Wildland Fires: How Can We Be Better Informed Through Earth Observation Capabilities and Modeling Strategies?

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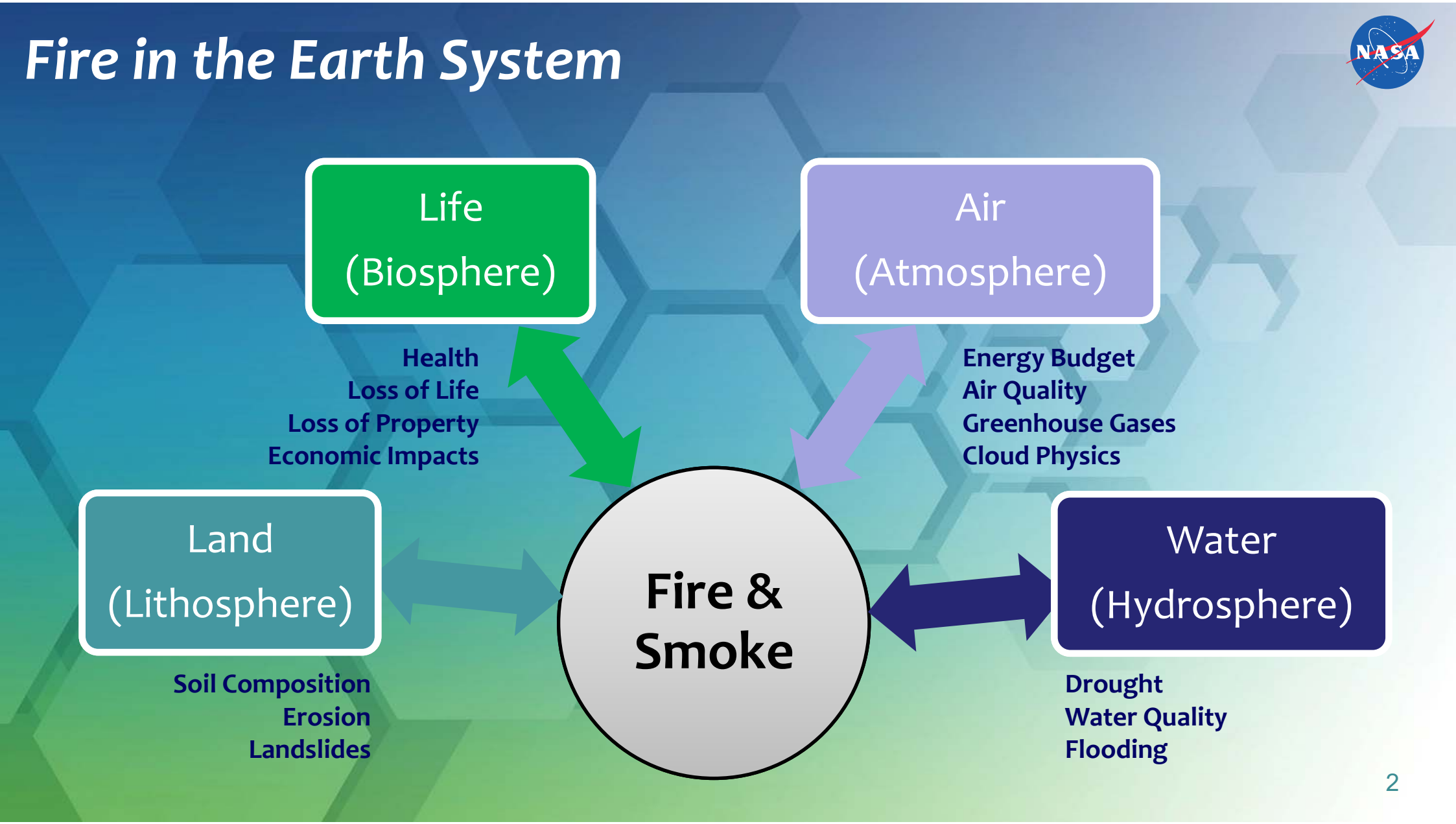
CSUMB ARC-CREST Co-Op / NASA-ARC

Trans-Atlantic Training (TAT)

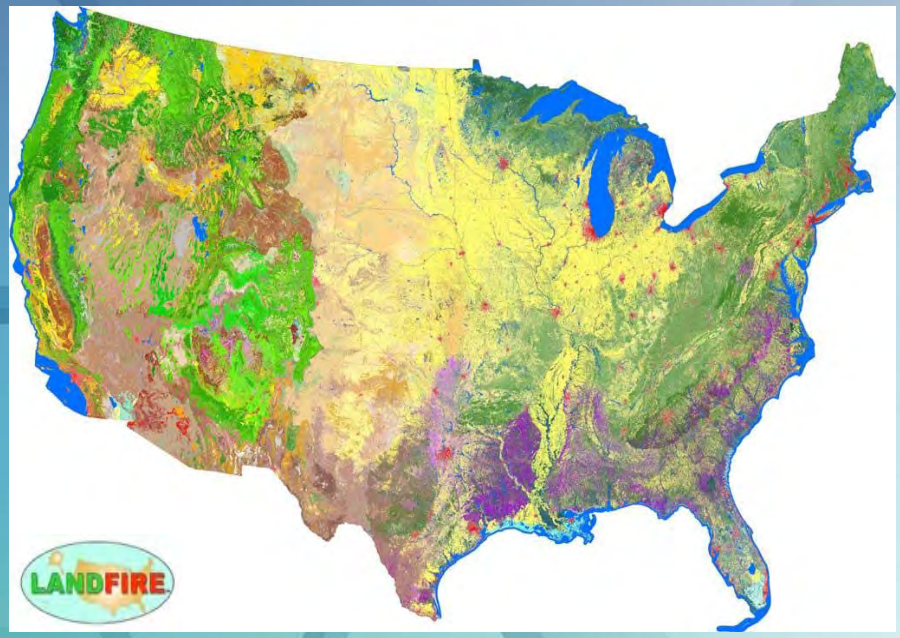
1 June 2021

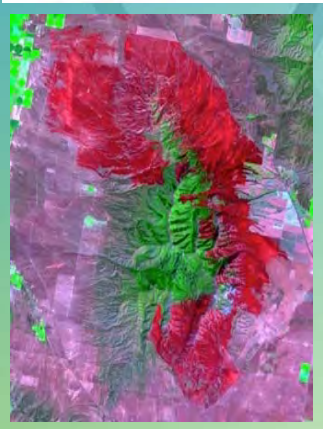
Fire in the Earth System

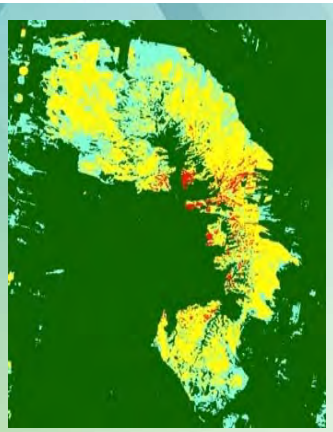


Employing Earth Observations for Wildfire Phases

- **Pre-Fire Risk Assessment**
  - Vegetation density and extent
  - Soil moisture/drought severity
  - Topography
- **Active Fire Detection**
  - Hot-Spot Detection
  - Total area currently burning
  - Fire Radiative Power (FRP) using thermal bands
- **Post-Fire Assessment**
  - Total area burned
  - Burn severity
  - Post-fire vegetation regrowth (NDVI)







Above: A USGS Landfire map.

Left: 2007 Black Pine 2 Fire, Idaho, U.S. On the left: imagery, right: burn severity. USDA RSAC.

PRE-FIRE RISK ASSESSMENT

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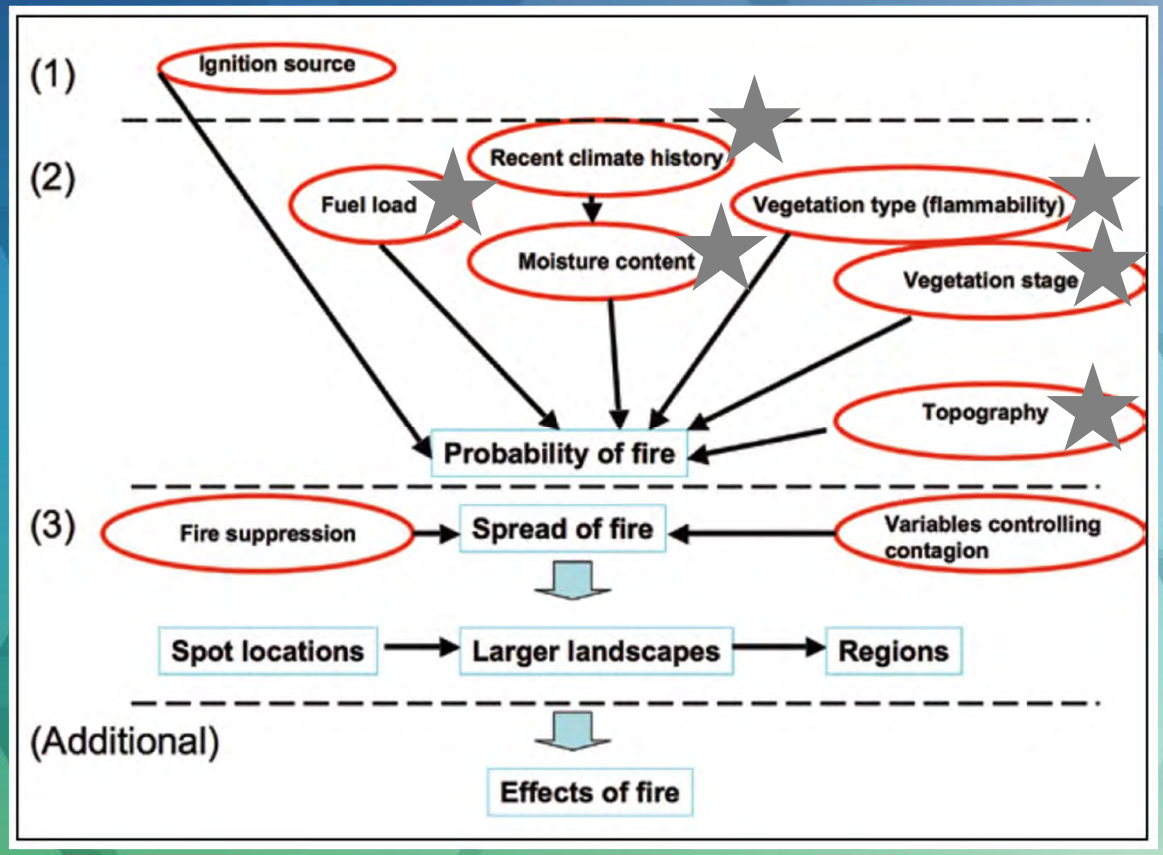
Fire Risk Mapping Framework

Where remotely sensed data can be used independently or with ground-based observations



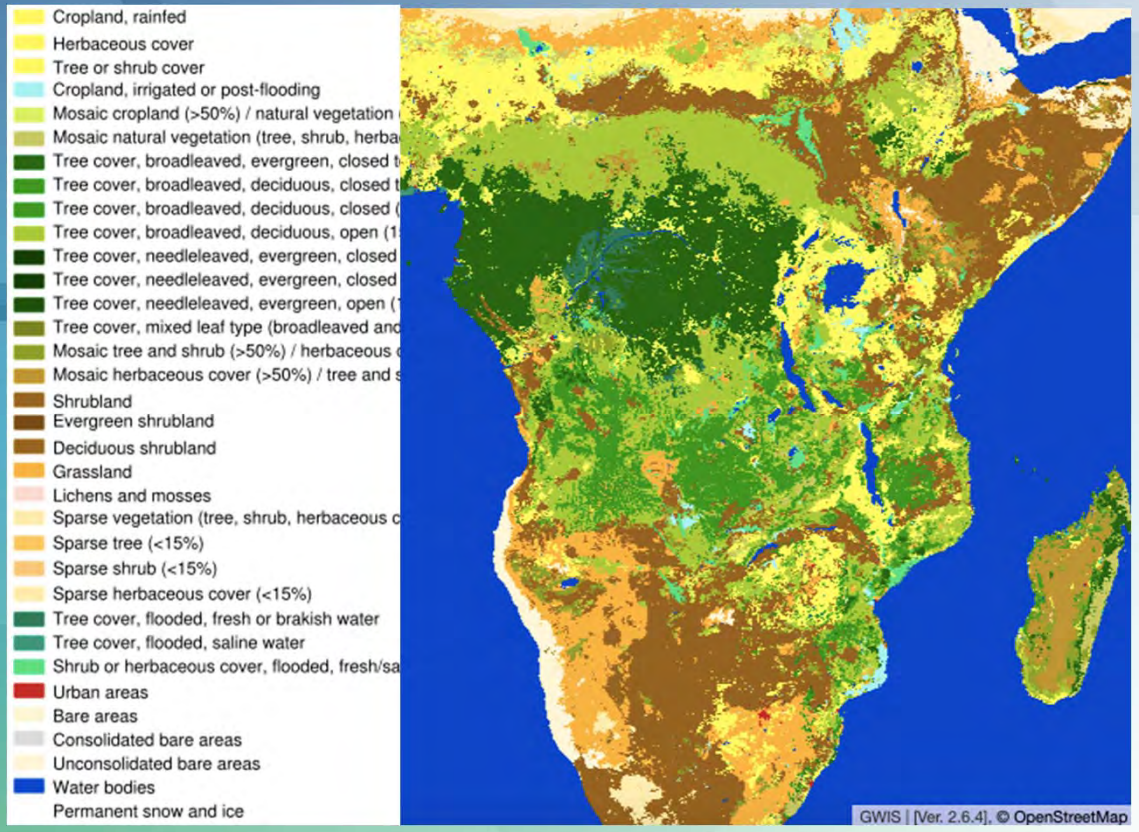
Calculation of fire risk. There are three aspects to predicting fire: (1) the probability of ignition; (2) the biophysical influences on fire, such as fuel load, moisture content, flammability of the vegetation, and topography; and (3) the spread of fire once it gets established.

Image Credit: Weinstein and Woodbury, USFS

- Comprehensive fire risk maps are challenging to produce due to the many factors that impact the probability of fire.

Land Cover Classification

- Grouping of spectrally similar pixels in remote sensing imagery based on land cover class (forest, shrubland, agriculture, etc.).
- Fuel behavior varies with vegetation type.
  - Example: Forests contain more biomass to sustain burning, but shrubland vegetations often ignites easier.
- Classification of a landscape differentiates available fuel types and maps their spatial extent.



