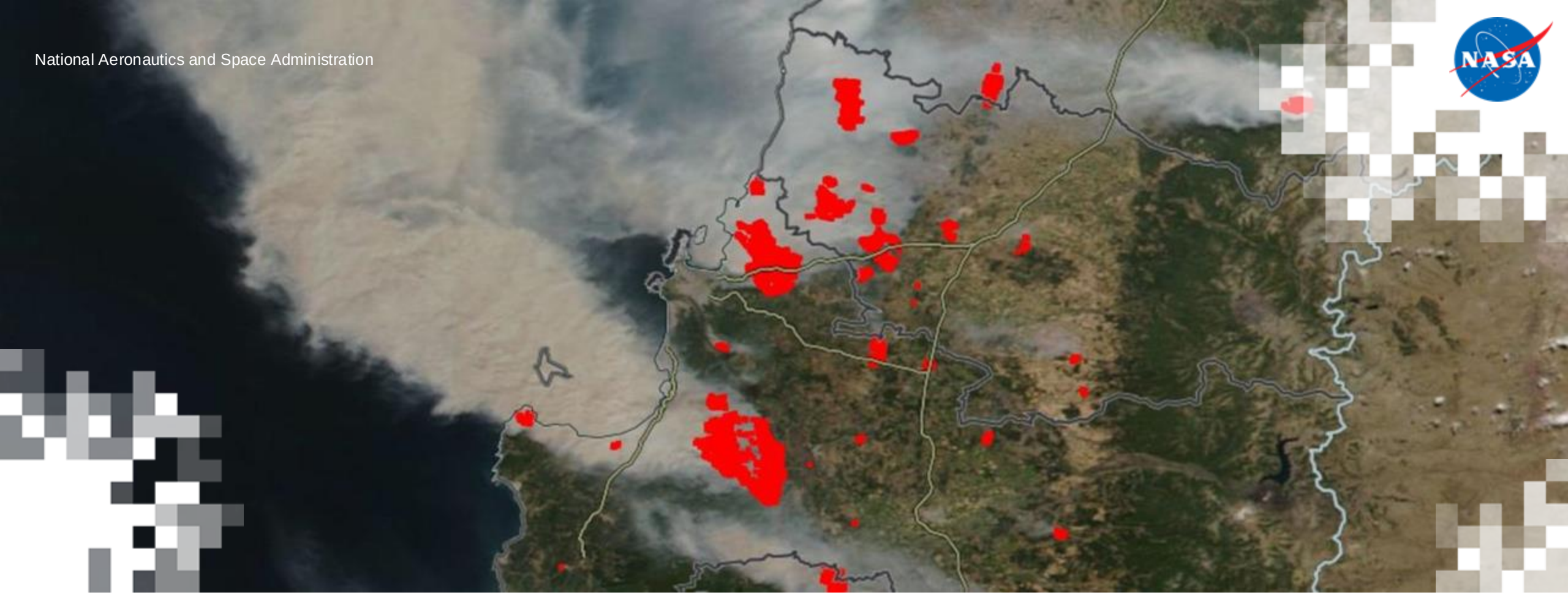
National Aeronautics and Space Administration

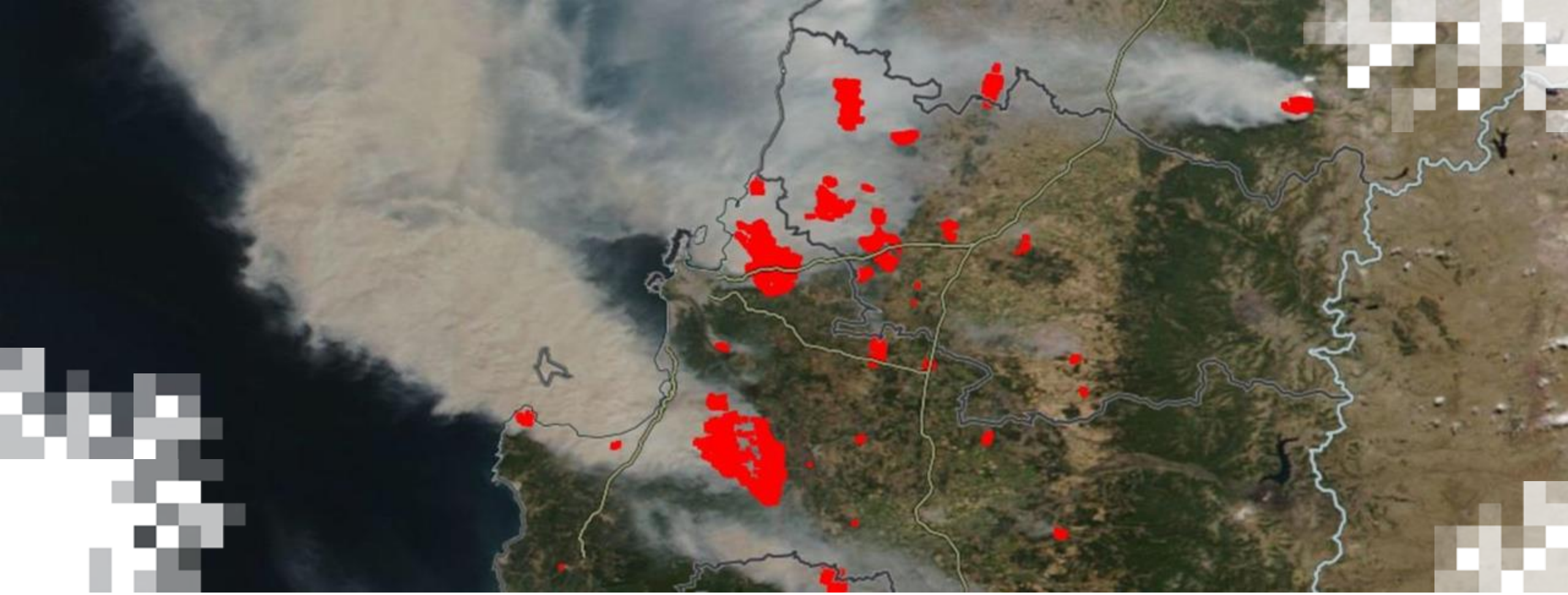


Introduction to NASA Earth Observations and Tools for Wildfire Monitoring and Management

Part 1: Introduction to Satellite-Based Active Fire Detection using FIRMS

Brad Quayle (USDA USFS), Jenny Hewson (SSAI), Diane Davies (SSAI/Trigg-Davies Consulting Ltd.), & Melanie Follette-Cook (NASA GSFC)

April 16, 2025



About ARSET

About ARSET

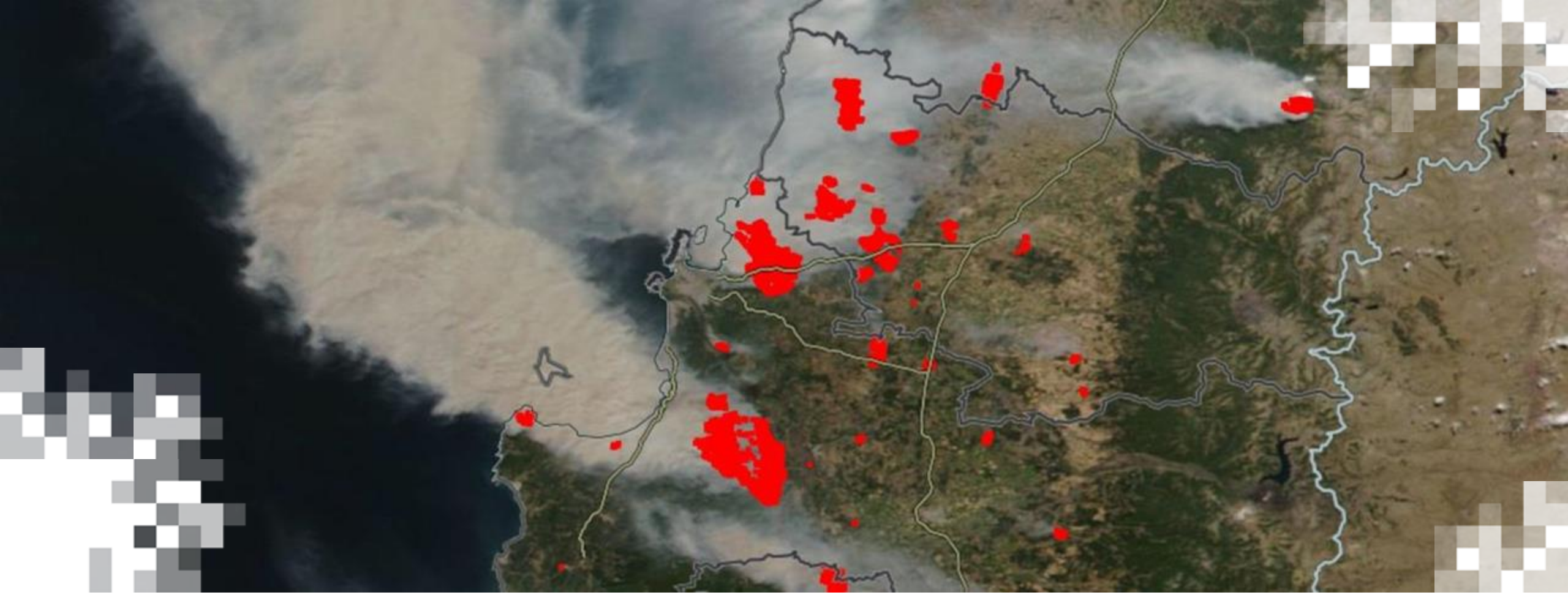
- **ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.**

- Trainings include a variety of applications of satellite data and are tailored to audiences with a variety of experience levels.

About ARSET Trainings

- Online or in-person
- Live and instructor-led or asynchronous and self-paced
- Cost-free
- Bilingual and multilingual options
- Only use open-source software and data
- Accommodate differing levels of expertise

- Visit the ARSET website to learn more.



