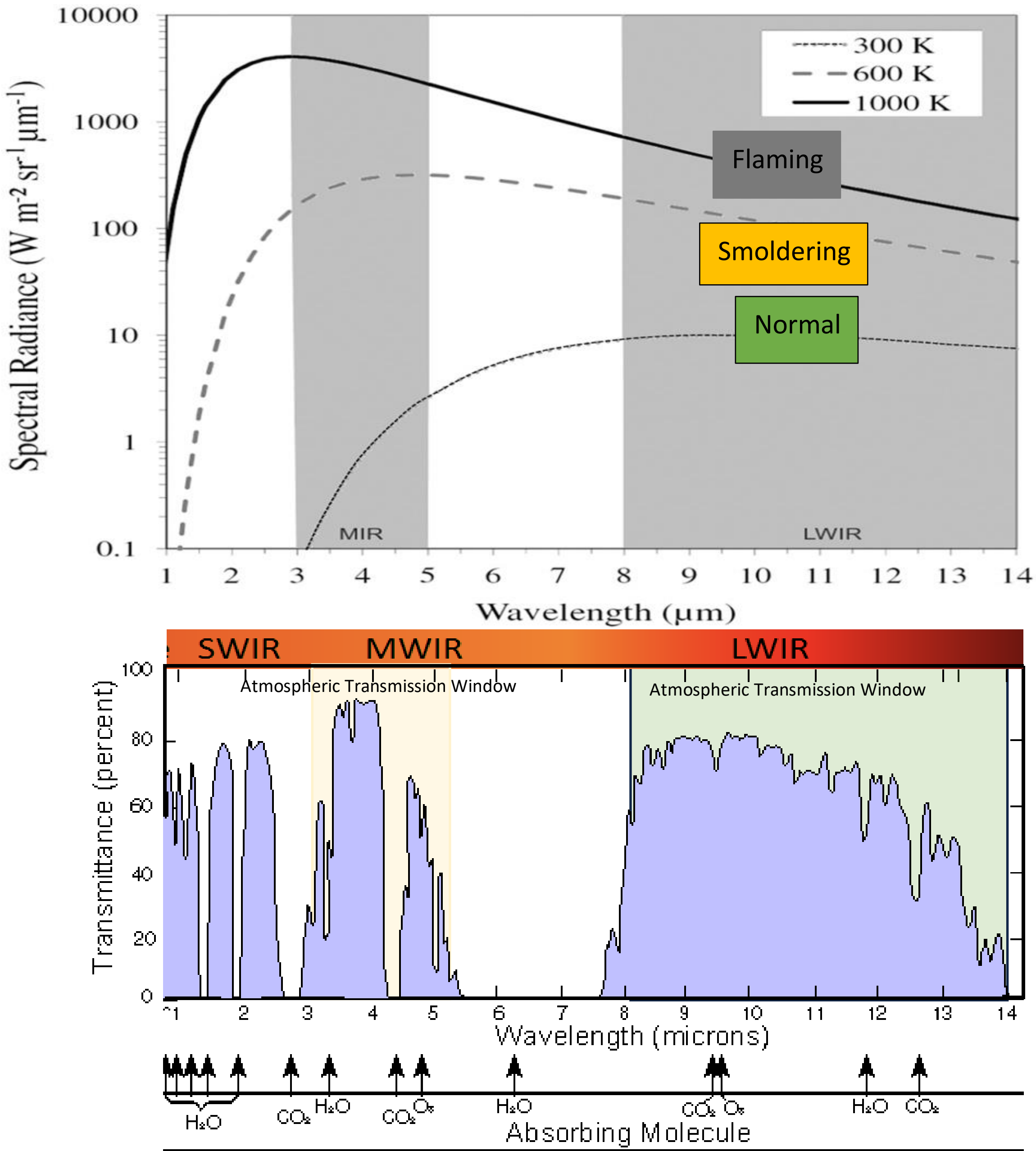

Figure 2: Spectral radiance and atmospheric transmission windows.

Section 2 – What Types of Satellites are Used for Wildfire Detection

There are two categories of satellite platforms used for fire detection. One is geostationary and the other is low earth orbit (polar orbiting) satellites. Satellites in geostationary orbits rotate with the Earth directly above the equator, continuously staying above the same spot. This position allows satellites to observe weather and other phenomena with very high temporal resolution like imaging of the same spot (5 mins frequency); however, to match rotation of the earth they are typically placed at an altitude of approximately 22,300 miles. Thus, spatial resolution is low for geostationary satellites. In contrast, polar orbiting satellites constantly circle the Earth in an almost north-south orbit, passing close to both poles, while the earth rotates under their orbit. They complete orbits about 14 – 15 times a day and are flying approximately 520 miles above the earth's surface which gives them the ability to take high resolution images. However, as they are on a lower orbit and moving fast, they only come back over the same area on the ground roughly in 12 hours, which means they have low temporal resolution. The figure below is a representation of the various satellite platforms that make wildfire detection possible.