Global Wildfire Information System (GWIS) land cover classification layer for Sub-Saharan Africa.
Image Credit: GWIS

Vegetation-Based Contributions to Fire Risk Mapping

- Remotely sensed observations can assist with the estimation of biophysical influences on fire.
- Fuel load, moisture, vegetation type and stage, and topography are parameters that can be used as inputs into fire models and risk assessments to incorporate the influence of fuels and topography on likelihood and behavior.

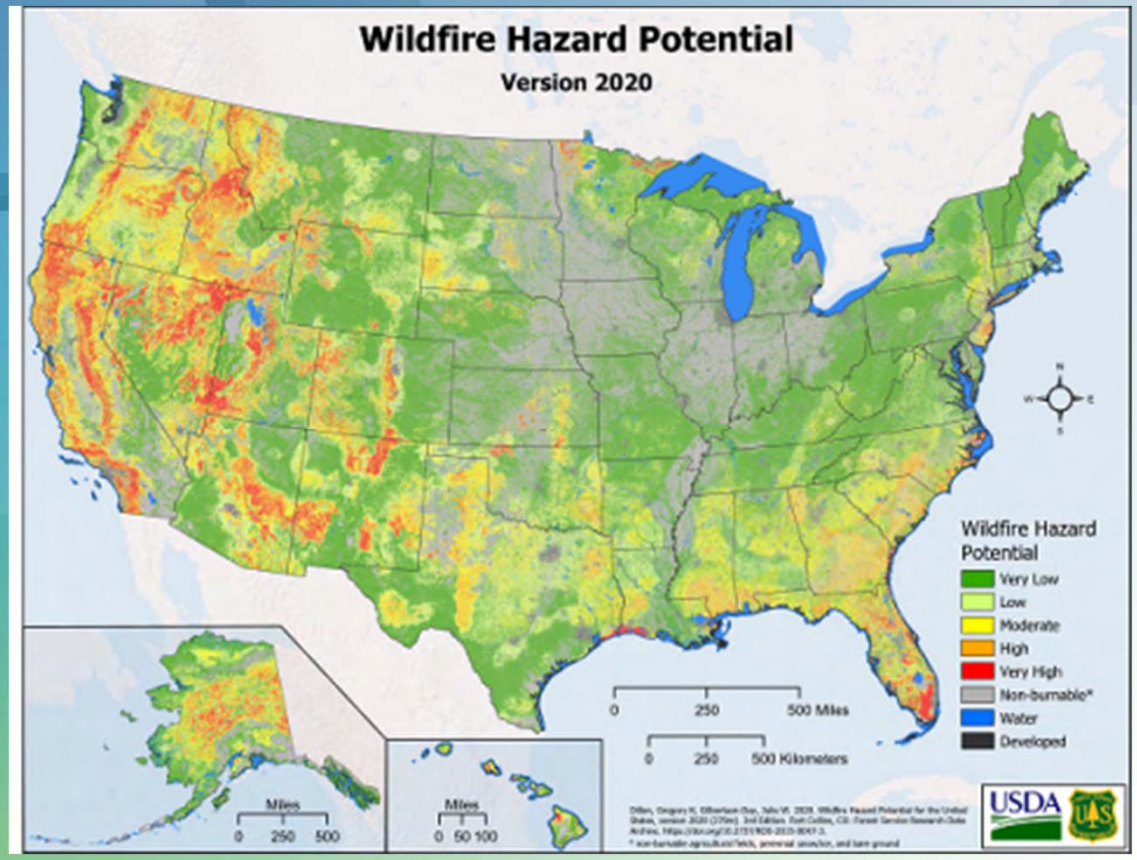
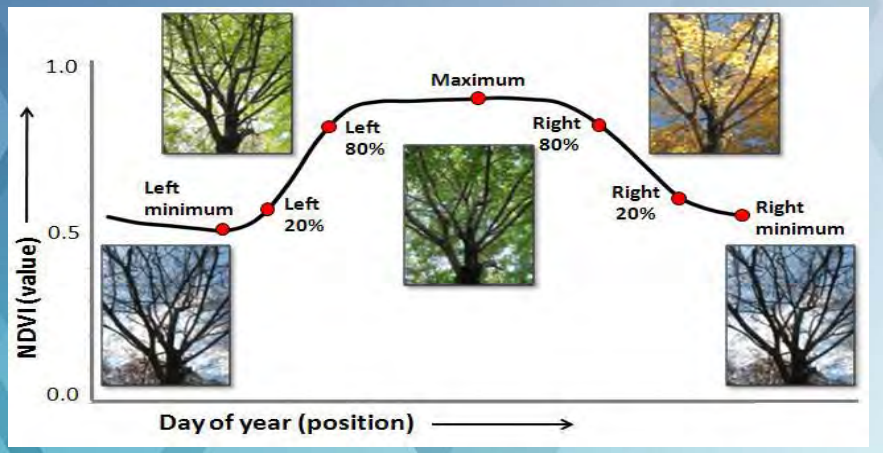


Image Credit: USFS

Vegetation Stage and Health

- Unhealthy vegetation has a higher percentage of dead branches and leaves, providing easier to burn fuel for fires. The stage of vegetation also dictates the amount and type of fuel available for fires.
- Vegetation Stage – Land Surface Phenology (LSP):
  - Use of satellites and sensors to track seasonal patterns of variation in vegetated land surfaces
- Monitoring Stage and Health – Indices:
  - NDVI - Normalized Difference Vegetation Index
  - EVI - Enhanced Vegetation Index
  - SAVI - Soil-Adjusted Vegetation Index
  - Vegetation index anomalies



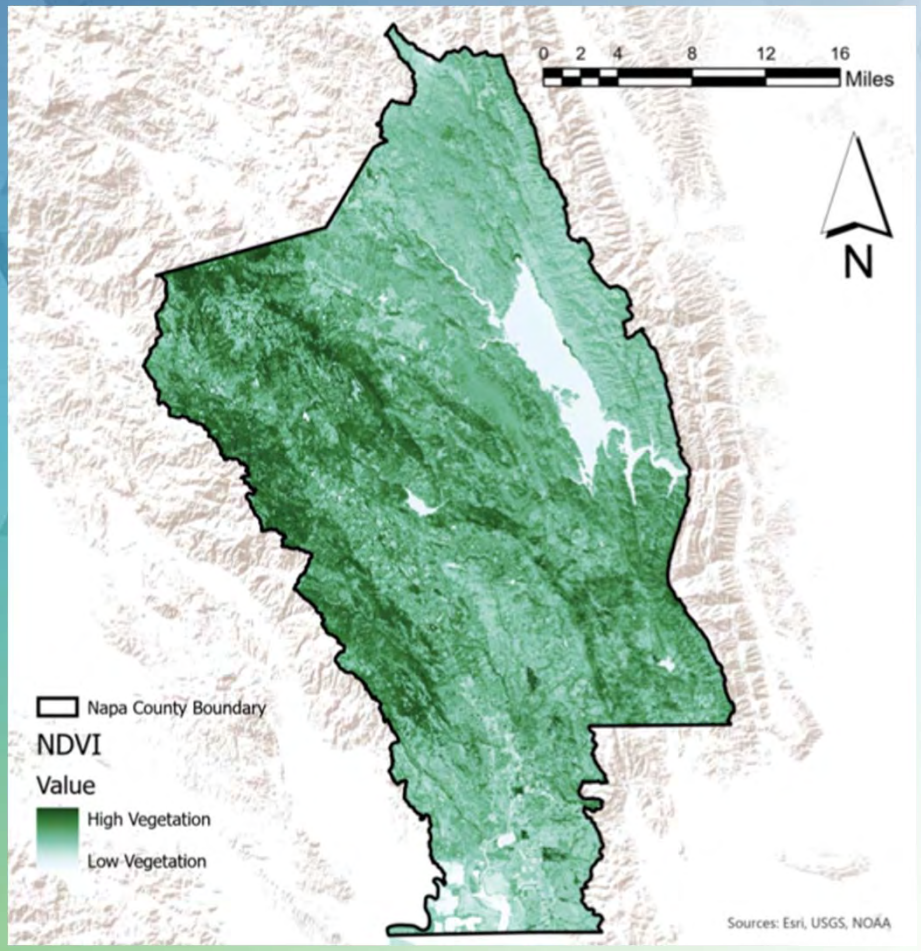
North America NDVI Images in Winter and Summer.

Image Credits: Montana Space Grant Consortium

Normalized Difference Vegetation Index (NDVI)

- NDVI is widely used as a metric for vegetation health and phenology.
- A measure of vegetation greenness
- Values range from -1.0 to 1.0
  - Negative values to 0 mean no green leaves.
  - Values close to 1 indicate the highest possible density of green leaves.
- NDVI Formula:

$$\frac{\text{Near-Infrared} - \text{Red}}{\text{Near-Infrared} + \text{Red}}$$



NDVI in Napa County, CA on July 8th, 2020.

Additional Vegetation Indices

Enhanced Vegetation Index (EVI)

$$EVI = G * \left(\frac{(NIR-R)}{(NIR+C1*R-C2*B+L)}\right)$$

Constants
$G = 2.5$
$C1 = 6$
$C2 = 7.5$
$L = 1$

- Can be used in place of NDVI to examine vegetation greenness
  - More sensitive in areas with dense vegetation, making it better for fuels assessment in dense forests
- Adjusts for canopy background and some atmospheric conditions

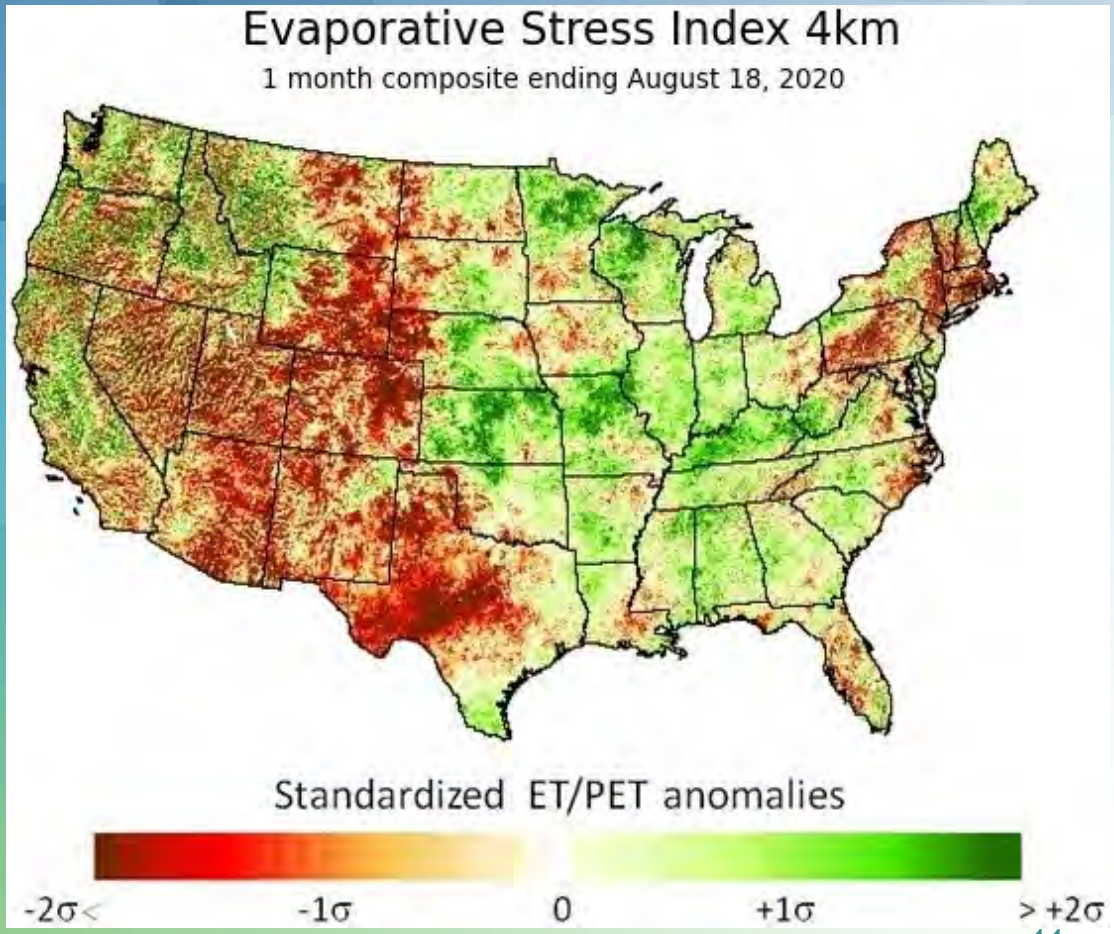
Soil Adjusted Vegetation Index (SAVI)

$$SAVI = \left(\frac{(NIR-R)}{(NIR+R+L)}\right) \times (1+L)$$

- Used to correct NDVI for the influence of soil brightness in areas where vegetative cover is low
  - Better index for areas with sparse vegetation and high bare soil coverage
- Contains a soil brightness correction factor (L)

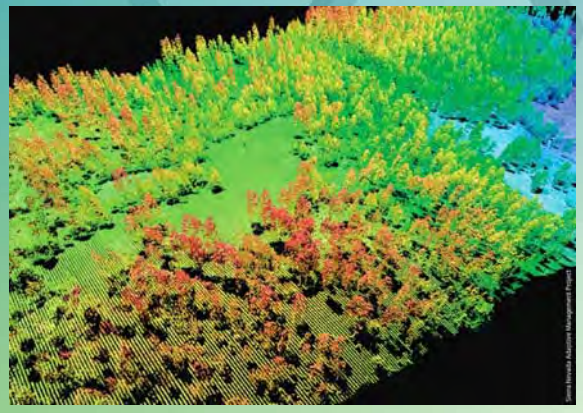
Evaporative Stress Index (ESI)

- ESI is based on satellite observations of land surface temperature, which are used to estimate water loss due to evapotranspiration (ET) – the loss of water via evaporation from soil and plant surfaces and via transpiration through plant leaves.
- Can be used as a measure of vegetation dryness prior to and during the fire season