Introduction to NASA Earth Observations and Tools for Wildfire Monitoring and Management

Overview

Observing Fires from Space

Wildfire Animation

Training Learning Objectives

By the end of this training, participants will be able to:

- Evaluate different satellite-based active fire detection data sources using FIRMS to build a wildfire narrative; understand the strengths and limitations of each source for different types and sizes of fires
- Apply FIRMS data and tools to evaluate rapidly growing wildfires using tools available in FIRMS
- Apply strategies using FIRMS to identify factors that can impact satellite-based wildfire detection, resulting in a 'missed' wildfire, and plan for when data may become available
- Use FIRMS to monitor a particular area of interest by accessing active fire data from the archive of available data, using web services to create an email alert for the area, and ingesting the resulting fire alerts into a GIS platform to enable evaluation

Prerequisites

- Fundamentals of Remote Sensing

Training Outline

Part 1

Introduction to Satellite-Based Active Fire Detection using FIRMS

April 16, 2025

Part 2

Wildfire Monitoring and Evaluation

April 23, 2025

Part 3

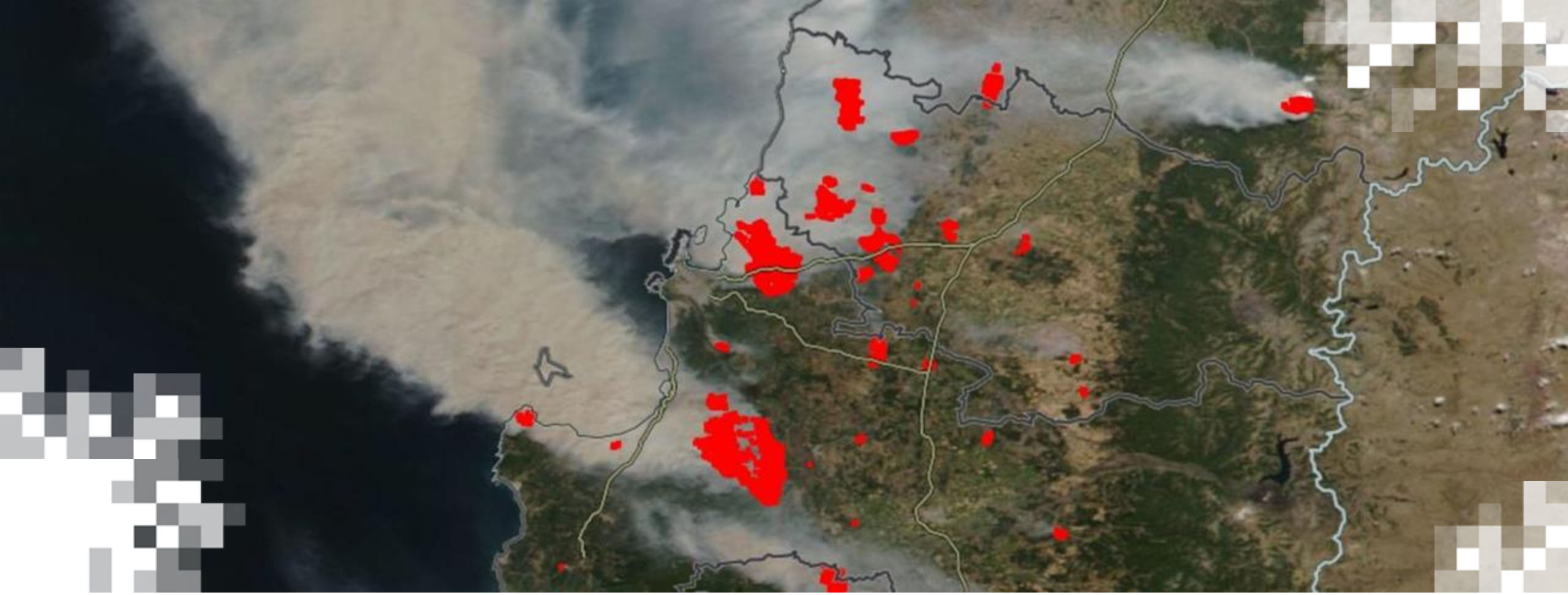
Data Access and Visualization

April 30, 2025

Homework

Opens April 30– Due May 14– Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.



Introduction to NASA Earth Observations and Tools for Wildfire Monitoring and Management

Part 1: Introduction to Satellite-Based Active Fire Detection using the Fire Information for Resource Management System (FIRMS)

Part 1 – Trainers

Jenny Hewson

LANCE Outreach & Implementation Manager
SSAI

Brad Quayle

Disturbance Assessment and Services Program
USDA USFS

Part 1 Objectives

By the end of Part 1, participants will be able to:

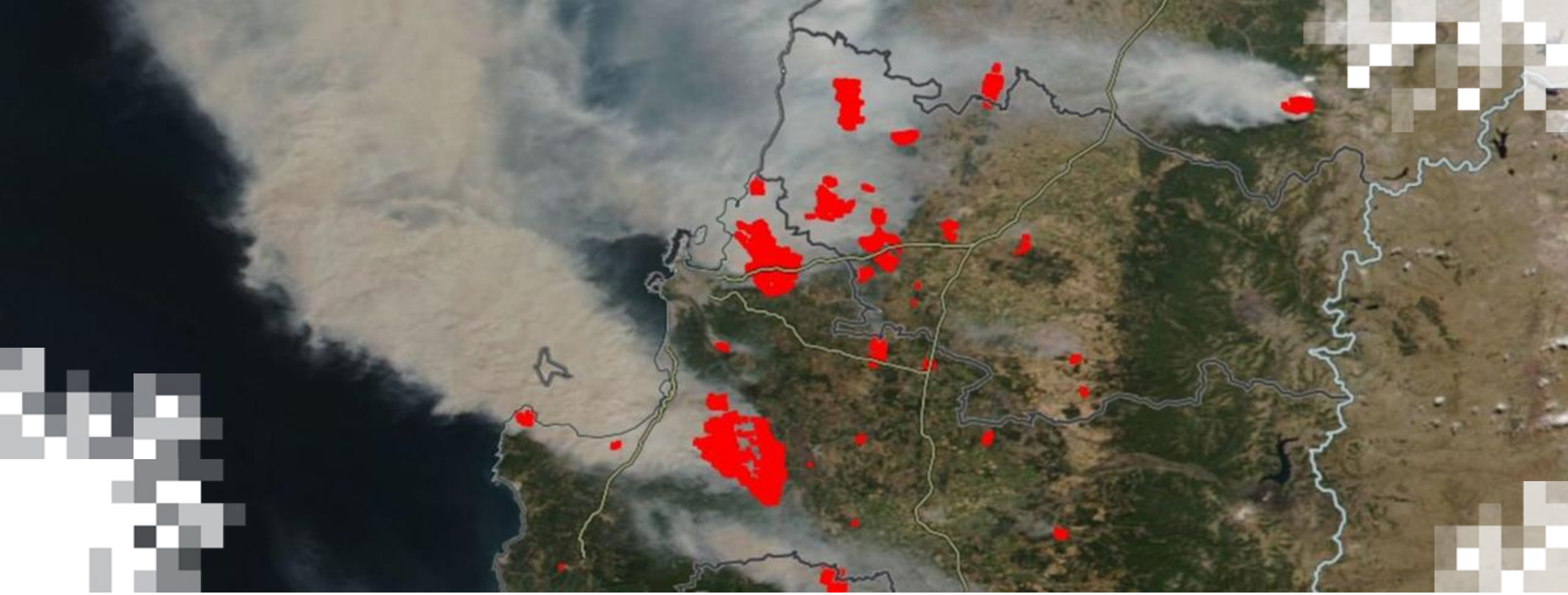
- Recognize how active fires can be detected by satellite sensors
- Use FIRMS to view active fire information
- Identify the strengths and limitations of polar and geostationary satellite sensors to detect different types and sizes of fires

How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

Part 1 Outline

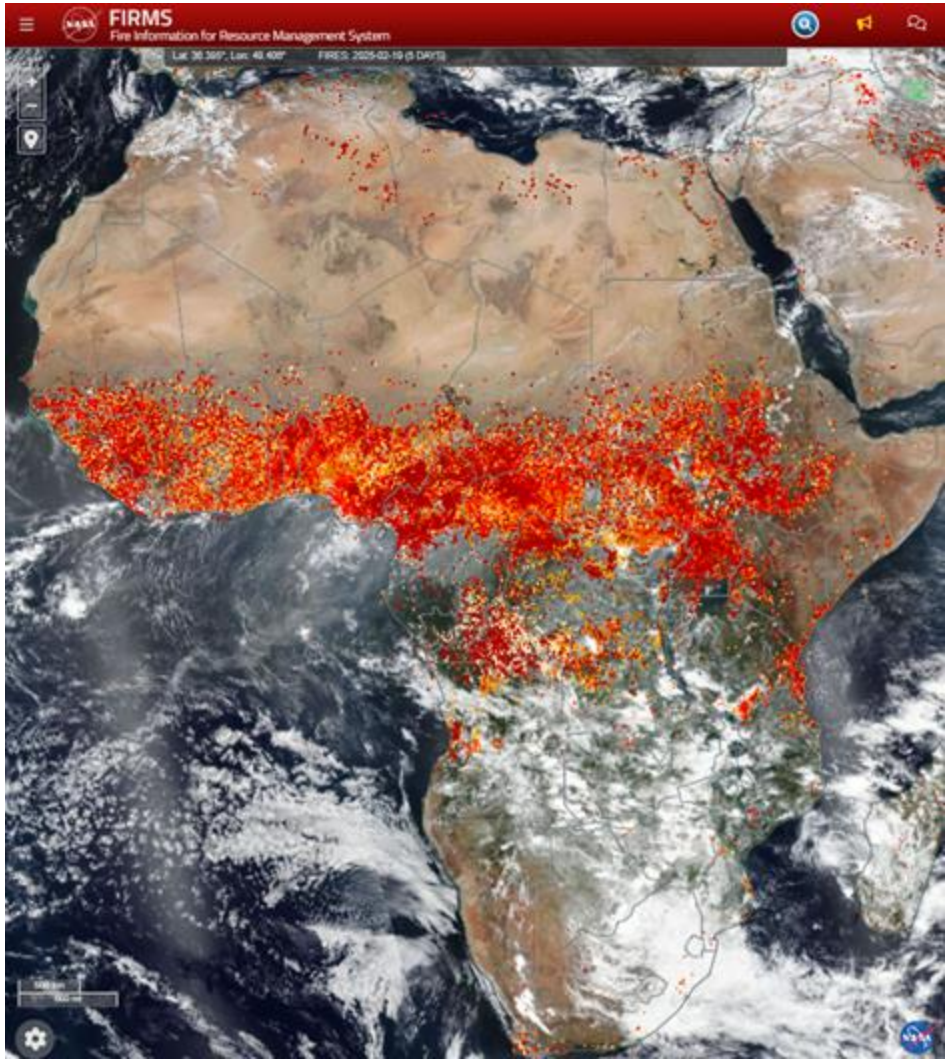
- Introduction to FIRMS
- Satellite-based detection of fires
- Overview of data available in FIRMS
- Strengths/limitations of different satellite-based active fire detection data products