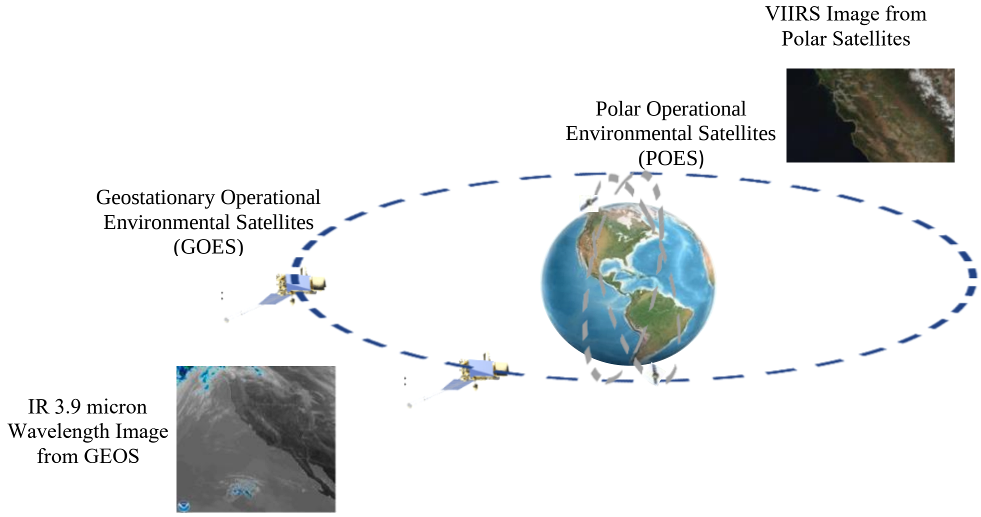

Figure 3: Representative location of different satellites and their orbits for wildfire detection.

Most of the fire detection in the US is done using these main satellites – geostationary Global Operational Environmental Satellites (GOES), Polar Operational Environmental Satellites (POES), Joint Polar Satellite System (JPSS), and NASA's Earth Observing Systems - Terra and Aqua and Landsat 8.

Section 2 – Instruments Used in Satellite Based Wildfire Detection

The table below summarizes the instruments and satellites used for fire detection today.

Satellite	Instrument	Spatial Resolution	Temporal Resolution	Agency

Polar Operational Environmental Satellites (POES 19)	Advanced Very High-Resolution Radiometer (AVHRR)	~ 1 km	~12 hours	NOAA-NASA
National Polar-orbiting Partnership (NPP SOUMI) and NOAA 20	Visible Infrared Imaging Radiometer Suite (VIIRS)	~ 0.37 km	~12 hour	NASA
Landsat 8	Thermal Infrared Sensor (TIRS)	~1 km	~12 hour	NASA-USGS
Terra and Aqua	Moderate Resolution Imaging Spectroradiometer (MODIS)	~1 km	~12 hour	NASA
GEOS 16 (East) and GEOS 17 (West)	Advanced Baseline Imager (ABI)	~ 2 – 4 km	~5 mins	NOAA-NASA

Note – Spatial and temporal resolution comment is relevant for fire detection

While MODIS and VIIRS fly on satellites with similar polar orbits, the spatial resolution of the "thermal bands" on each instrument is different. The MODIS thermal band detects hot spots with a resolution of 1,000 meters per pixel; VIIRS detects hot spots at a resolution of 375 meters per pixel. So VIIRS can make fire observations that are about three times more detailed than MODIS.

ABI on geostationary platforms like GEOS on other hand produces fire maps that are about 2 km per pixel resolution.

Section 3 – Data Processing and Availability of Fire Detection Products

Instruments onboard various satellites capture imagery in different spectral channels and send them back to earth stations via various downlink communications channels. It takes many steps to convert raw satellite instrument data to usable information (called products) that are then available to general users via interagency collaboration. The diagram below explains the intricacies of data product generation from satellite imagery.