Canopy Height and Density: LiDAR & SAR

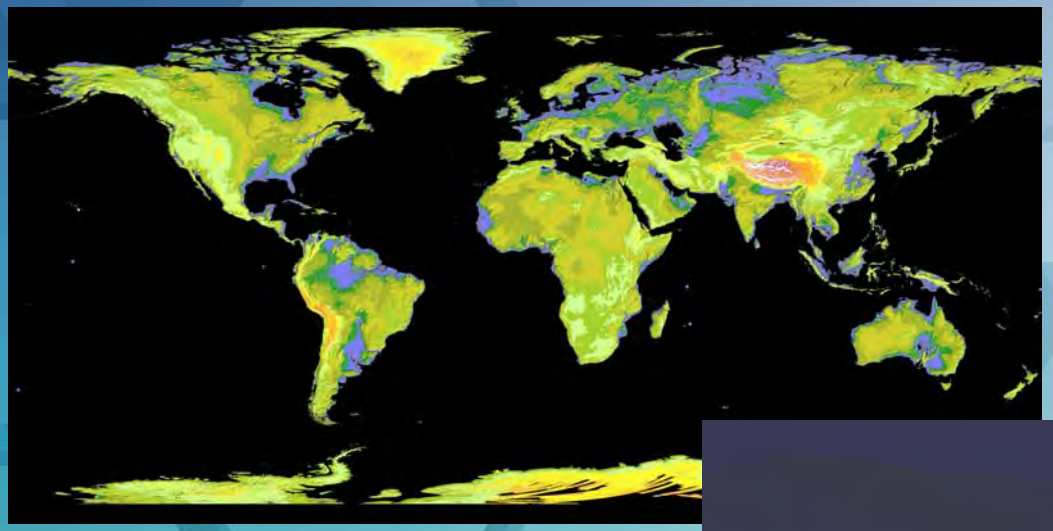
- **The vertical and horizontal distribution of plant material in a forested ecosystem is a driver of fire spread.**
- **Canopy structure influences fire dynamics directly as fuel and indirectly through its influence on other variables in the fire environment, like fuel moisture below the canopy.**
- **Synthetic Aperture Radar (SAR) and Airborne Light Detection and Ranging (LiDAR) data (such as GEDI on the ISS) can assess canopy structure over large areas.**



Lidar points show trees in the Sierra National Forest, California. Image Credit: Keley and Tommaso, 2015

Topography and Elevation

- **Topography:** Relief and landforms of the Earth's surface
- Factors that affect fire:
  - Elevation, Slope, Aspect, Topographic features (canyons, ridges, bowls, etc.)
- **Elevation Impacts:**
  - Amount and timing of precipitation
  - Wind exposure
  - Seasonal drying of fuels
  - Lightning strikes
- Examples: Lower elevations tend to dry out faster, thus they experience increased fire spread



Global Digital Elevation Model via ASTER. Image Credit: NASA

Landsat and Sentinel-2

- **Landsat**
  - First Landsat launched in 1972
  - Landsat 8 launched in 2013
  - Multispectral, 30-meter pixels, 15-meter panchromatic band, 16-day revisit
- **Sentinel-2**
  - Launched in June 2015
  - Multispectral, 10, 20, and 60-meter pixel bands, 2-5-day revisit

- **Vegetation-Based Fire Applications:**
  - Vegetation Extent and Type: Land cover classification
  - Vegetation Stage and Health: Variety of vegetation indices, including NDVI, EVI, SAVI
  - Vegetation Moisture: NDWI

Image Credits: USGS, ESA

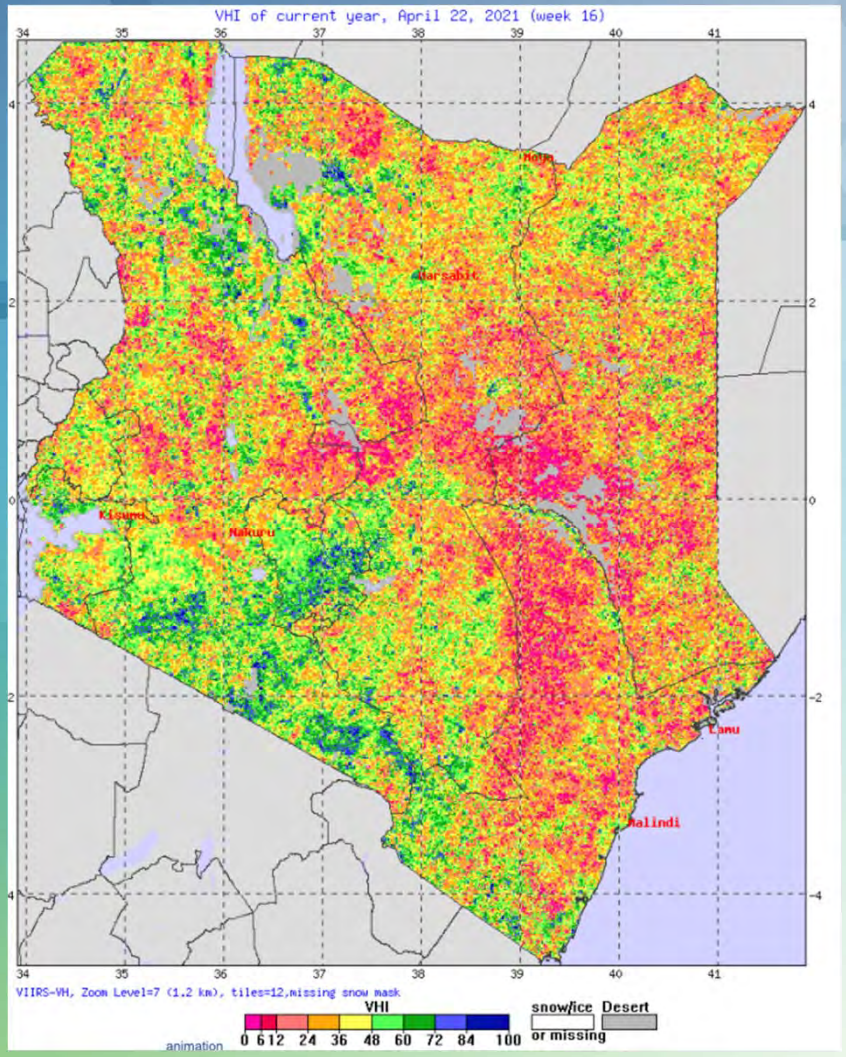
MODIS

- **Vegetation-Based Fire Applications:**
  - Vegetation Extent and Type: Land cover classification
  - Vegetation Stage and Health: NDVI, EVI, High Temporal Resolution Phenology
- **Spatial Resolution:**
  - 250 m, 500 m, 1 km
- **Temporal Resolution:**
  - Daily, 8-day, 16-day, monthly, quarterly, yearly
  - 2000–Present
- **Spectral Coverage:**
  - 36 bands

Time lapse of MODIS NDVI in Africa.
Image Credit: Google Earth Engine Developers

Visible Infrared Imaging Radiometer Suite (VIIRS)

- **Vegetation-Based Fire Applications:**
  - **Vegetation Stage: VIIRS Vegetation Index include NDVI and EVI**
  - **Vegetation Health: VIIRS Vegetation Health product includes Vegetation Condition Index, Temperature Condition Index, and Vegetation Health Index**
- **Launched in 2011 (on Suomi-NPP) and in ; collects visible and infrared imagery**
- **Daily temporal resolution and global coverage**
- **Spatial Resolution:**
  - **5 high resolution bands: 375 m**
  - **16 moderate resolution bands: 750 m**



VIIRS Vegetation Health Index map of Kenya (April 22, 2021).
Image Credit: NOAA NESDIS

Soil Moisture Active Passive (SMAP)

- **Vegetation-Based Fire Applications:**
  - Vegetation Moisture: Soil moisture acts as a proxy for vegetation moisture and evaporative stress.
  - Drought information can also identify areas with dry fuel.
- Measures the moisture in the top 5 cm of the soil globally every 3 days
- Launched in January 2015

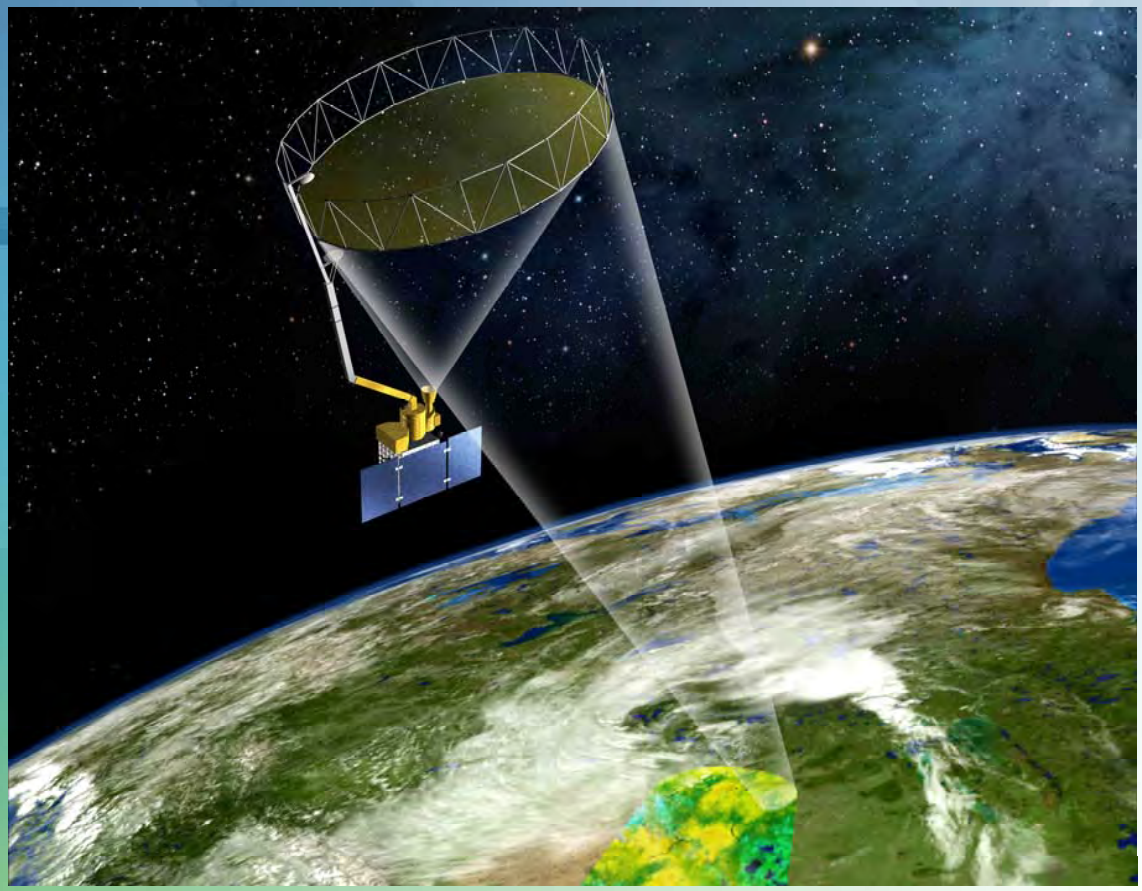
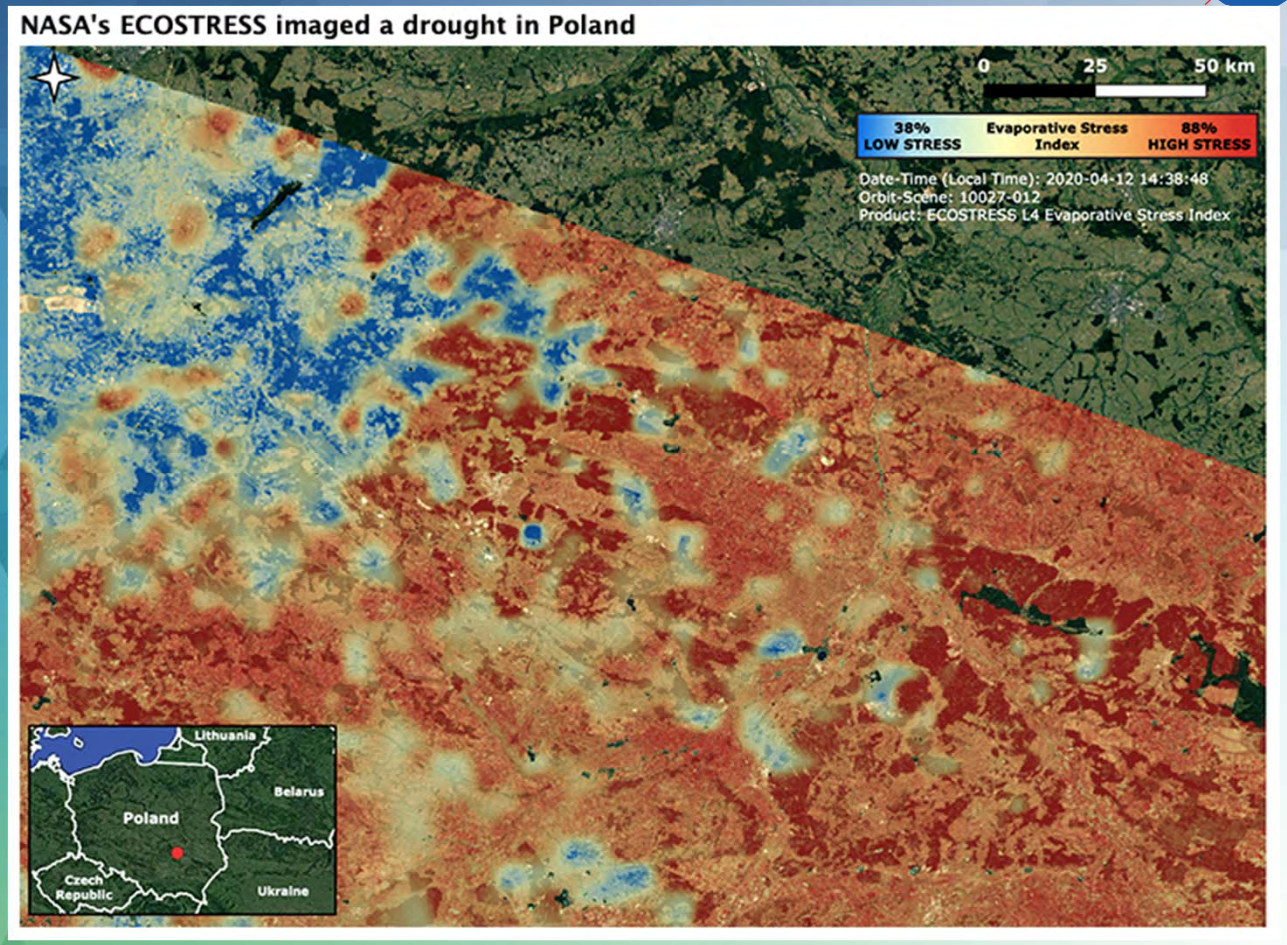