Introduction to FIRMS

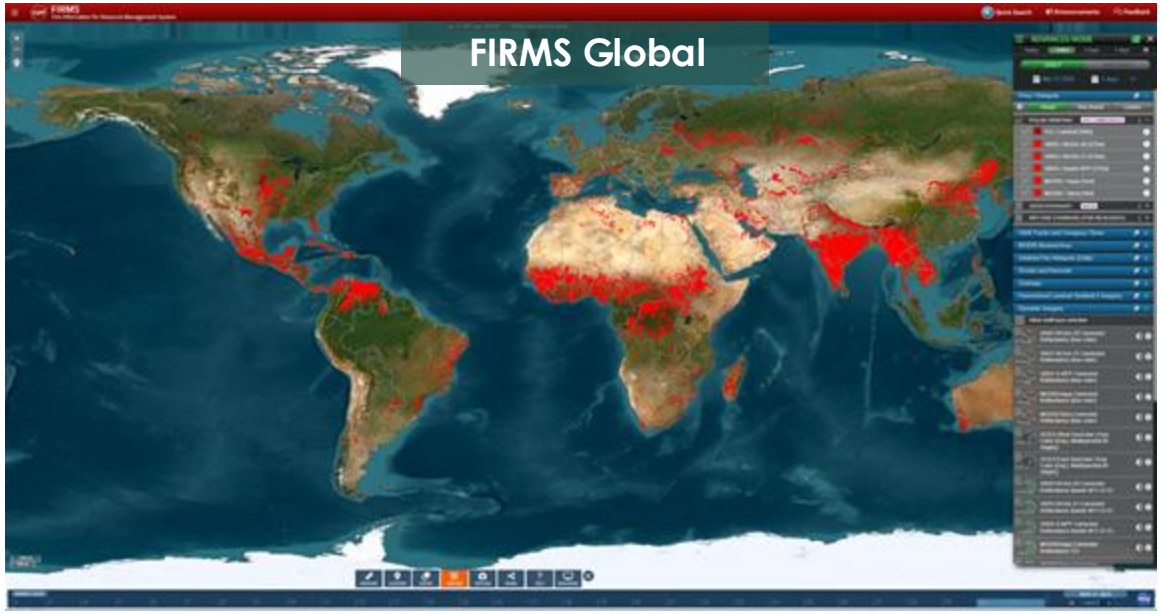
Fire Information for Resource Management System (FIRMS)

- Provides multiple sources of time sensitive derived active fire detection data products and satellite imagery
- Objectives:
  - Enable access to global, very low-latency satellite imagery, active fire/hotspots and related products from multiple satellite missions
  - Detect and monitor the location, extent and intensity/severity of fire activity, its effects on the environment, and to support event response
  - Inform science-based decision making through standardized, readily interpretable interfaces and services to support operational users, researchers, and other stakeholders



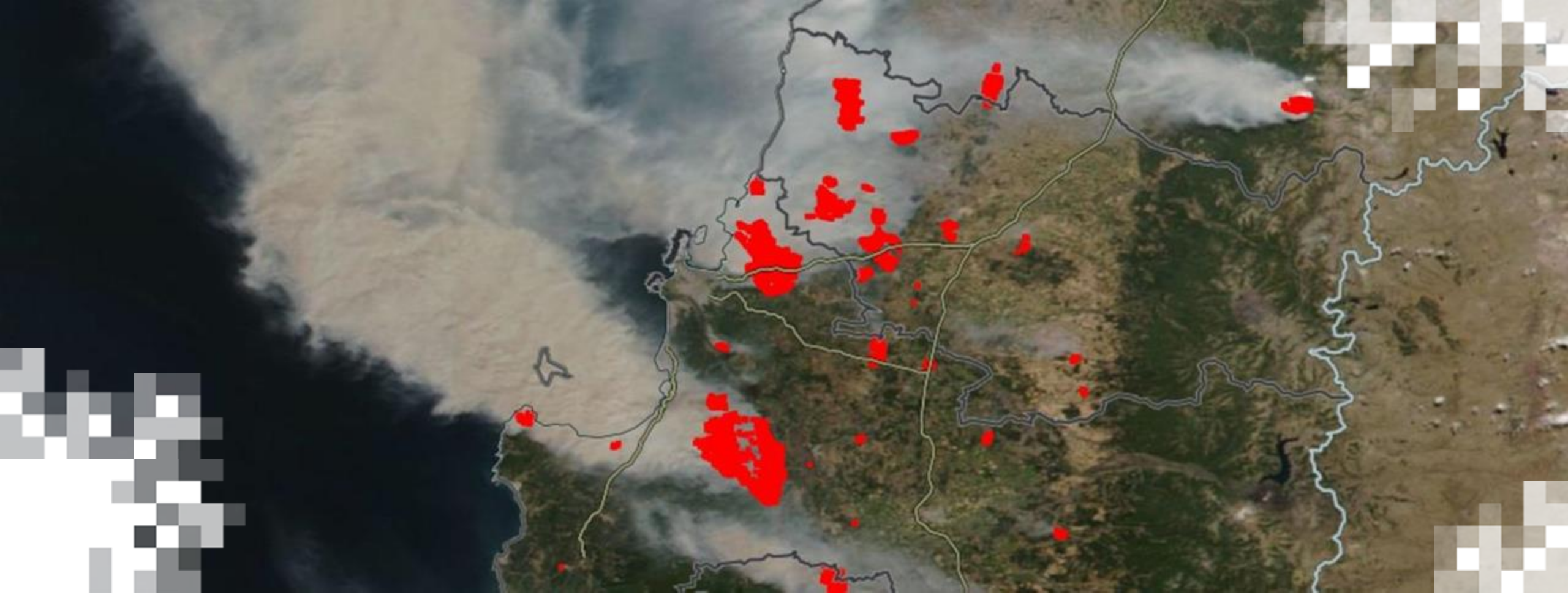
FIRMS - Global

- FIRMS Website
- Low-latency imagery and active fire detection products for the world
- Developed by University of Maryland in early 2000s and used data from MODIS
- Transitioned to NASA's Land, Atmosphere Near real-time Capability for Earth observation (LANCE) in 2012



FIRMS US/Canada

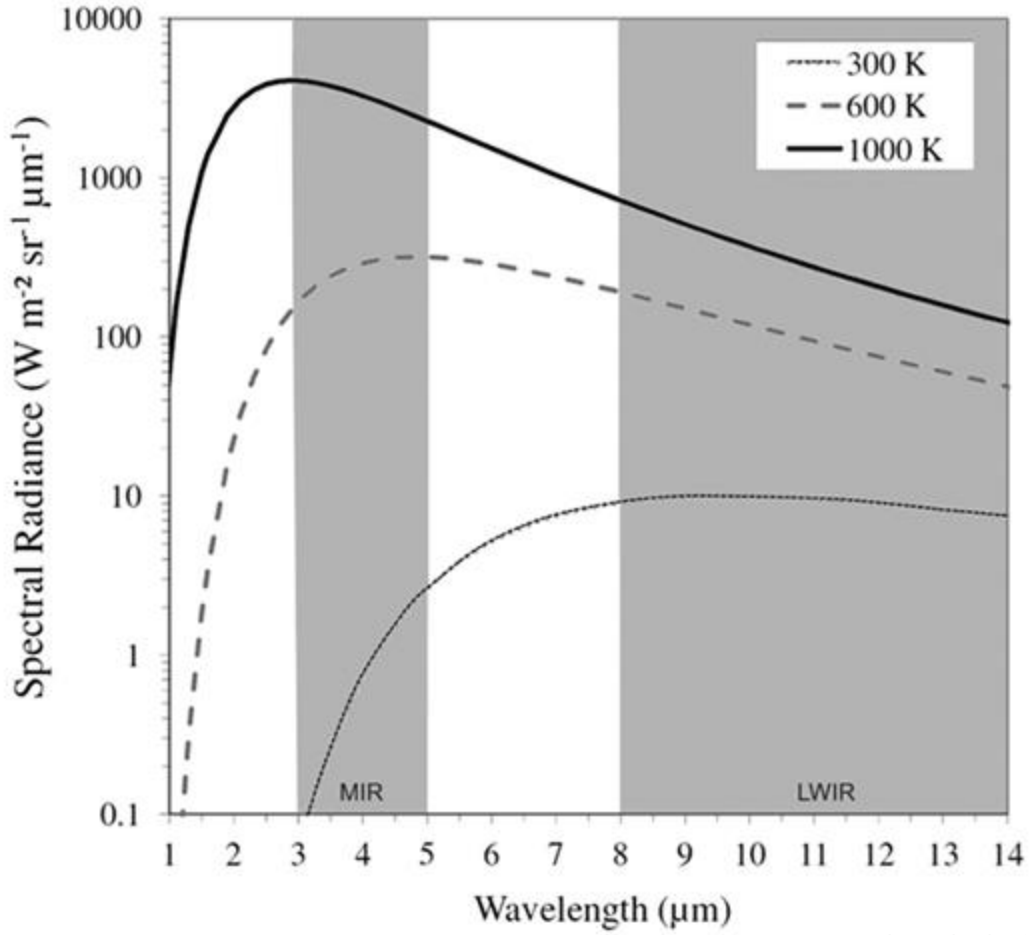
- FIRMS US/Canada Website
- Low-latency imagery and active fire detection products for the US & Canada
- Developed in partnership with USDA Forest Service
- Extension of the Forest Service's Active Fire Mapping Program developed in 2001 that used data from MODIS and direct broadcast/direct readout
- Integrated with FIRMS Global within NASA LANCE in 2021



Satellite-Based Detection of Fires

How is a fire detected by satellite?