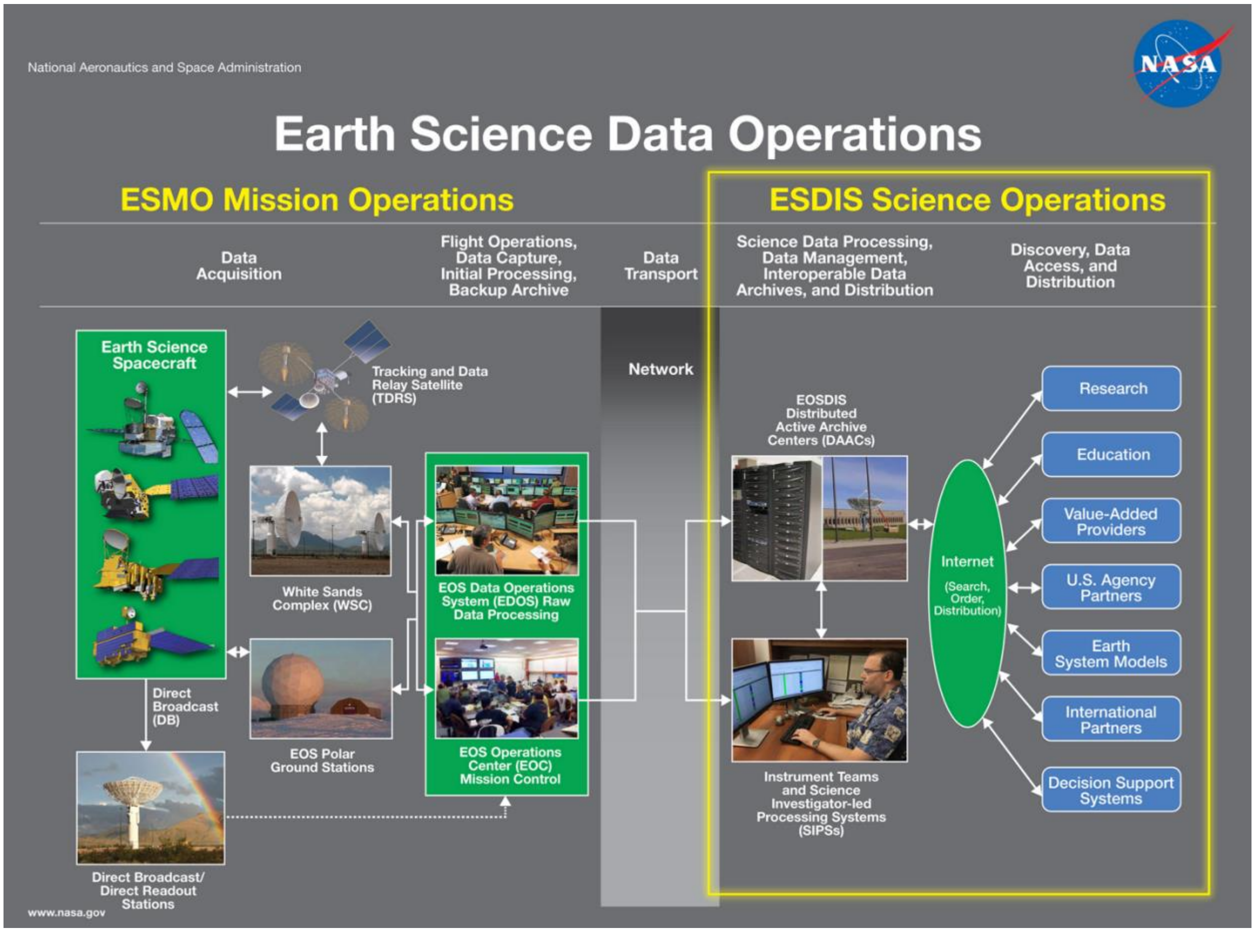

Figure 4: NASA's Earth Science Data Operations which creates different data products from satellite measurements used for wildfire detection.

Providing information about hotspots detected by instruments aboard Earth observing satellites in near real-time is a capability that has been available for more than a decade through NASA's Fire Information for Resource Management System (FIRMS). FIRMS US/Canada is a joint effort by NASA and the USDA Forest Service to provide access to low latency satellite imagery and science data products from Earth Observation System (EOS) satellite assets to identify the location, extent and intensity of wildfire activity and its effects. FIRMS is enabled by data and applications provided by NASA's Earth Observing System Data and Information System (EOSDIS), including NASA's Land, Atmosphere Near real-time Capability for EOS (LANCE), as well as data from the direct readout community and technologies facilitated by the NASA Direct Readout Laboratory.

Section 4- Limitations of the Satellite Based Data for Active Fire Determination

Undoubtedly satellite data represents an important tool in active fire determination. However, satellite-based data and fire detection products suffer from unique challenges – they require complex image processing techniques, temporal dependencies across time steps, the complexity of spectral channels, and adverse impact of environmental conditions such as smoke, cloud and illumination, and data latency.

Data latency is defined as the total time elapsed between when data are collected, acquired by a satellite and when they are made available for public access via the internet. For example, NASA's FIRMS system that distributes near real-time (NRT) active fire data, typically takes three hours from satellite observations from NASA's MODIS (aboard the Terra and Aqua satellites) and VIIRS aboard the Suomi NPP and NOAA-20 satellites. Another big factor is cost – launching and maintaining satellites with advanced imaging equipment is expensive, and most satellites and their instrumentation have limited life span. Also, there are times when instruments on-board satellites suffer technical difficulties and the data products from those instruments can become unavailable for unpredictable periods of time. Satellite imagery still requires great deal of sophisticated human intervention for accurate determination of hot spots to ensure early detection and minimal false positives.

In conclusion, satellites fill a big need in real-time wildfire detection however the tradeoffs are temporal and spatial resolutions; where Geostationary platforms provide the highest temporal resolution, and lower earth orbit platforms provide the highest spatial resolution but low temporal resolution. Perhaps the future generation of satellites, such as those under development by NASA's CubeSate Launch Initiative can fill the gap providing continuous coverage with high resolution IR imaging at more reasonable cost.

Disclaimer – The information presented here is summarized from various sources and are cited throughout the text where appropriate.

Contact Information: info@n5sensors.com