Image Credit: NASA

ECOSTRESS

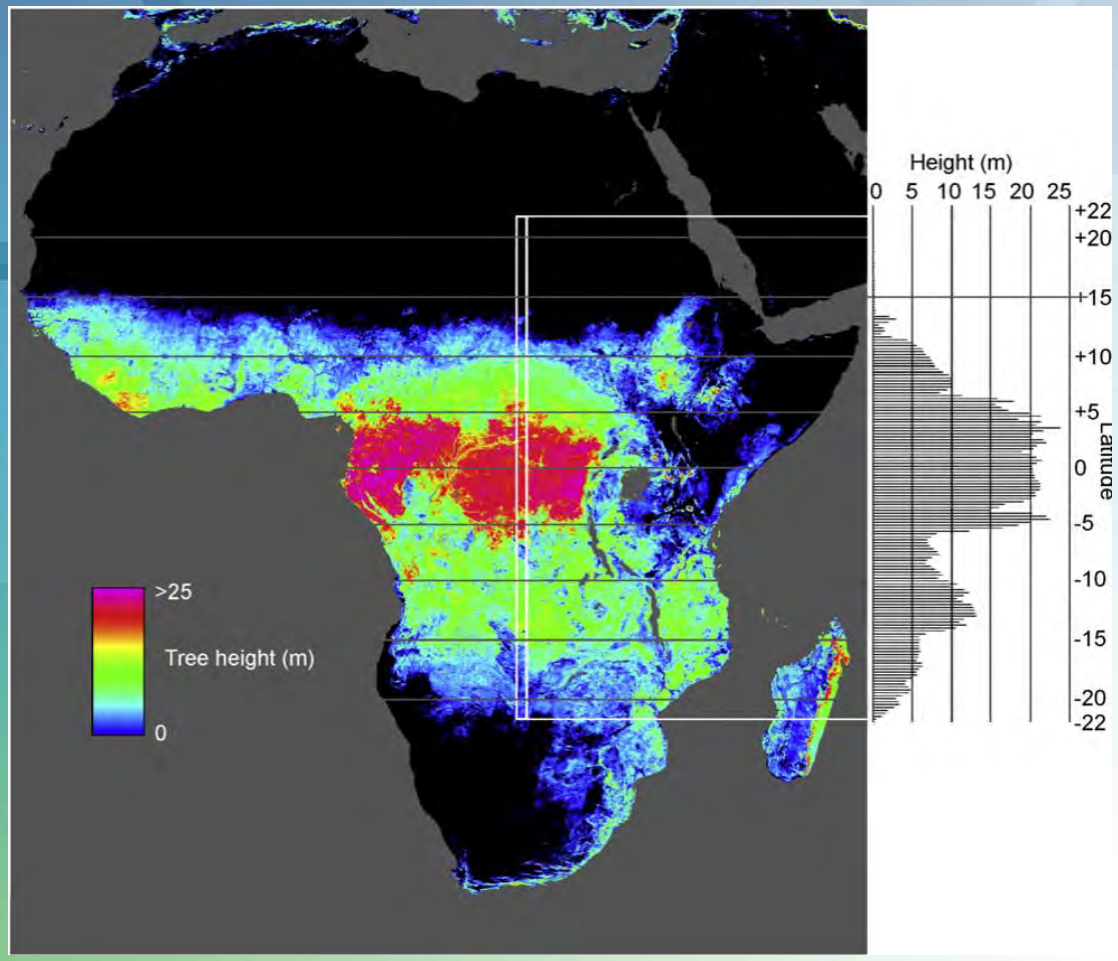
- **Vegetation-Based Fire Applications:**
  - Vegetation Moisture: Evaporative stress due to temperature
- Data from Aug 2018-Present
- Spatial resolution of 70 m
- Spectral Resolution:
  - 6 bands (160-1200 nm)
- Range:
  - 53.6° N latitude to 53.6° S latitude



Vegetation stress measurement in Poland using the ECOSTRESS Evaporative Stress Index. Vegetation under stress due to drought is more susceptible to ignition and sustained burning.
Image Credit: NASA JPL

Global Ecosystem Dynamics Investigation (GEDI)

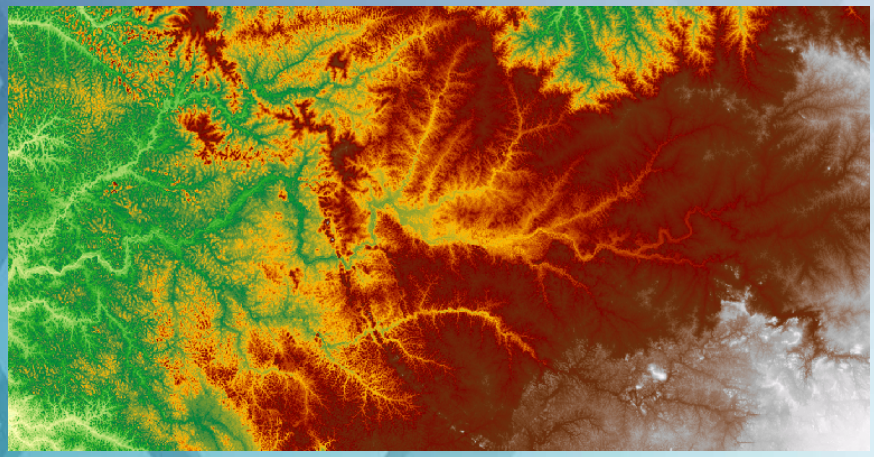
- **Vegetation-Based Fire Applications:**
  - Vegetation Structure: Canopy height metrics and 3D structure data for fuel load estimation and characterization
  - Topography: Surface altimetry
- High resolution laser ranging (LiDAR) of Earth's forests and topography, launched in April 2019
- 3 lasers, 8 data tracks, 25 m spatial footprint



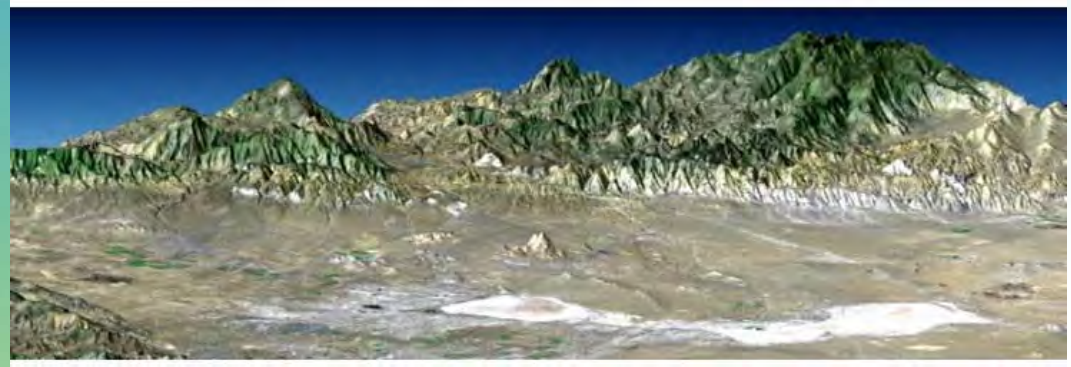
GEDI-derived tree height map for Africa.
Image Credit: GEDI

Shuttle Radar Topography Mission (SRTM)

- **Vegetation-Based Fire Applications:**
  - Topography: DEM data includes slope, aspect, elevation, and topographic feature data useful in the assessment of physical geography that influences fire risk
- Topographic (elevation) data of Earth's surface, SRTM used the technique of interferometry flown onboard the Space Shuttle Endeavour
- C-band and X-band, 30 m and 90 m spatial resolution



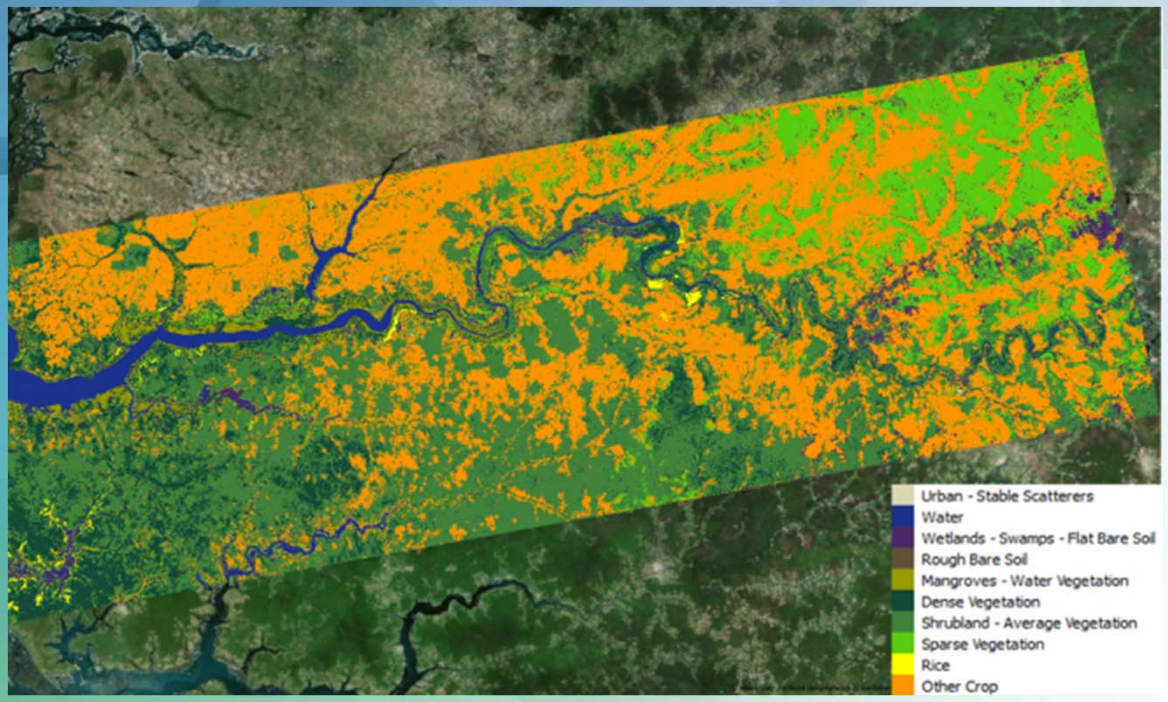
A sample elevation map of Central Africa at 90m spatial resolution (Tile 42_12).
Image Credit: ICGIAR CSI



Perspective with Landsat Overlay: Antelope Valley, California.
Image Credit: NASA

Sentinel-1 SAR

- **Vegetation-Based Fire Applications:**
  - Vegetation Type and Extent: Land classification, fuels mapping
  - Vegetation Structure: Density and height
  - Vegetation Moisture: Fuel moisture content and dryness
- European Radar Observatory for the Copernicus joint initiative of the European Commission and the European Space Agency, launched in April 2014
- C-band SAR data, 12-day revisit, Resolution: 5 x 20 meters



Sentinel-1 swath land cover assessment of Gambia study area.
Image Credit: ERMES

Satellite/Sensor Supporting Veg-based Fire Applications

Satellite/Sensor	Vegetation-Based Fire Applications	Data Products
Landsat	Land Class, Vegetation Indices, Moisture	Imagery, NDVI, EVI, SAVI, NDWI
Sentinel-2	Land Class, Vegetation Indices, Moisture	Imagery, NDVI
MODIS	Land Class, Vegetation Indices	Imagery, NDVI & EVI
VIIRS	Vegetation Indices	Imagery, Vegetation Health
SMAP	Soil Moisture	Soil Moisture
ECOSTRESS	Moisture, Evaporative Stress	Thermal Data, ESI Documentation
EO-1 Hyperion	Land Class, Dry Matter Content	Hyperspectral Imagery
AVIRIS	Land Class, Dry Matter Content	Hyperspectral Imagery
GEDI	Vegetation Structure	LiDAR Data
SRTM	Topography	Topography (DEM)
Sentinel-1	Land Class, Structure, Moisture	Synthetic Aperture Radar Data
ALOS PALSAR	Structure, Topography	Synthetic Aperture Radar Data

***This is not an inclusive list of all satellites/sensors useful for vegetation-based fire applications, and the suggested data products are just a sample of what is available for each satellite/sensor.**

ACTIVE FIRE DETECTION

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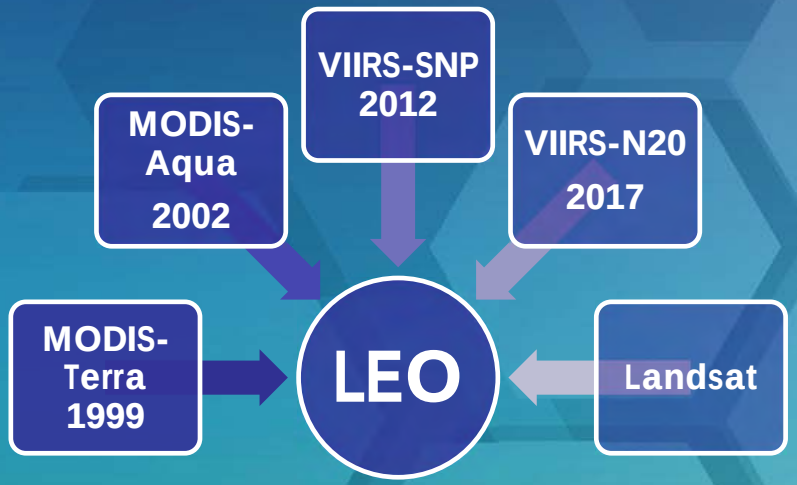
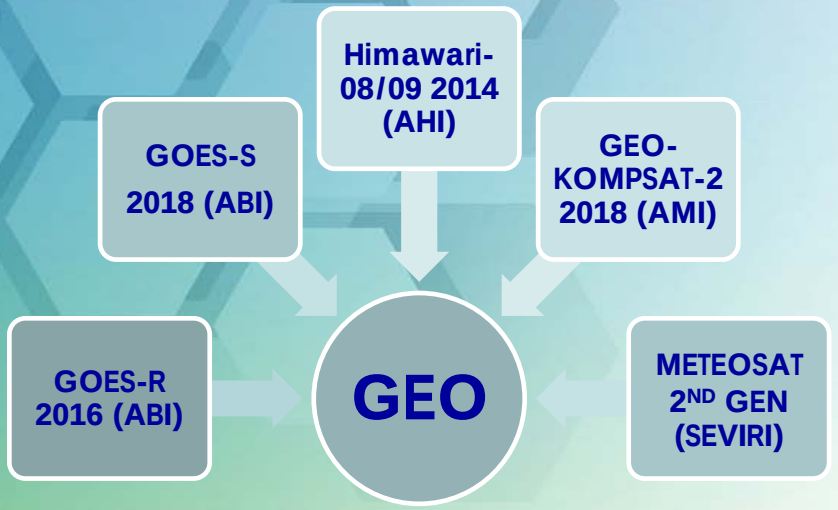
2 June 2021