- Satellites detect fires at the time of observation or overpass.
- Specific reflective and emissive bands located on the satellite sensor are used to detect fires.
  - Leverage response from fires in Mid-Wave InfraRed (MWIR) and Long-Wave (LWIR) bands
  - Other bands used for masking, rejection of false positives, etc.
- Typical Temperatures:
  - Earth's Surface: ~300K
  - Smoldering Fires: 600K to 800K
  - Flaming Fires: ~1000K and Higher



Wooster et al., 2021

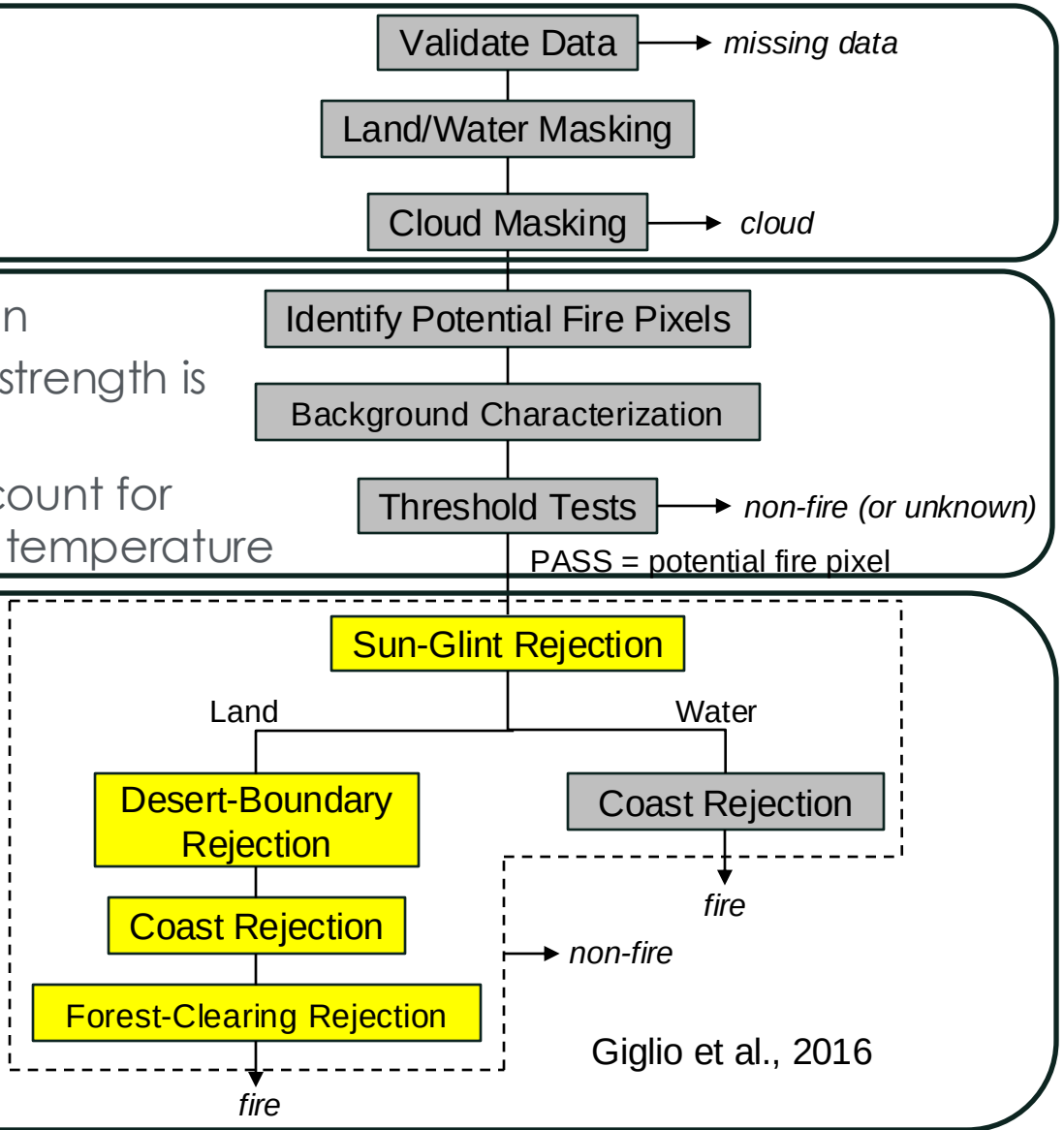
How is a fire detected by satellite?

- Legacy algorithm approach:

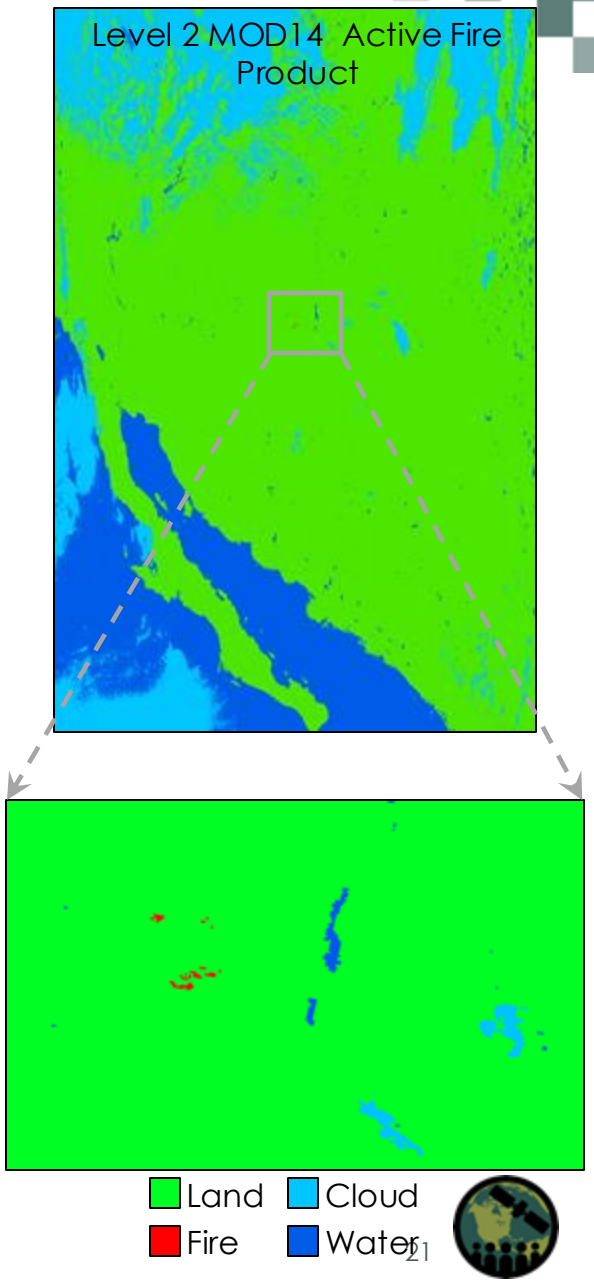
– Exclude invalid input data
– Masking processes

– Tentative fire pixel detection
  - Absolute thresholds: fire strength is sufficient to detect
  - Contextual analysis: account for variability of the surface temperature

– Rejection tests
– Final fire pixel identification

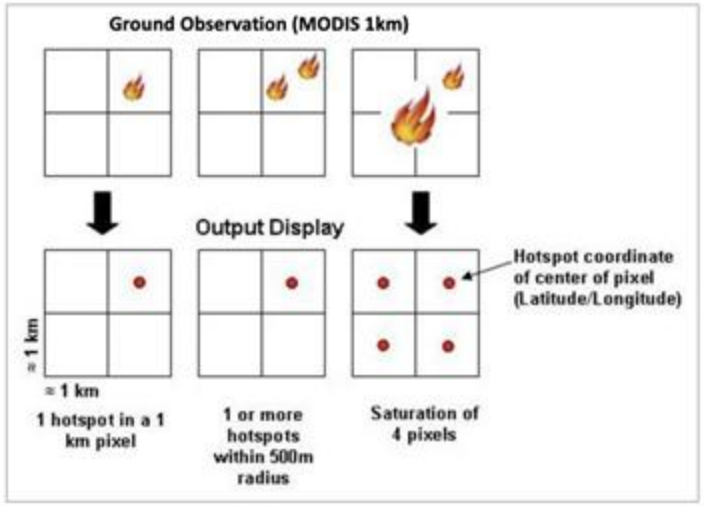


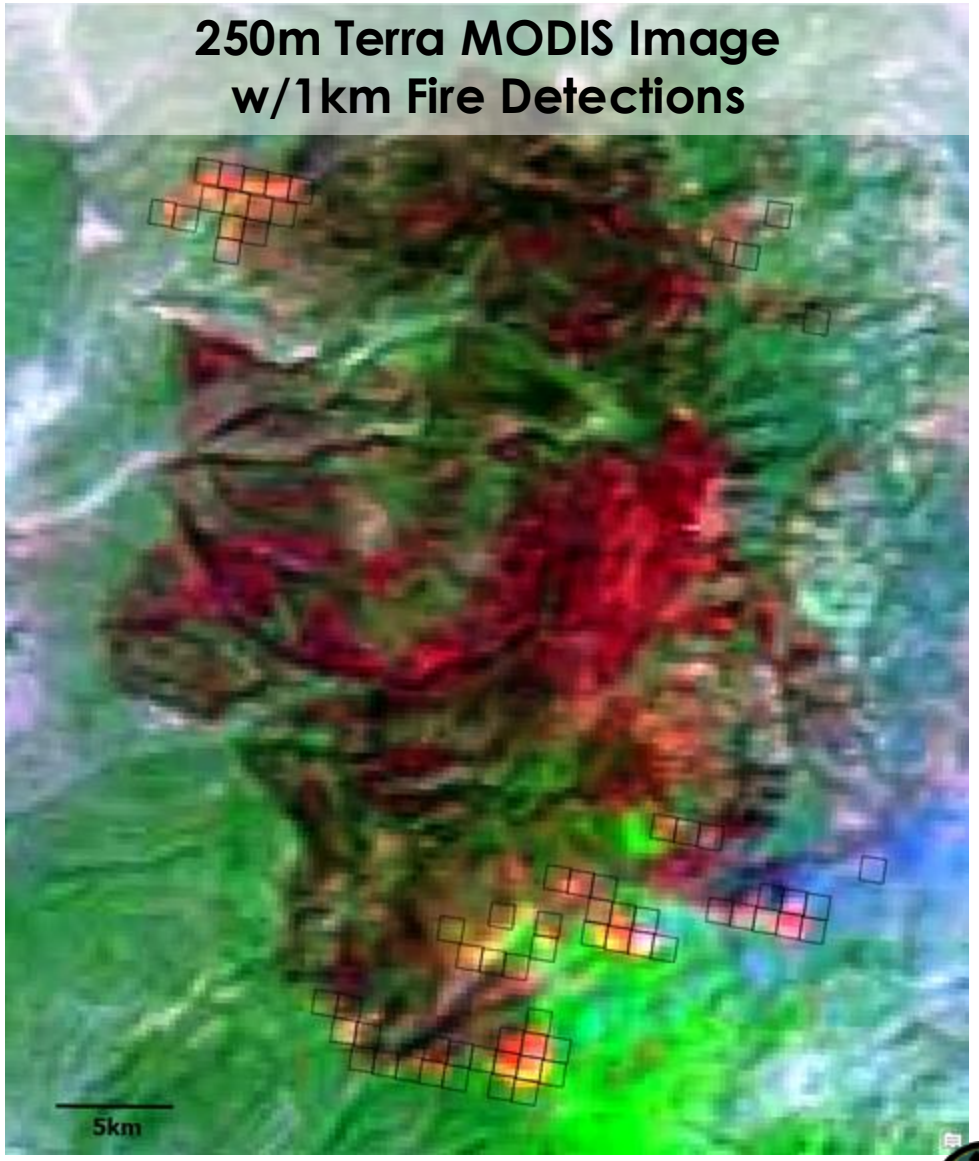
Giglio et al., 2016



What does a detection mean on the ground?

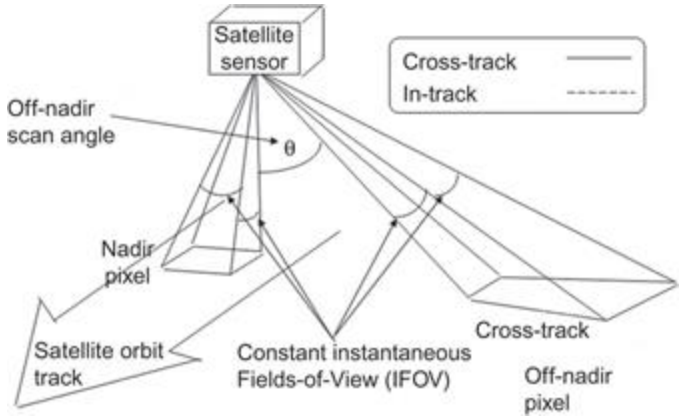
- Driven by the characteristics of the fire.
- Detected fire activity is often less than the pixel size.
  - Small or large, intense fire(s)
  - Less intense fire burning over a broader area
- Pixel size for fire detection data is determined by sensor spatial resolution.
- Detection coordinates are the center of a pixel containing fire activity.





What does a detection mean on the ground?

- Sensor altitude, view angle affects ground footprint covered by a pixel
- Time of sensor observation or overpass relative to fire activity



Schueler and Barnes, 1998
Schueler et al., 2013

- Other factors affecting detection ability:
  - Fire Size and Intensity
  - Cloud Cover
  - Smoke
  - Canopy Cover
  - Terrain
  - Land Cover Heterogeneity

What sizes/types of fires can be detected by satellite?

MODIS (1000m)

- ~1,000m^2 smoldering to flaming fires in good conditions (day)
- ~100m^2 flaming fire in good conditions (day)

VIIRS I-Band (375m)

- ~100m^2 smoldering to flaming fires in good conditions (day)
- ~20m^2 flaming fire in good conditions (day)
- ~2m^2 flaming fire in good conditions (night)

Landsat OLI (30m)

- ~10-20m^2 smoldering to flaming fires in good conditions (day)
- ~4m^2 flaming fire in good conditions (day)
- ~1m^2 flaming fire in good conditions (night)

Algorithms and products are not perfect!

Schroeder et al., 2016

Schroeder et al., 2014

Schroeder & Giglio, 2017

Earth Observation Satellites and Sensors Used in FIRMS

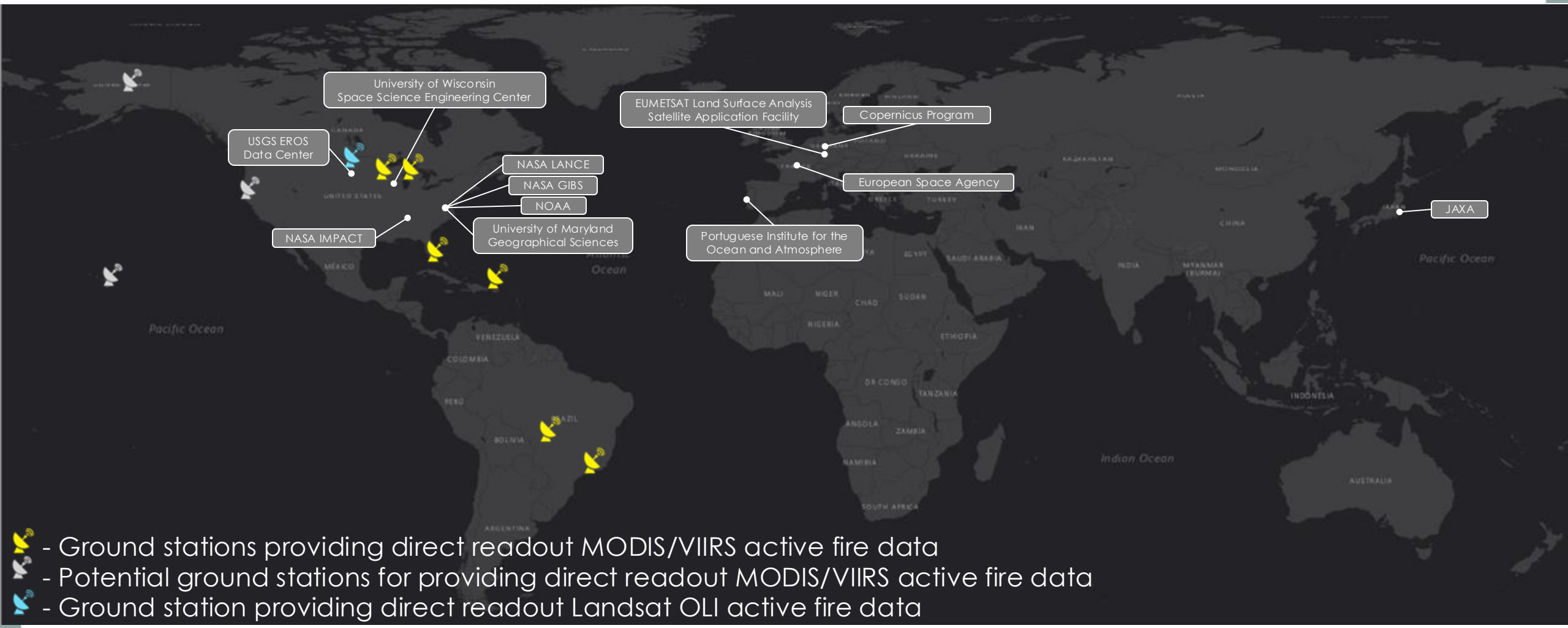
- 15 Satellites
  - 10 Polar-Orbiting
  - 5 Geostationary
- 16 Sensors
- 5 Space Agencies
  - NASA
  - NOAA
  - ESA
  - EUMETSAT
  - JAXA

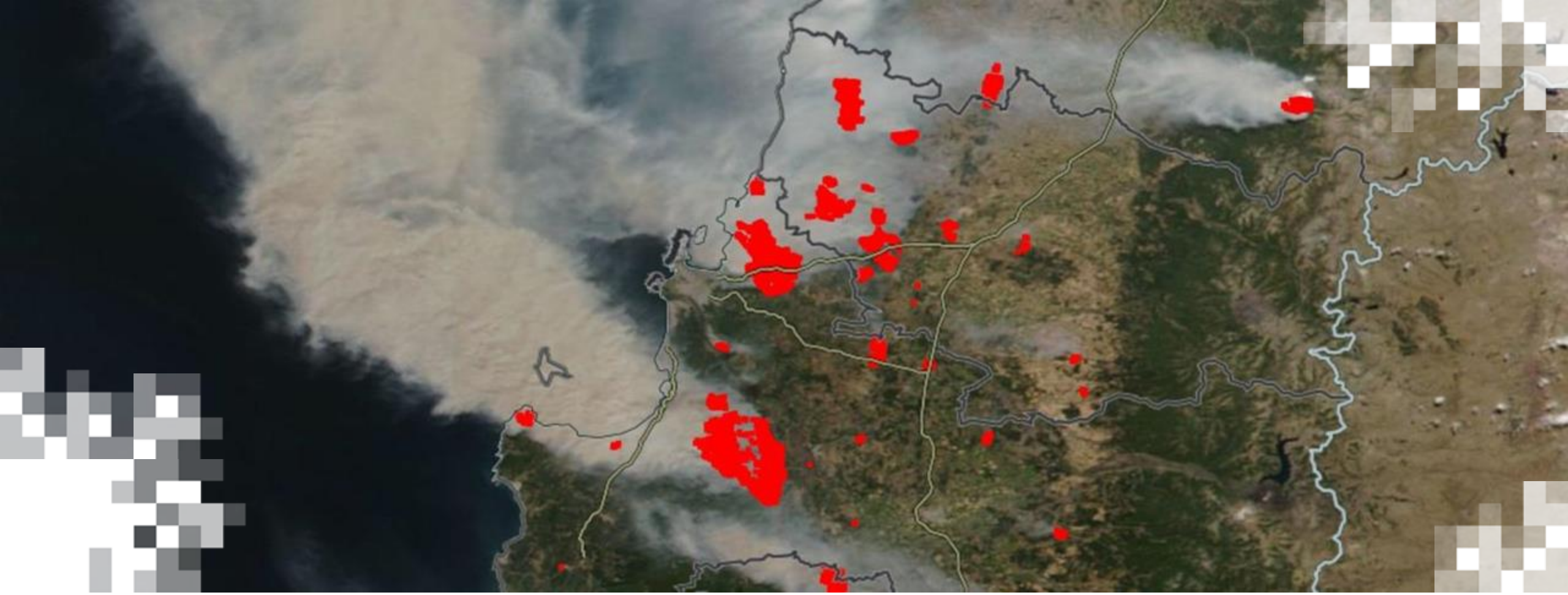
Summary of Satellite Data Product Availability in FIRMS