Satellites and Sensors for Fire Detection



Global Coverage, typically twice per 24 hours



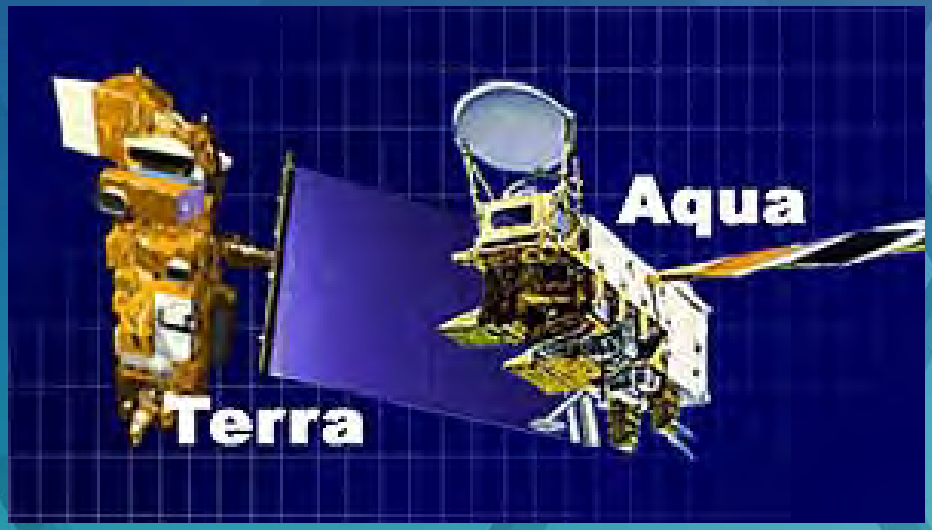
Regional Coverage, minutes to hours

LEO – Low Earth Orbit
GEO – Geostationary
ABI – Advanced Baseline Imager

Several Satellite Instruments For Fire Detections

	MODIS	VIIRS	ABI
Platform	Terra , Aqua	Suomi NPP, NOAA-20	GOES 16, GOES 17
Launched	Dec 1999, May 2002	Oct 2011, Nov 2017	Nov 2016, Mar 2018
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

Earth Observing Systems For Active Fire Detection



MODIS on AQUA & TERRA

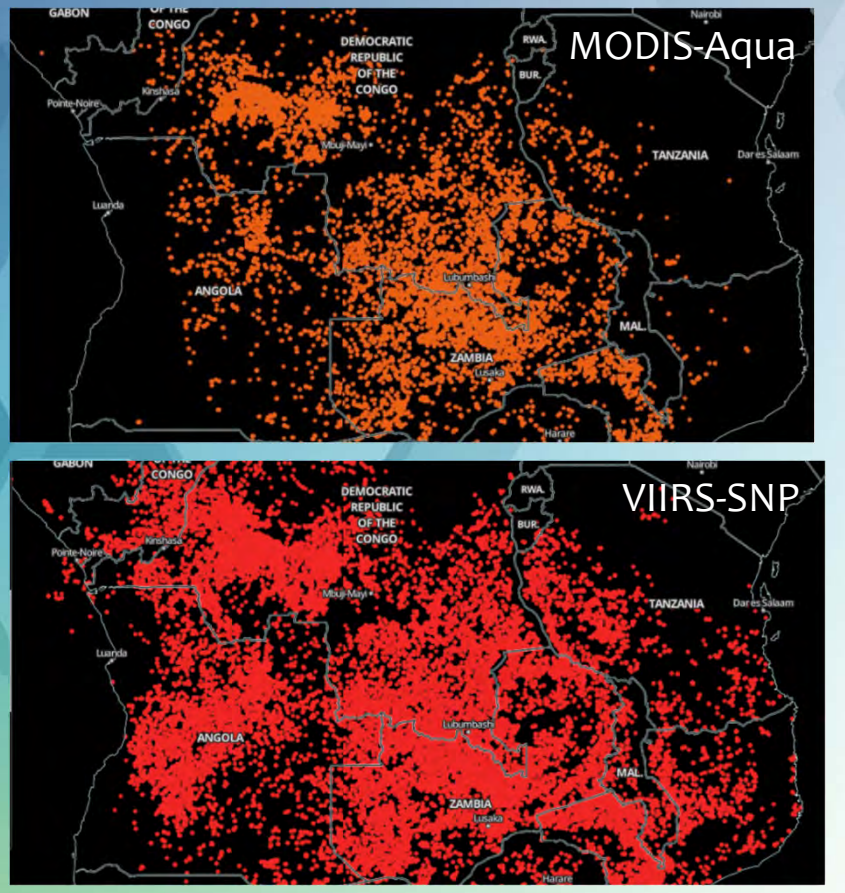
- **Orbital Pass Time:** 10:30 AM / PM (TERRA) equatorial overpass time; or 1:30 PM / AM (AQUA);
- **Cross track resolution:** 2330 km.
- **TIR band spatial res.:** 1 km (1000m)

VIIRS on SUOMI NPP & NOAA-20

- **Orbital Pass Time:** 1:30 AM / PM & ~12: 40 AM / PM
- **Cross Track Resolution:** 3060 km
- **TIR Band Spatial Resolution:** M-bands 750m; I-Bands: 375m

Fire Detection From MODIS & VIIRS

- **Fire Detection:**
  - Pixel flagged as containing one or more fires
  - MODIS: 1 km
  - VIIRS: 750 m and 375 m
  - ABI (GOES-R/S): 2 km
  - Can also detect volcanic signatures
  - VIIRS Detects 3-4x more fires than MODIS globally.



August 12, 2020, NASA Worldview

MODIS C6 Fire Detection Algorithm

Table 2: MODIS channels used for active-fire detection and characterization.

Channel	Central wavelength (μm)	Purpose
1	0.65	Sun glint and coastal false alarm rejection; cloud masking.
2	0.86	Bright surface, sun glint, and coastal false alarm rejection; cloud masking.
7	2.1	Sun glint and coastal false alarm rejection.
21	3.96	High-range channel for fire detection and characterization.
22	3.96	Low-range channel for fire detection and characterization.
31	11.0	Fire detection, cloud masking.
32	12.0	Cloud masking.

- Potential fire pixel is identified when:
  - 0.86 reflectance < 0.35
  - BT4 > BT4* (where 300 K ≤ BT4* ≤ 330 K)
  - BT4 – BT11 > ΔBT* (where 10 K ≤ ΔBT* ≤ 35 K)
- Otherwise flagged as a non-fire pixel

http://modis-fire.umd.edu/pages/manuals.php

VIIRS Fire Detection Algorithm

Channel	Spatial Resolution (m)	Spectral resolution (µm)	Primary Use
I1	375	0.60 – 0.68	Cloud & water classification
I2	375	0.846 – 0.885	Cloud & water classification
I3	375	1.58 – 1.64	Water classification
I4	375	3.55 – 3.93	Fire detection
I5	375	10.5 – 12.4	Fire detection & cloud classification
M13*	750	3.973 – 4.128	FRP retrieval, fire detection over water and across the South Atlantic magnetic anomaly region

https://viirsland.gsfc.nasa.gov/PDF/VIIRS_activefire_375m_ATBD.pdf

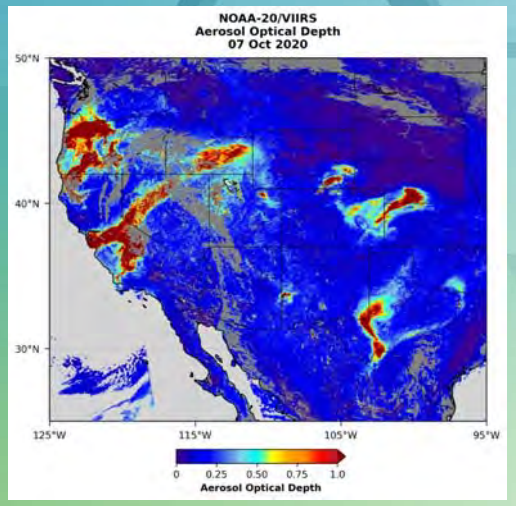
Satellites for Air Quality Data

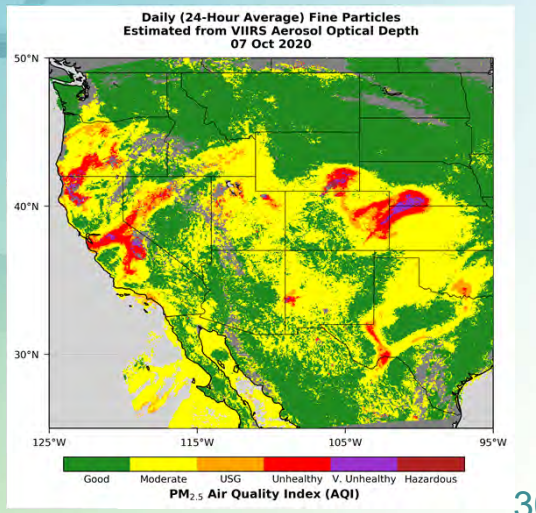
- MODIS (Terra and Aqua)
  - AOD: Columnar Aerosol Loading – Can be used to estimate $PM_{2.5}$ or PM_{10}
- MISR (Terra)
  - Columnar Aerosol Loading in different particle size bins
  - In some cases, Aerosol Heights
- OMI (Aura), OMPS, TROPOMI
  - Absorbing Aerosols, Total Aerosols
  - Trace Gases
  - Aerosol Height
- VIIRS (NPP, JPSS)
  - Aerosol Optical Depth
  - Aerosol Type

Geostationary Sensors (GOES-R, S, Himawari, KOMPSAT-2, GEMS, GOCI, INSAT)

Aerosol Optical Depth
Smoke Mask
Regional PM2.5 (Research)

CALIPSO, POLDER, etc. and more coming (i.e., MAIA, TEMPO, Sentinel-4)





POST-FIRE ASSESSMENT

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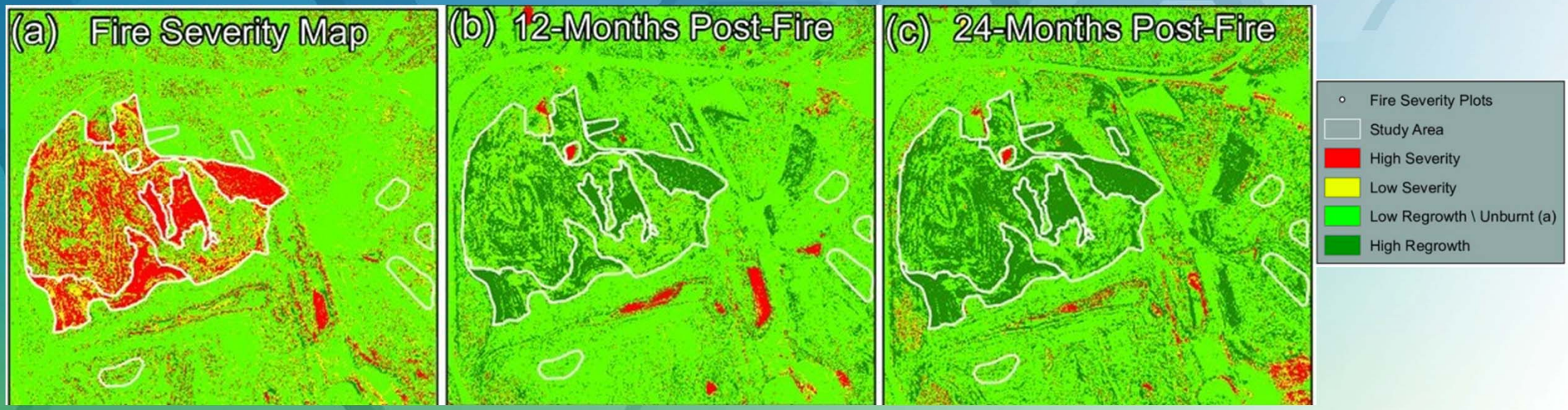
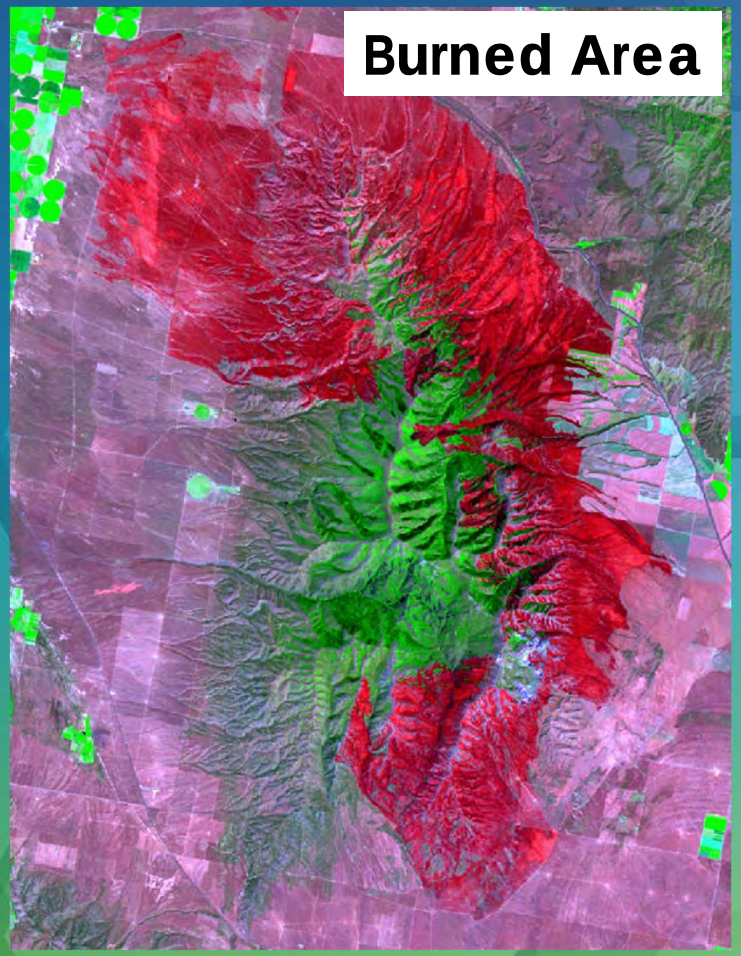
Post-Fire Recovery / Rehabilitation Remote Sensing Support

- Vegetation indices and land classifications use imagery to assess vegetation regeneration and condition at various post-fire intervals