Satellite - Sensor	Active Fire	True Color Composite Imagery	False Color Composite Imagery	DNB Imagery	DNB/IR Composite Imagery	Burned Area	Vegetation Indices	Aerosol Indices	Snow Cover
GOES-16 ABI									
GOES-18 ABI									
Meteosat-9 SEVIRI									
Meteosat-11 SEVIRI									
Himawari-9 AHI									
Terra MODIS									
Aqua MODIS									
S-NPP VIIRS									
NOAA-20 VIIRS									
NOAA-21 VIIRS									
Sentinel-3A SLSTR									
Sentinel-3B SLSTR									
Landsat 8 OLI									
Landsat 9 OLI									
Sentinel 2A MSI									
Sentinel 2B MSI									

Available – Provided in FIRMS	Available – Planned to Include in FIRMS	Available – Not Planned to Include in FIRMS	Available – Not Provided in FIRMS	Not Available

FIRMS Partners and Sources of Satellite Products



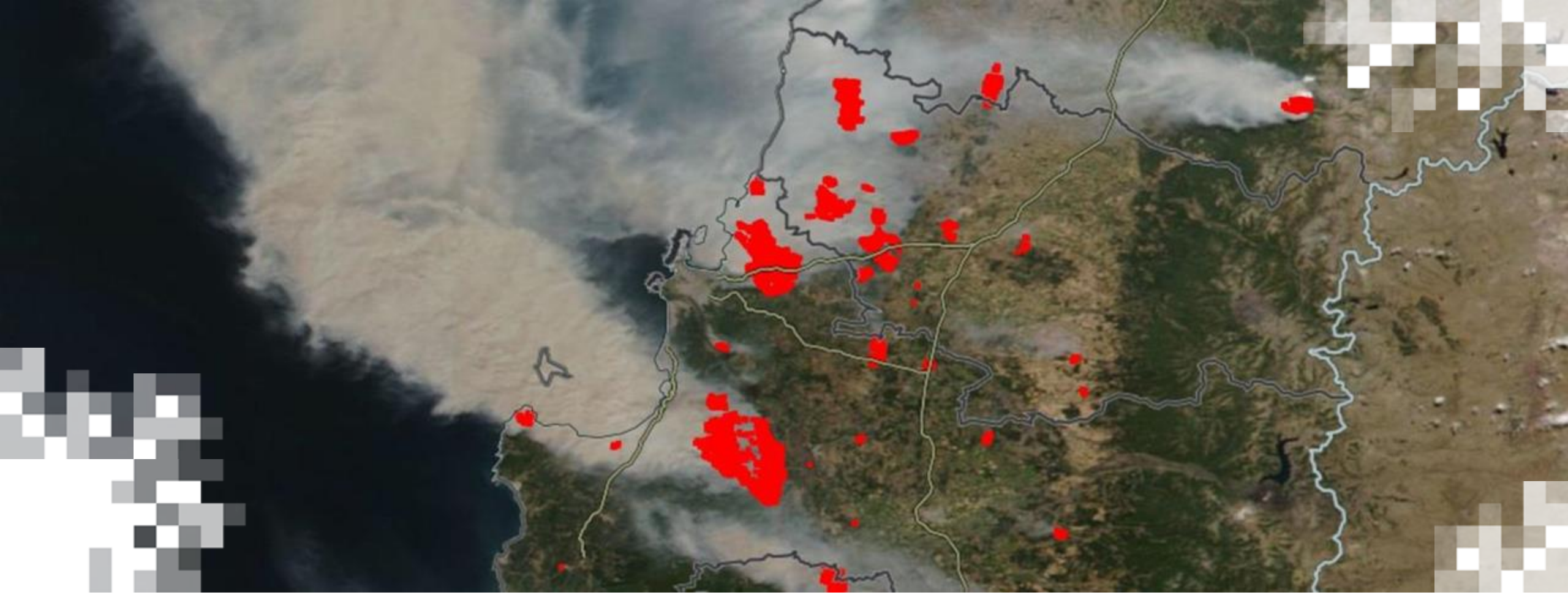


Access Active Fire Information using FIRMS

Access Active Fire Information using FIRMS

Demo Outline

- How is FIRMS organized?
- Where are fires burning?
- Where is a fire in relation to me?
- How do I access satellite imagery in FIRMS?
- Can I display active fires on other contextual layers in FIRMS?
- How can I share FIRMS fire maps?



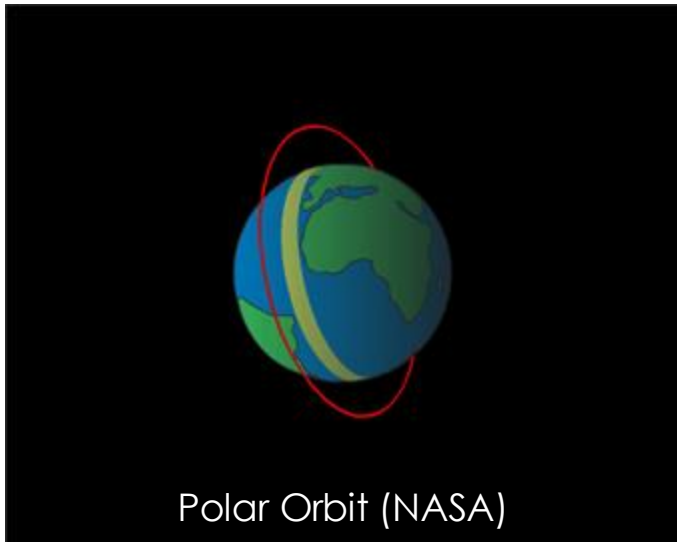
Strengths and Limitations of Available Satellite-Based Active Fire Data Products

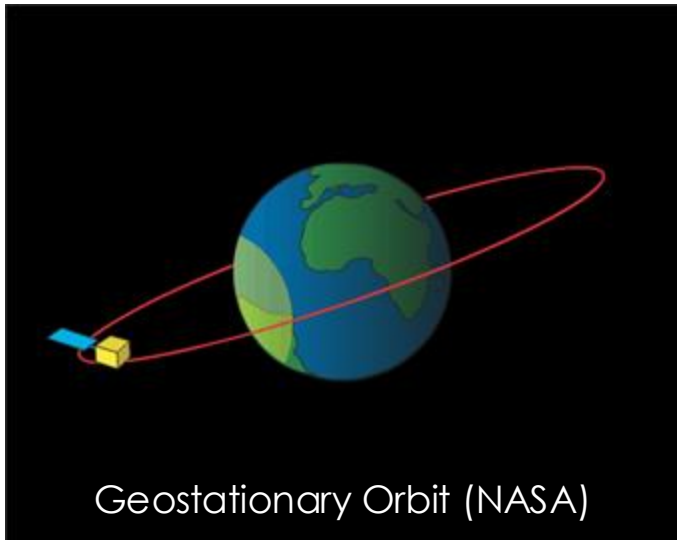
Why does FIRMS include multiple satellites and sources of active fire data?

- No one satellite sensor meets all requirements.
- Technical Requirements:
  - Global coverage
  - Frequent observations
  - Relatively high spatial resolution
  - Accuracy, consistency, and reliability of products
- Fire management information needs:
  - Detect new ignitions
  - Monitor fire progression
  - Fire risks to human populations, resources
  - Effects of smoke

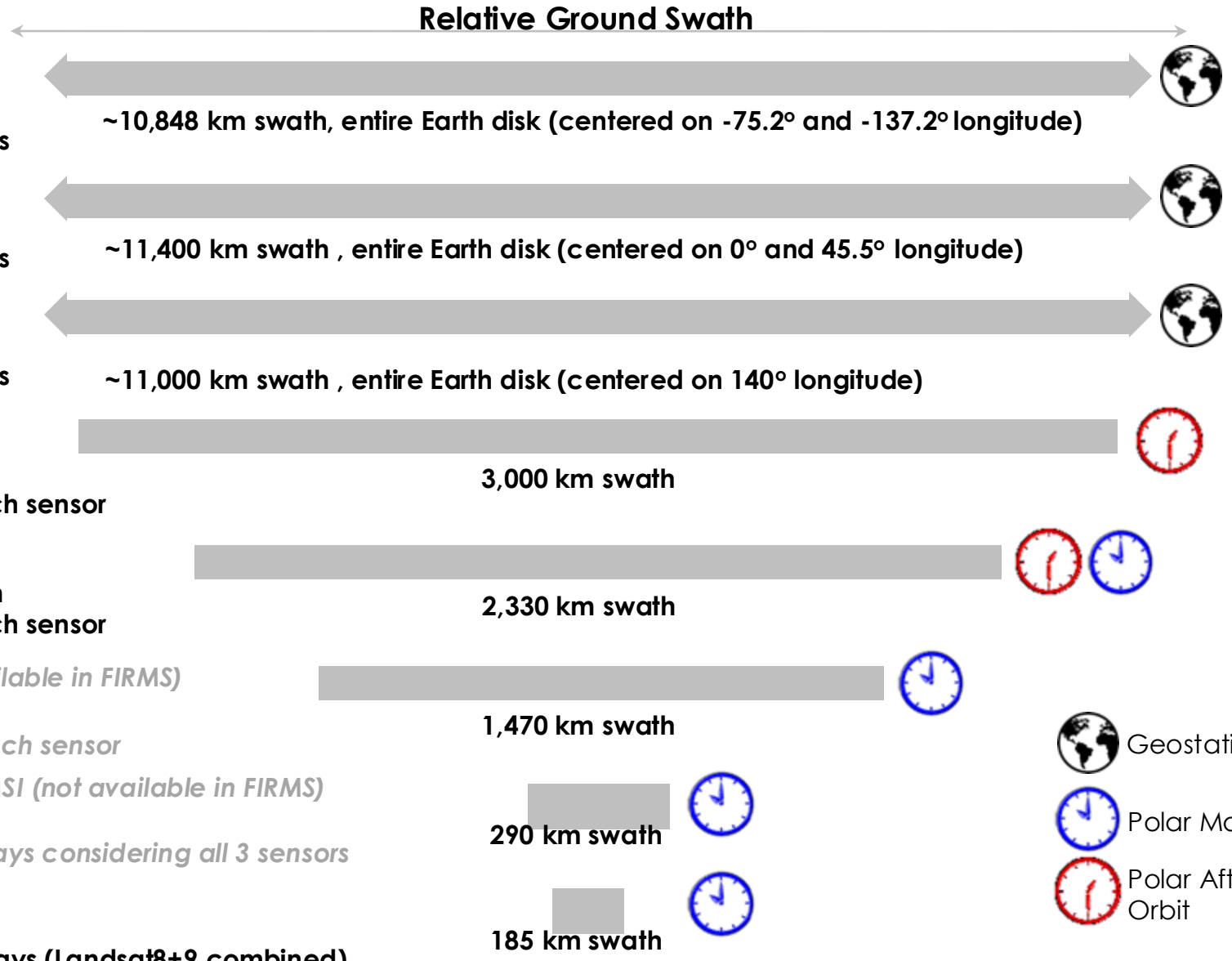
Satellite Orbits

- Polar-Orbiting Satellite Orbits
  - Orbit from pole to pole while Earth rotates beneath
  - Sun-synchronous; collect on both daytime and nighttime sides
  - Low orbit (<1,000km)
  - 1-2 observations daily (more in higher latitudes)
  - Sensors cover a defined swath width
  - Relatively higher spatial resolution
- Geostationary Satellite Orbits
  - Locked on fixed point while Earth rotates
  - High orbit (35,000km)
  - Sensors observe full-disk of Earth's hemisphere
  - Multiple observations per hour
  - Relatively coarser spatial resolution


Polar Orbit (NASA)


Geostationary Orbit (NASA)

Properties of Satellite Sensors Used in FIRMS for Active Fire Detection products



GOES-16 & GOES-18 ABI
Fire detection spatial resolution **2,000m**
Temporal resolution: **Every 10 min or less**

Meteosat-9, Meteosat-11 SEVIRI
Fire detection spatial resolution **3,000m**
Temporal resolution: **Every 15 min or less**

Himawari AHI
Fire detection spatial resolution **2,000m**
Temporal resolution: **Every 10 min or less**

SNPP, NOAA-20 & NOAA-21 VIIRS
Fire detection spatial resolution: **375m**
Temporal resolution: **Twice daily by each sensor**

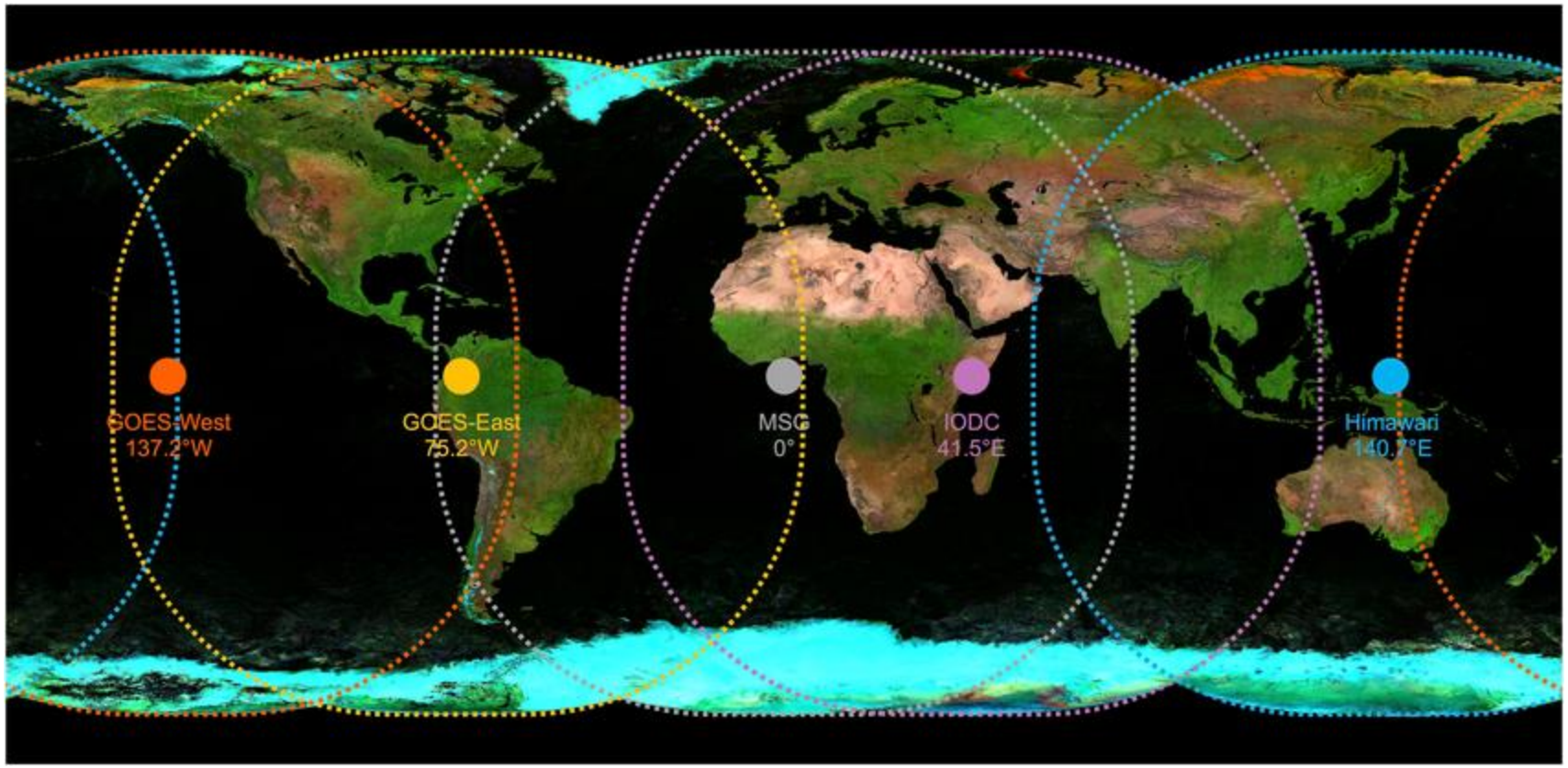
Terra & Aqua MODIS
Fire detection spatial resolution: **1,000m**
Temporal resolution: **Twice daily by each sensor**

Sentinel 3A & Sentinel 3B SLSTR (not available in FIRMS)
*Fire detection spatial resolution: **1,000m***
*Temporal resolution: **Every 2 days by each sensor***

Sentinel 2A, Sentinel 2B & Sentinel 2C MSI (not available in FIRMS)
*Fire detection spatial resolution: **20m***
*Temporal resolution: **Once every 2-3 days considering all 3 sensors***

Landsat 8 & Landsat 9 OLI
Fire detection spatial resolution: **30m**
Temporal resolution: **Once every 8-9 days (Landsat8+9 combined)**

Geographic Coverage by GEO Satellites

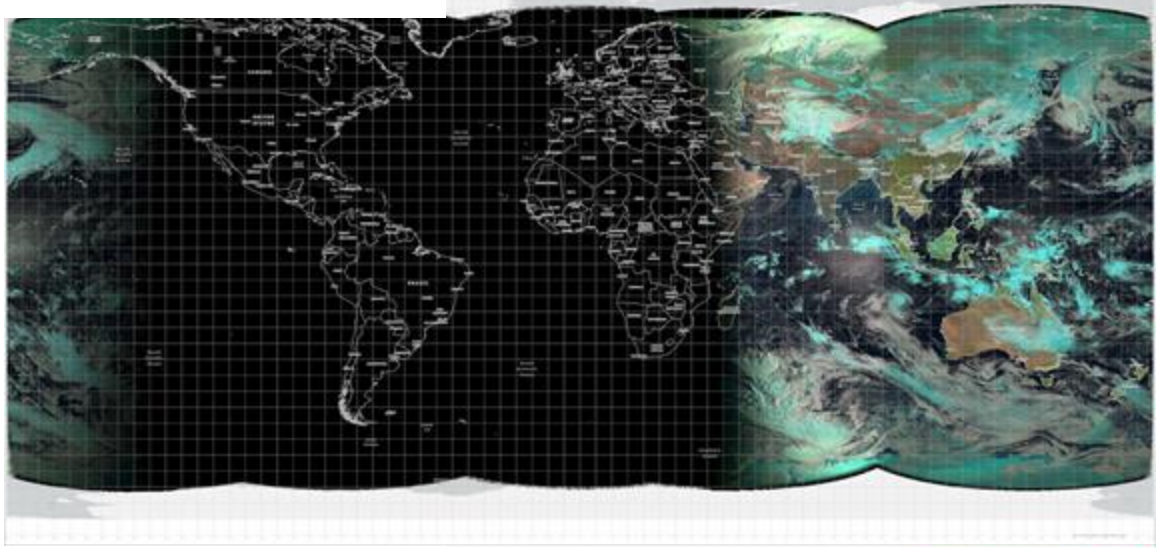


Geographic Coverage by GOES-18, GOES-16, Meteosat-9 (IODC), Meteosat-11 (MSG) and Himawari-9