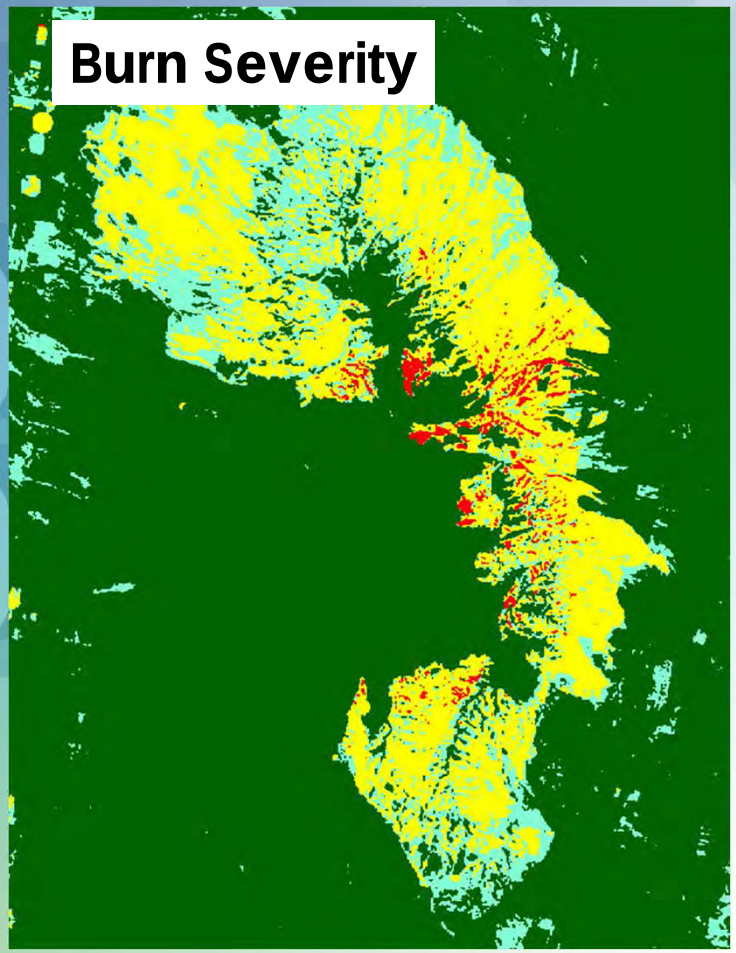
Differenced Normalized Difference Vegetation Index (dNDVI) analysis of WorldView-3 images showing: (a) fire severity map; (b) fire recovery 12-months post-fire; and (c) fire recovery 24-months post-fire at a coal mine rehabilitation in semi-arid Central Queensland, Australia.
Credit: McKenna, Phinn & Erskine, 2018

Post Fire Burned Area and Burn Severity Mapping



- Burned area uses imagery to assess the extent of impacts on vegetation for a particular fire event

- Burn severity compares burned area information to pre-fire imagery to assess relative magnitude of burn impacts



Normalized Burn Ratio: Landsat

- Derived from surface reflectance of the Landsat series (4-5 TM, 7 ETM+, and 8 OLI)
- 30m resolution NBR data product ordered from:
  - https://espa.cr.usgs.gov/
- Landsat 4-7, NBR = (Band 4 – Band 7) / (Band 4 + Band 7)
- Landsat 8, NBR = (Band 5 – Band 7) / (Band 5 + Band 7)
- Data specifications:
  - https://www.usgs.gov/core-science-systems/nli/landsat/landsat-normalized-burn-ratio

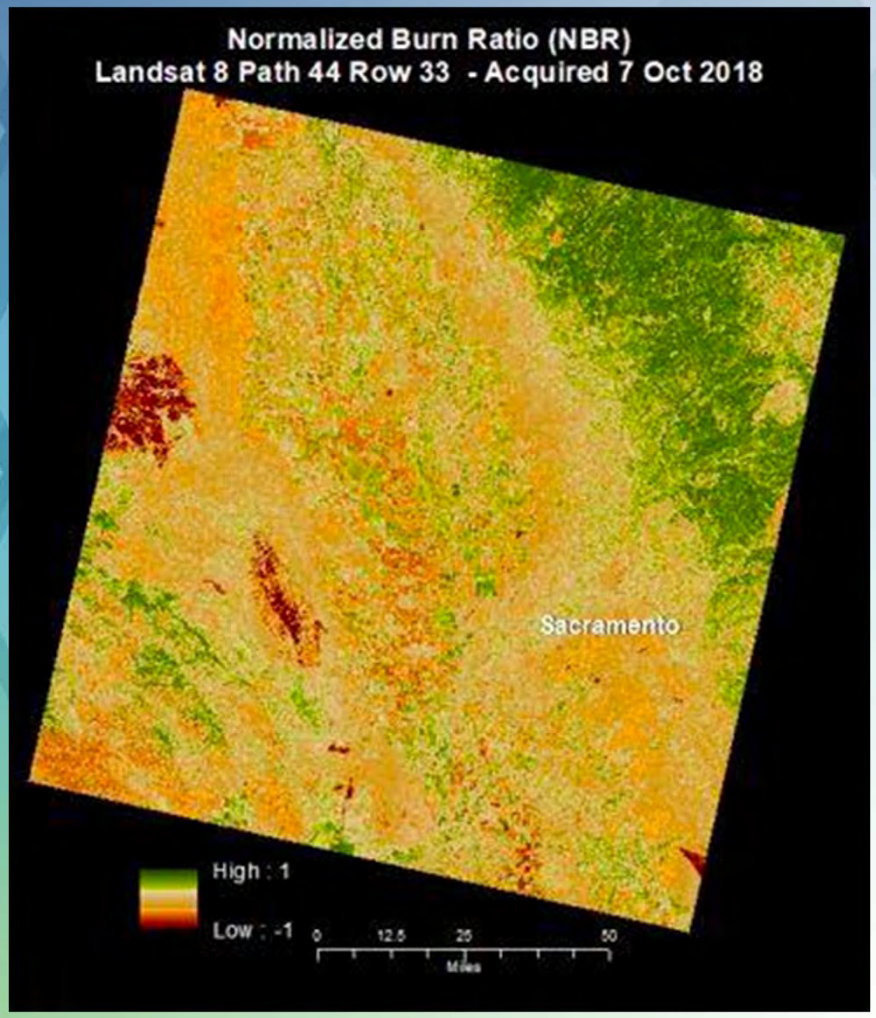
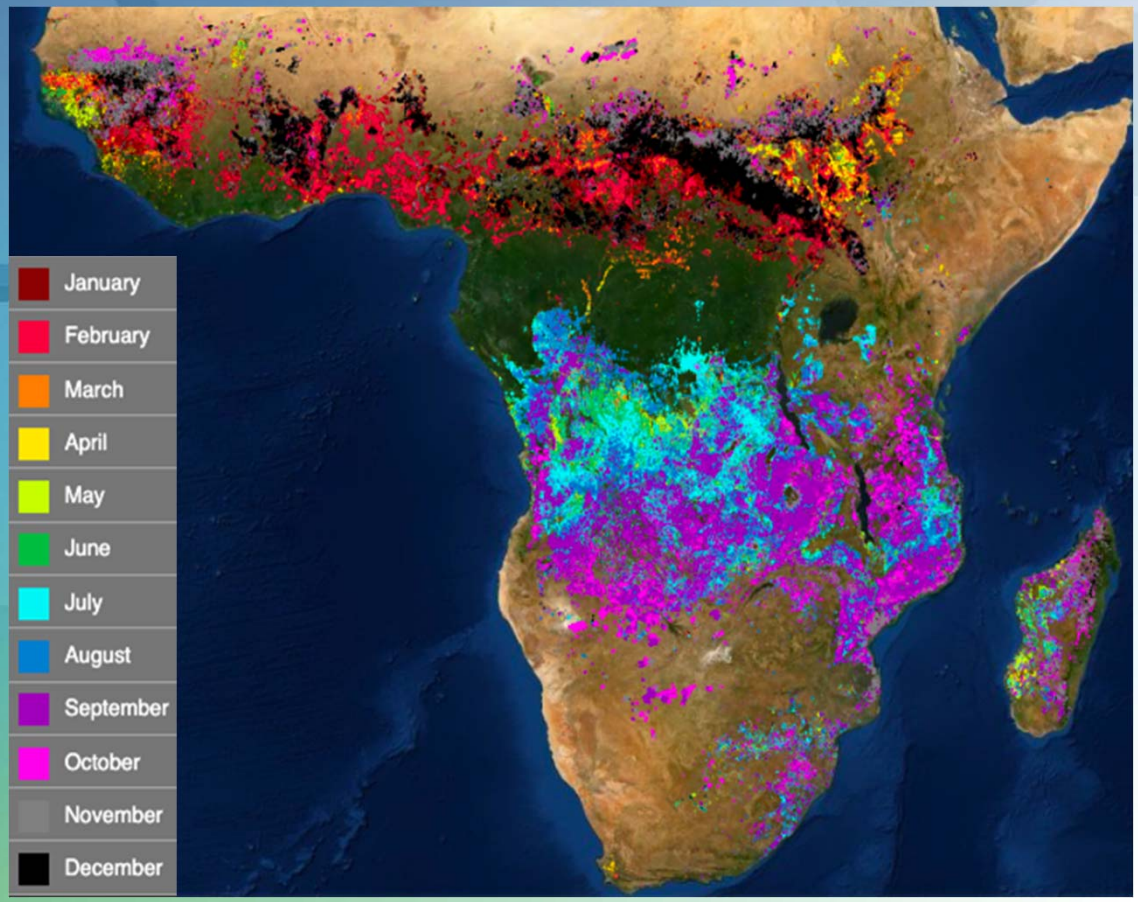


Image Credit: USGS

Burned Area: MODIS

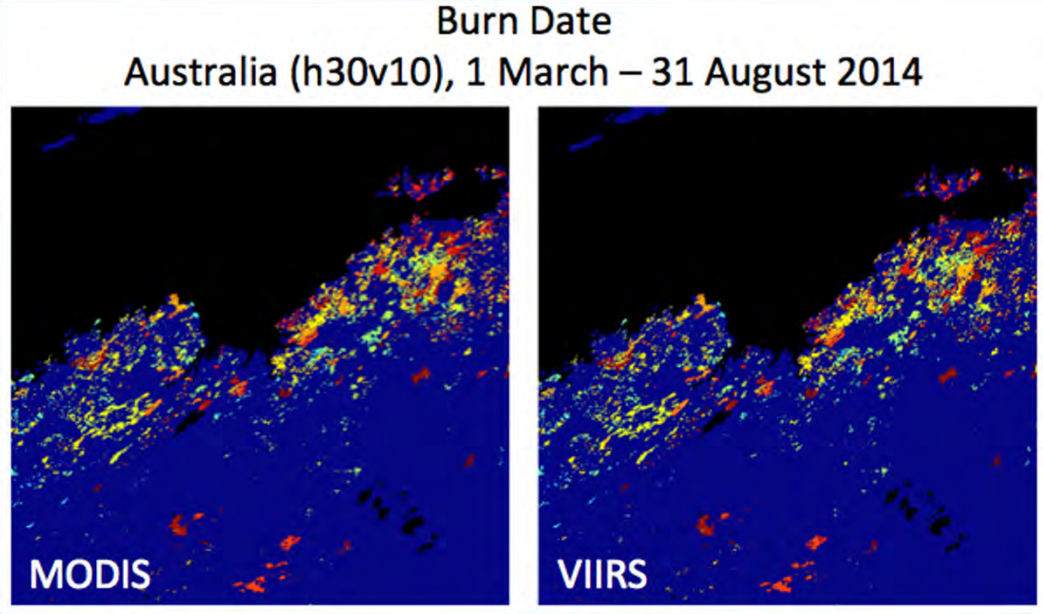
- Takes advantage of fire related changes to the landscape, like deposits of charcoal and ash, removal of vegetation, and alteration of the vegetation structure
- The high temporal resolution of MODIS means this data can detect occurrence of rapid changes in daily surface reflectance time series data and map the spatial extent of burned area for recent and previous fires
- Terra and Aqua combined MCD64A1 Version 6 Burned Area data product is a monthly, global gridded 500m product containing per-pixel burned area



MODIS burned area mapped for 2020 by month in sub-Saharan Africa.
Image Credit: NASA FIRMS

Burned Area: VIIRS

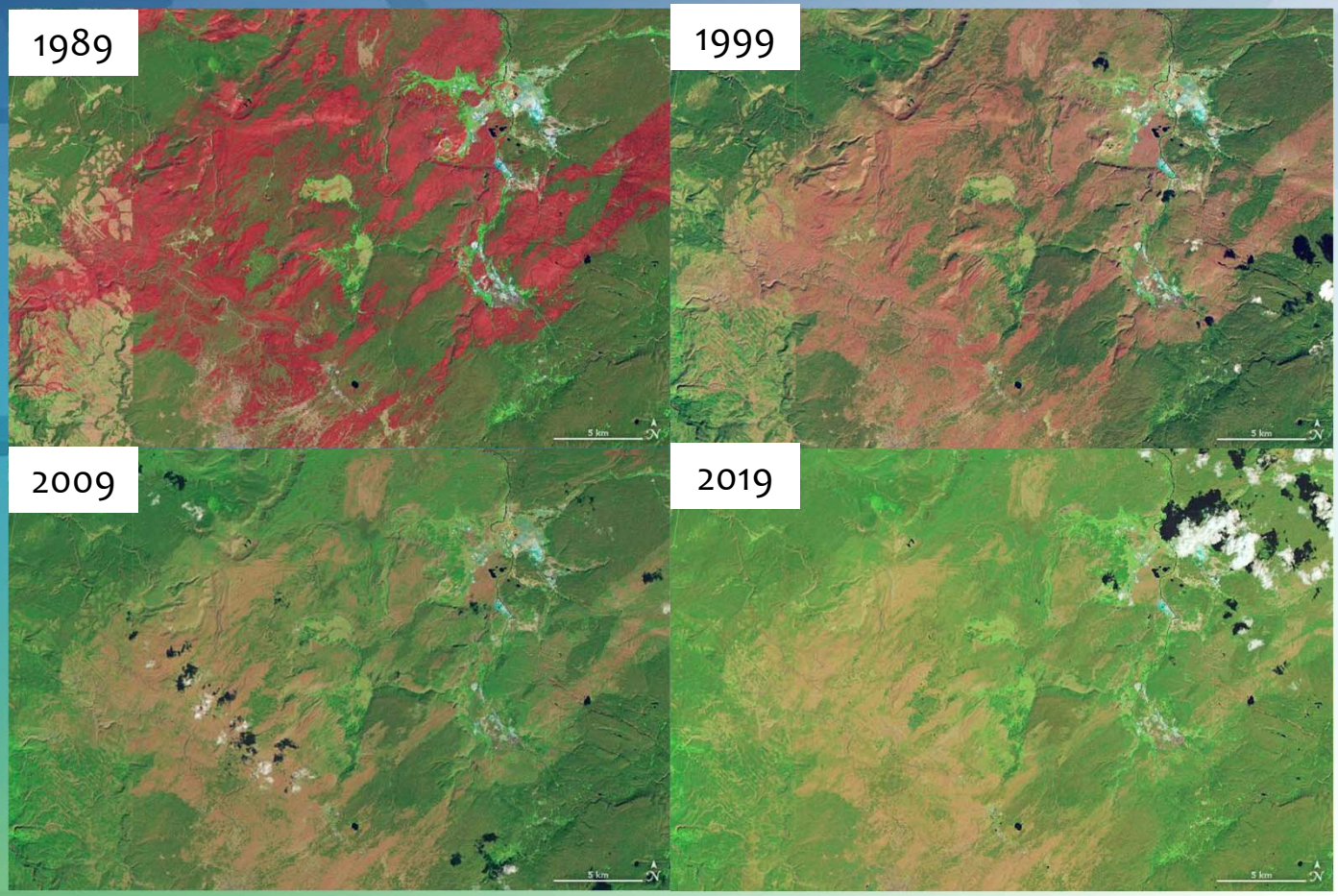
- The VNP64A1 data product is designed similarly to the MODIS burned area product to promote the continuity of the Earth Observation System (EOS) mission
- Provisional data released on a limited basis due to issues identifying burned area at the edges of inland water bodies and at high latitudes, version 2 of this data product will address these issues
- Monthly, global gridded 500 m product containing per-pixel burned area and quality information



VIIRS burned area products will provide continuity with MODIS burned area products.
Image Credit: NASA

Post-Fire Vegetation Regrowth: NDVI

- In the summer of 1988, lightning- and human-ignited fires consumed vast stretches of Yellowstone National Park
- 793,000 of the park's 2,221,800 acres burned
- Landsat 5 and 8 Normalized Difference Vegetation Index (NDVI) estimates show the slow recovery of vegetation over the burn scar



NDVI estimates over the course of 30 years show increase in greenness, indicating vegetation regrowth across the burn scar.
Image Credit: NASA

FIRE WEB MAP SERVICES

Trans-Atlantic Training (TAT)

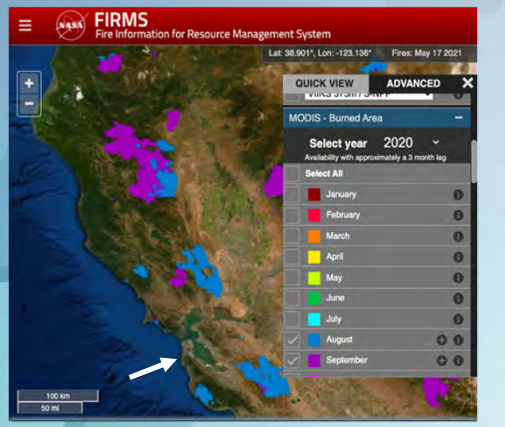
1 June 2021

Global Access Fire Web Map Services

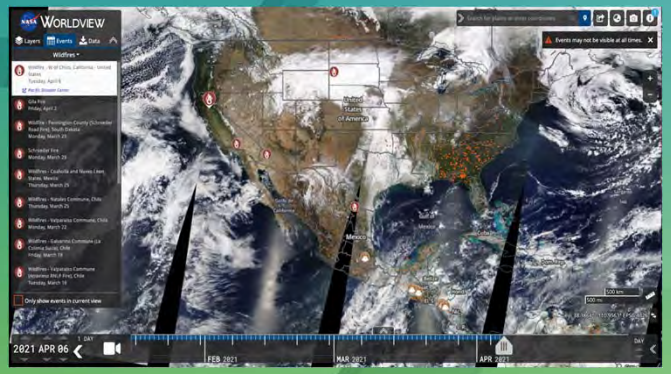
GWIS

NASA / USFS FIRMS US-Canada

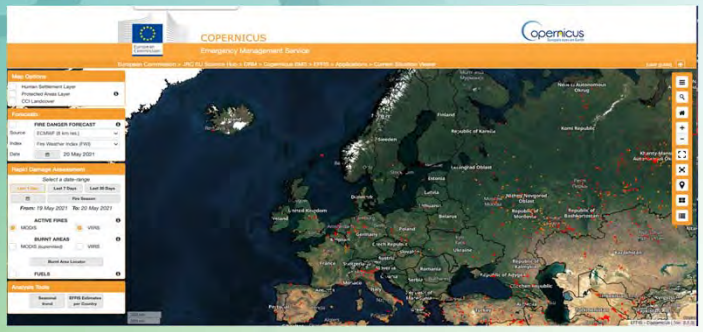
FIRMS



NASA EOSDIS WORLDVIEW



EFFIS

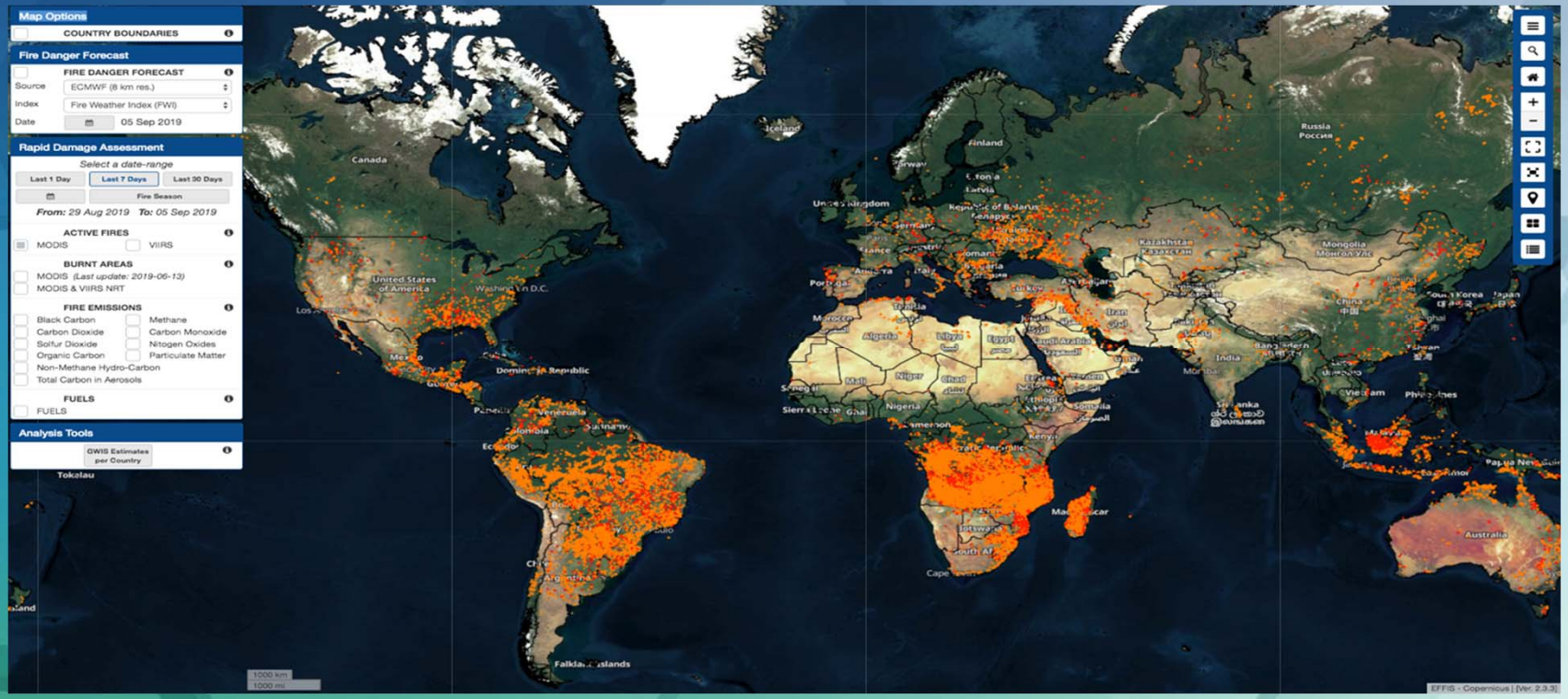


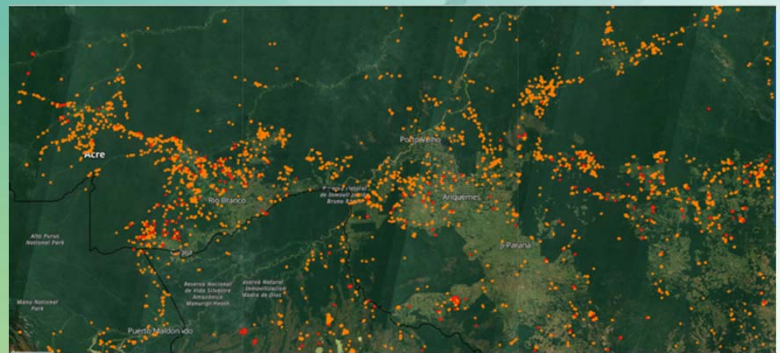
Fire Information for Resource Management System (FIRMS)

- **NASA FIRMS**
  - https://firms2.modaps.eosdis.nasa.gov/
- **Data available globally**
- **MODIS Burned Area Product**
- **Also includes VIIRS and MODIS fire detection and active fire data**
- **Near Real-Time (NRT) data are replaced with standard science quality data as they become available (usually with a 2-3 month lag)**
- **Data download**
  - **https://firms2.modaps.eosdis.nasa.gov/download/**

MODIS burned area displayed for Northern California displaying burned areas in August and September 2020.
Image Credit: FIRMS

Global Wildfire Information System



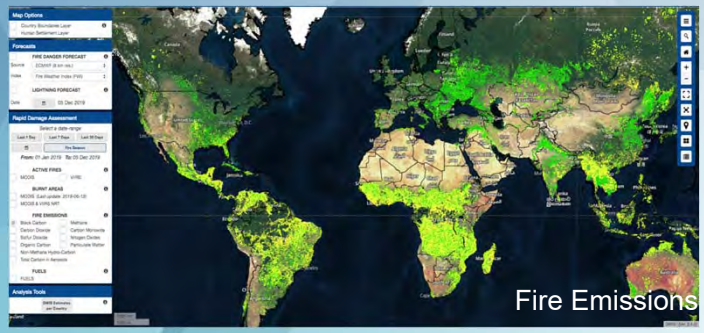


Global Wildfire Information System (GWIS)

GWIS Provides Comprehensive Global WMS and Archival Data

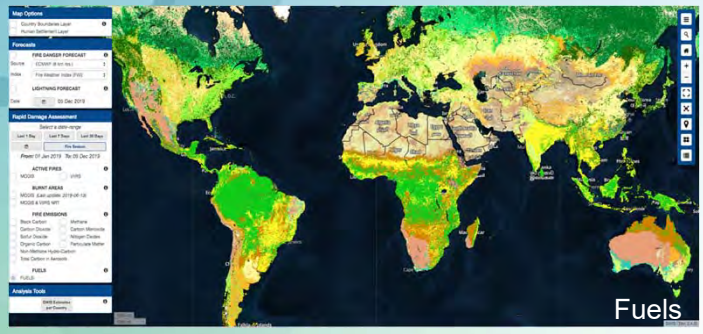

Fire Danger Forecast


Active Fire Detections

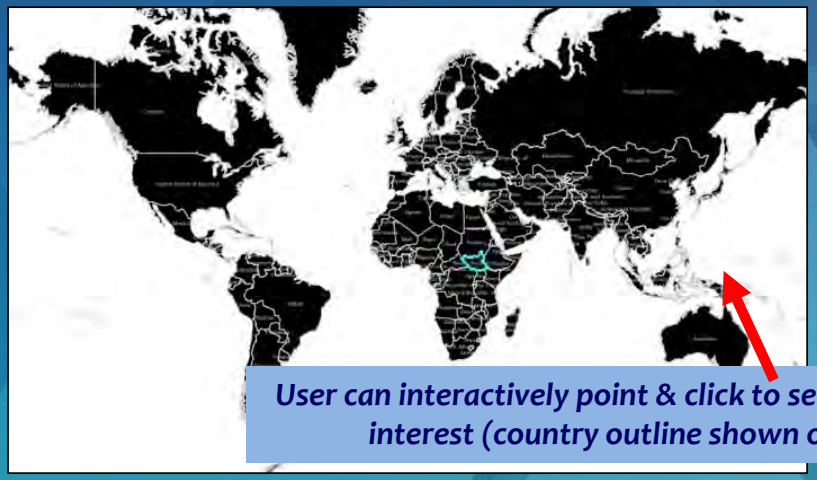

Fire Emissions


Lightning Forecast


Burned Area


Fuels

New NASA Contributions to GEO-GWIS

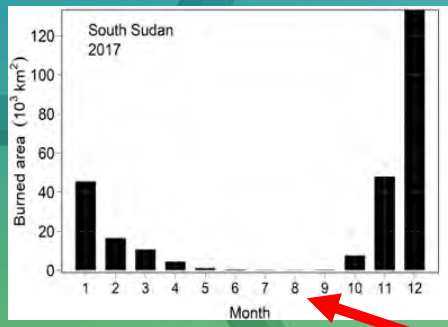


User can interactively point & click to select country of interest (country outline shown on map)

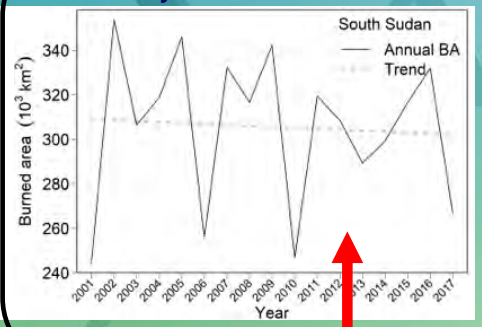
Fire Analysis Portal: South Sudan 2017

This user selected region and analysis year; page spawned as a separate window (a user can spawn many windows e.g. several different years for the same region, e.g. several different regions for the same, e.g. for different regions and years).

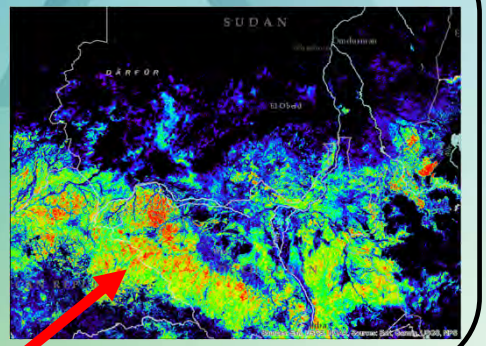
2017 statistics



Multi-year statistics

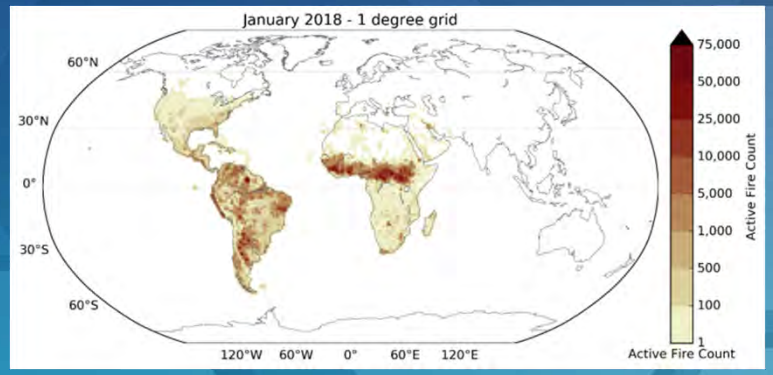


Maps

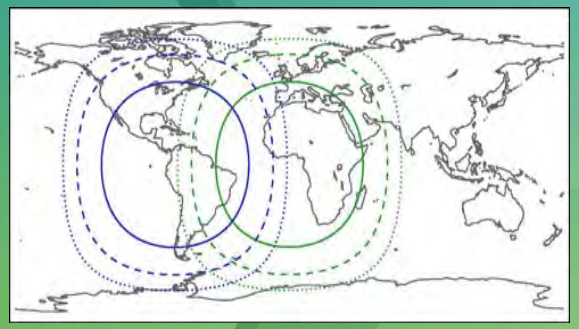


User can interactively select three options; (note, these 3 options graphics should show real results for the selected region and year)

Harmonize Multi-Sensor Global Active Fire Data



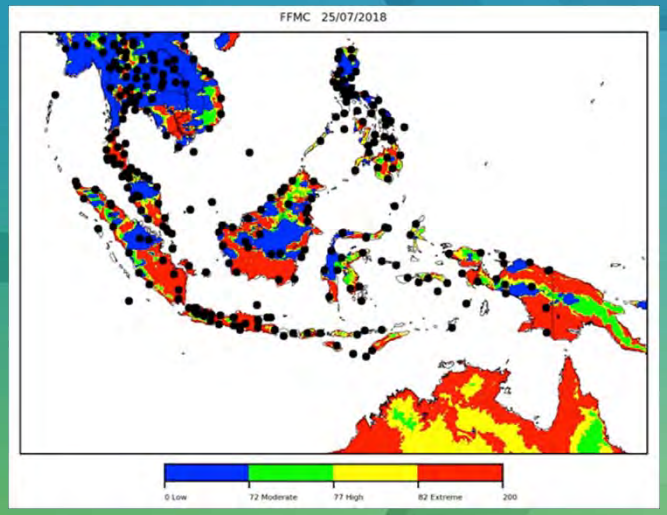
Objective: Reconcile existing geostationary fire products, addressing differences in methodology, and leveraging algorithm development efforts



Augment existing GWIS fire mapping capabilities with the delivery of a harmonized global multi-sensor fire data set

	GOES-16 ABI	MSG SEVIRI
Product	Fire Detection and Characterization (FDC; Schmidt et al., 2012)	Fire Radiative Power (FRP-PIXEL; Wooster et al., 2015)
Spatial Resolution	2km at nadir	3km at nadir
Temporal Resolution	Full Disk: 15 minutes CONUS: 5 minutes	Full Disk: 15 minutes Europe: 5 minutes
Active Fire Product Values	10(30) = processed 11(31) = saturated 12(32) = cloudy 13(33) = high prob. 14(34) = med prob. 15(35) = low prob.	Fire Confidence (0 – 100%)

GWIS Fire Danger Rating Enhancements



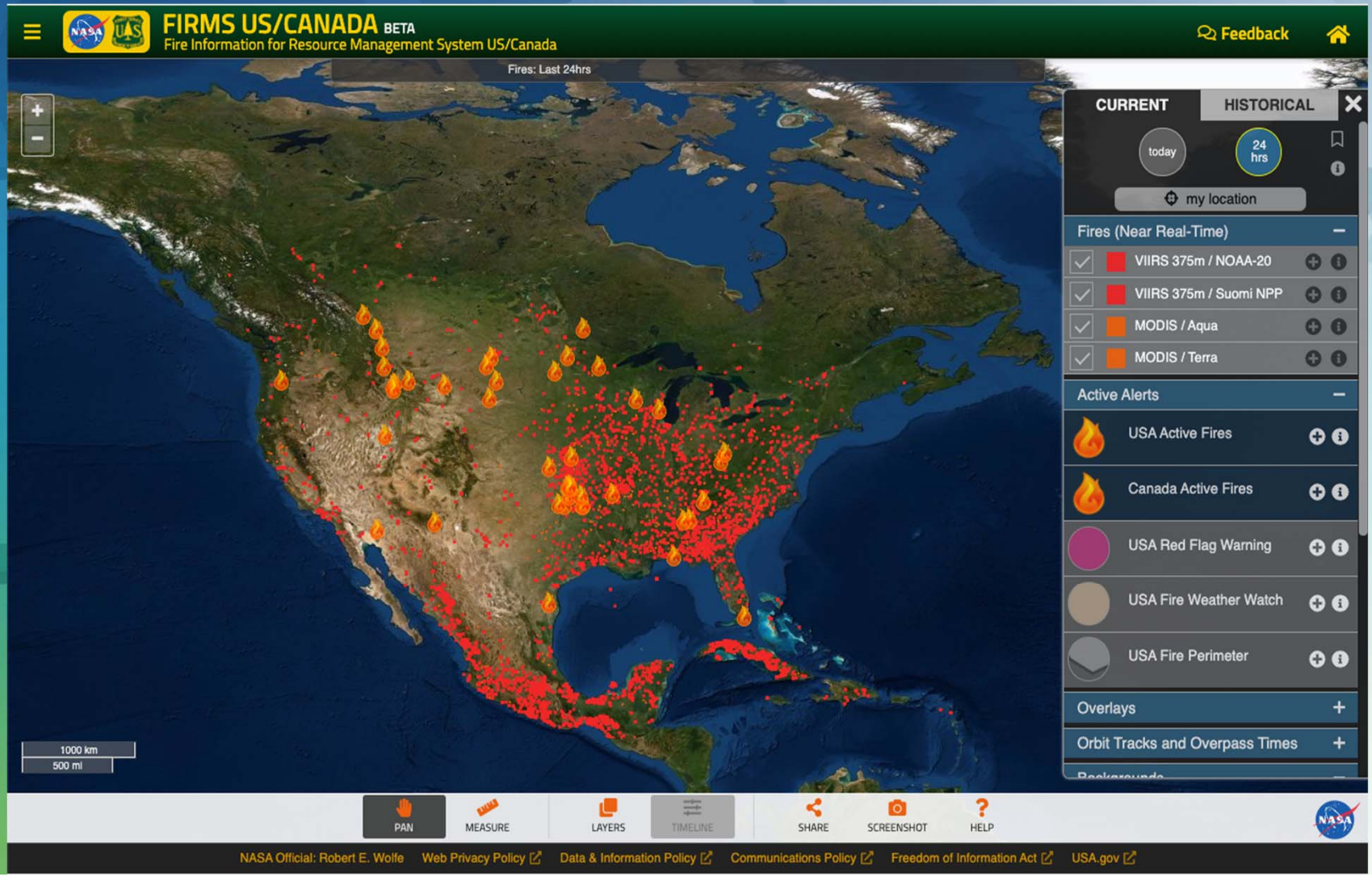
Preliminary Fire Weather Index Map calculated for July 25, 2018

Goals:

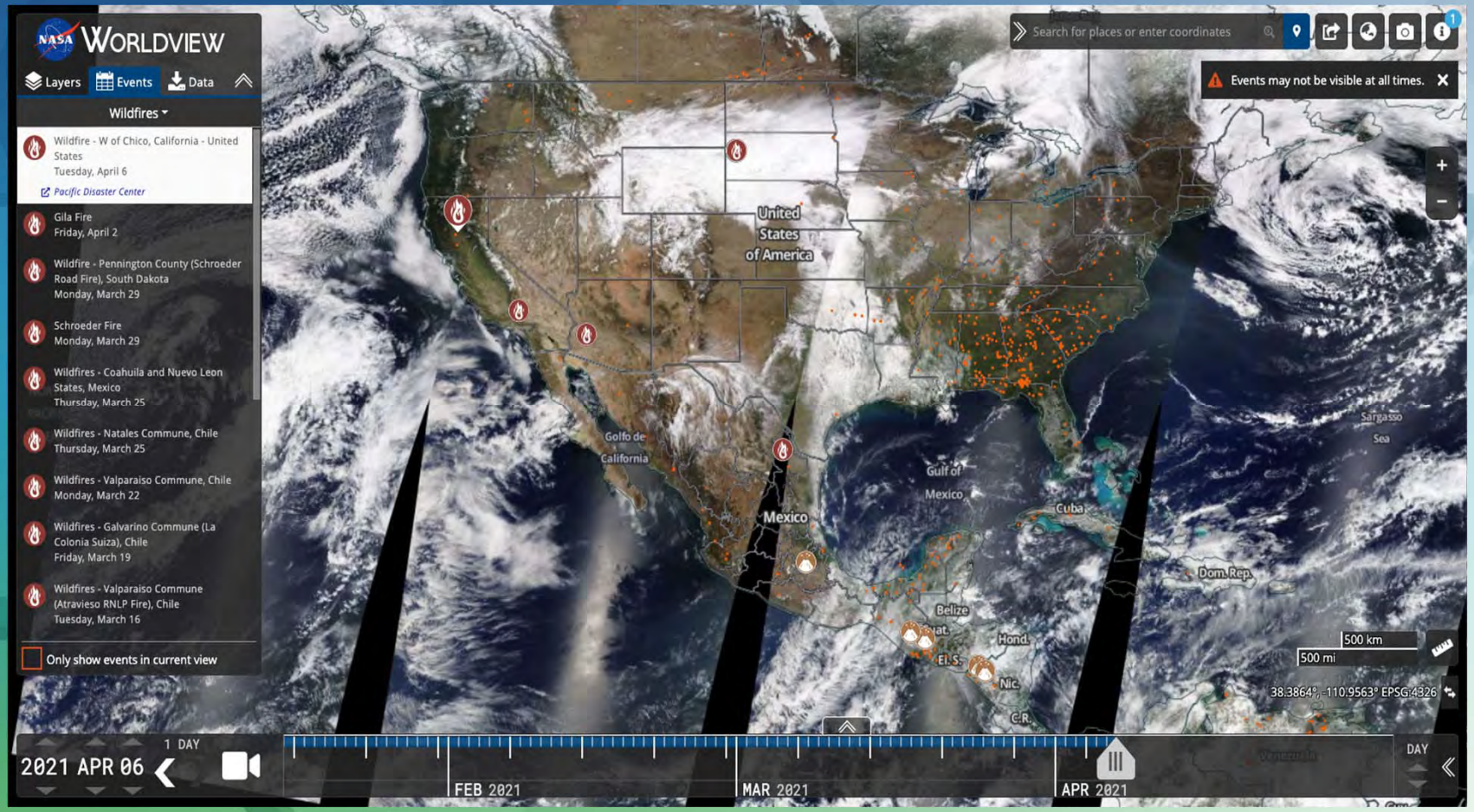
- ***Enhance the NASA Global Fire Weather Database (GFWED) with short-term fire weather forecasts;***
- ***Contribute selected GFWED data to GWIS;***
- ***Improve the Indonesian Fire Danger Rating System using NASA Global Precipitation Measurement mission (GPM) precipitation estimates to enhance fire management decision aids.***

Indonesian Workshop

NASA - USFS FIRMS US / CANADA



NASA EOSDIS Worldview WMS



https://worldview.earthdata.nasa.gov/

NASA ARSET Wildfire Webinar Series

National Aeronautics and Space Administration

Satellite Observations and Tools for Fire Risk, Detection, and Analysis

May 11, 13, 18, 20, 25, & 27, 2021

English Session: 11:00 - 13:00 EDT (UTC-4), Spanish Session: 15:00 - 17:00 EDT (UTC-4)

NASA satellite data are a valuable resource for monitoring and assessing fire risk and the associated impacts on vegetation, soils, and air quality. This 6-part, intermediate training will provide lectures and case studies on the use of satellite remote sensing for fire monitoring pre-, during-, and post-event. Specific topics will include monitoring of weather and climate conditions, fuel characterization, fire risk, smoke detection, fire behavior, and assessing post-fire landscape dynamics such as burn severity and vegetation regrowth.

Part 1: Satellites, Sensors, and Models for Climate and Hydrologic-Based Applications (Pre-Fire)

- Overview of fires, types of fires, and the three components (pre, during, post)
- Weather and climate conditions
- Temperature anomalies
- Soil moisture
- Case Study
- Fire danger rating
- Question & Answer Session

Part 2: Satellites and Sensors for Vegetation-Based Wildfire Applications (Pre-Fire)

- Satellites and sensors for vegetation fire monitoring
- Overview of fire risk and fuels mapping
- Pre-fire landscape monitoring and pre-fire mapping tools
- Demonstration and case study
- Question & Answer Session

Continued on next page

ARSET empowers the global community through remote sensing training.

appliedsciences.nasa.gov/arset

National Aeronautics and Space Administration

Part 3: Satellites and Sensors for Active Fire Monitoring (During-Fire)

- Overview of satellite observations of active fires
- Satellite observations of smoke
- Available sensors
- Available smoke datasets
- NOAA's Smoke Detection Product
- Case Studies
- Question & Answer Session

Part 4: Smoke Modeling and Forecasting (During-Fire)

- Satellite-based emissions datasets
- U.S. - Smoke and air quality forecasting
- Global - Smoke and air quality forecasting
- Case Studies
- Question & Answer Session

Part 5: Satellites, Sensors, and Earth System Models for Climate and Hydrology-Based Applications (Post-Fire)

- Precipitation and Runoff
- Terrain
- Soil Moisture
- Burned Area
- Landslides
- Case Study
- Question & Answer Session

Part 6: Satellites and Sensors for Vegetation-Based Wildfire Applications (Post-Fire)

- Review of the fire lifecycle dynamics
- Burned area and burn severity mapping
- Post-fire vegetation regrowth
- Demonstration and case study
- Question & Answer Session

ARSET empowers the global community through remote sensing training.

appliedsciences.nasa.gov/arset

www.nasa.gov

About NASA ARSET

- *ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.*
- The trainings are:
  - Online and in-person
  - Open to anyone
  - Live, instructor-led or self-guided
  - Tailored to those with a range of experience in remote sensing, from **introductory** to **advanced**

- ARSET offers trainings for:
  - Disasters
  - Health & Air Quality
  - Land Management
  - Water Resources

For more information, visit appliedsciences.nasa.gov/arset

Further Information

appliedsciences.nasa.gov/arset

https://effis.jrc.ec.europa.eu/

https://gwis.jrc.ec.europa.eu

https://firms.modaps.eosdis.nasa.gov/

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