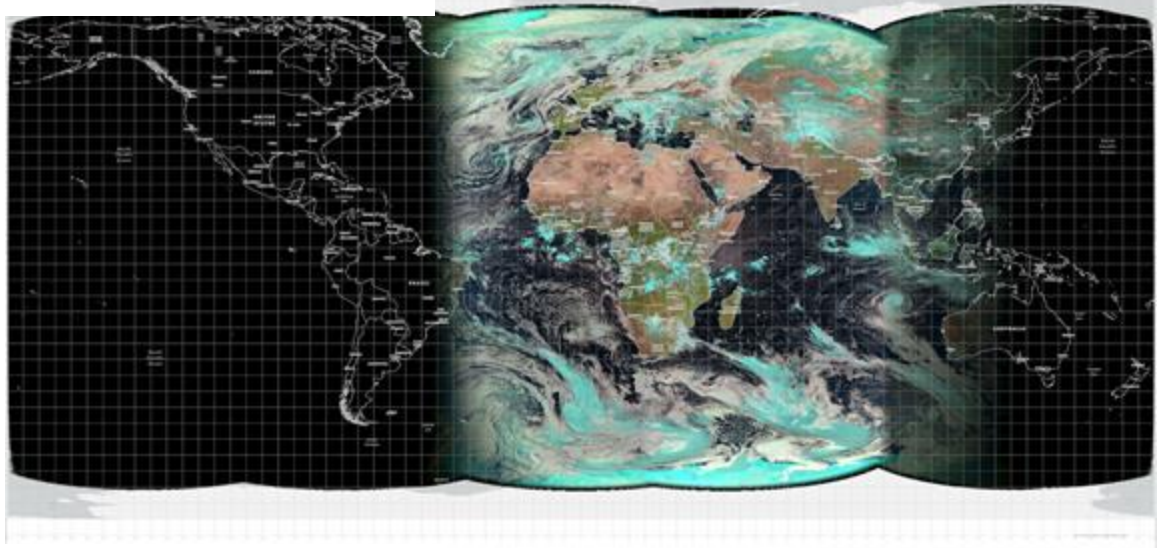
Credit: Ceamanos et al., 2021; https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JD034906

Geostationary and Polar: Time Stamp Coverage Comparison

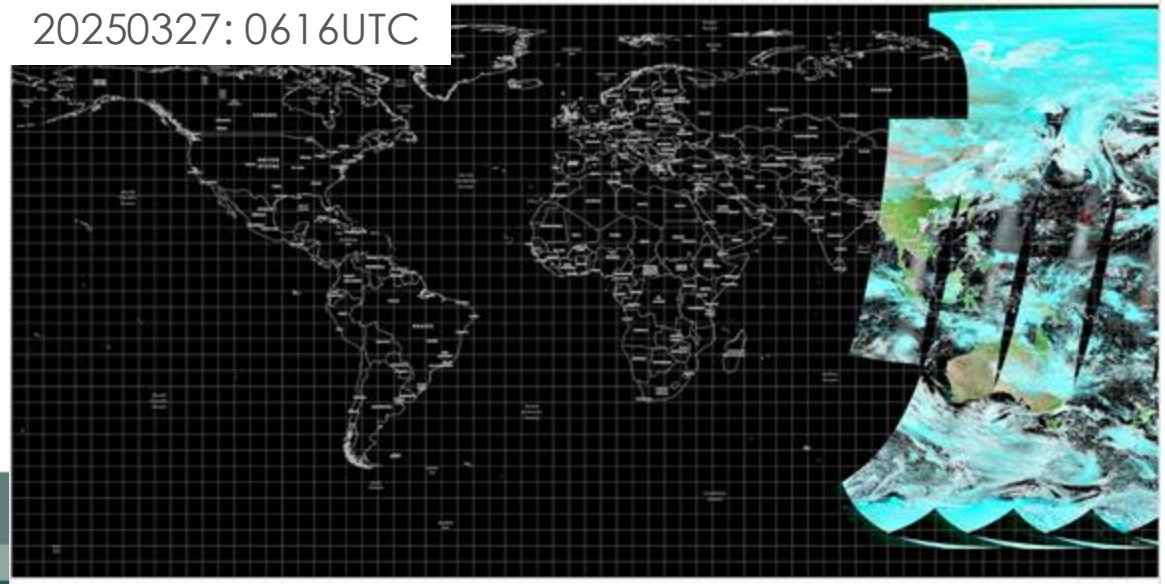
20250327: 0614UTC



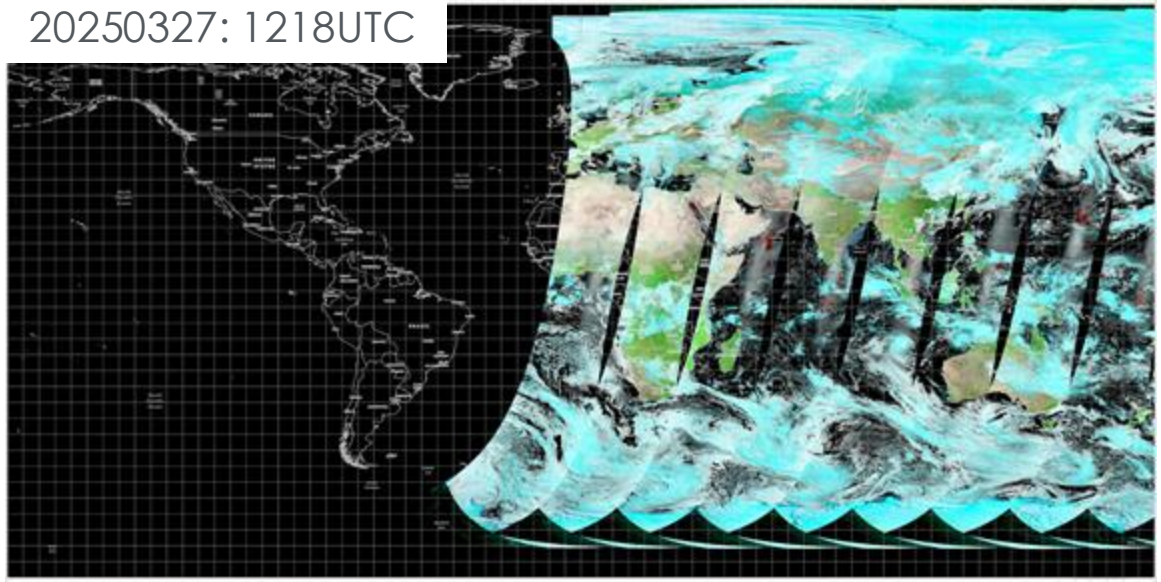
20250327: 1217UTC



20250327: 0616UTC



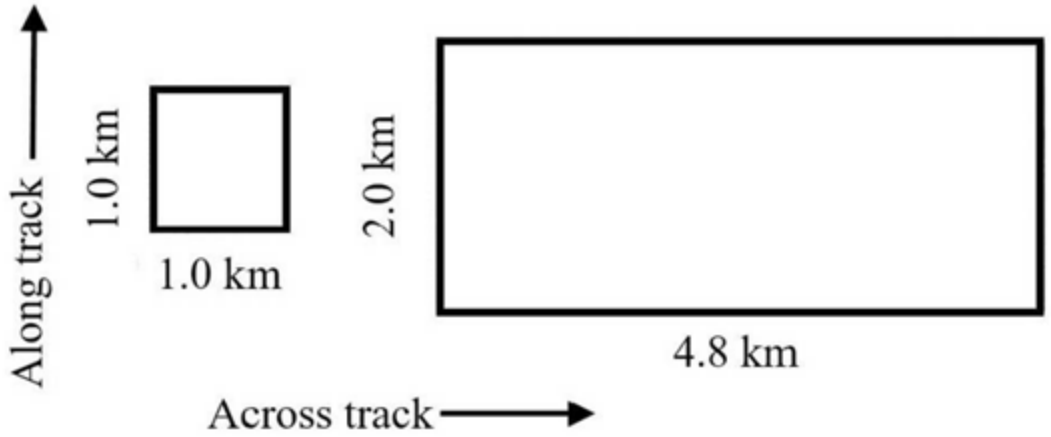
20250327: 1218UTC



Change in Pixel Size with Viewing Angle

Pixel size will change as the sensor views further off-nadir

Change from nadir on MODIS sensors
(onboard Terra and Aqua polar-orbiting satellites)

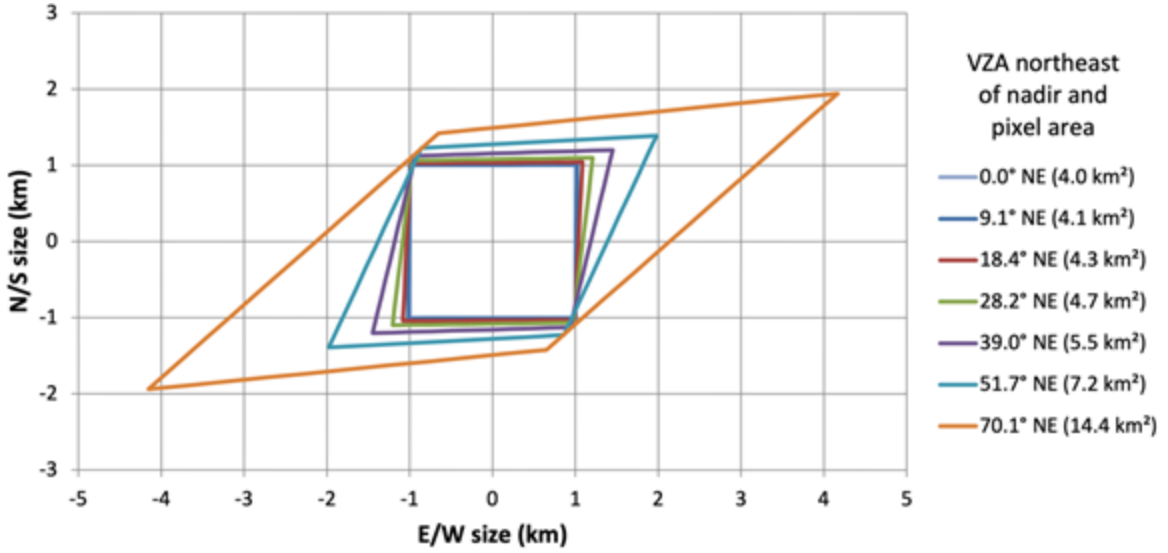


MODIS pixel growth from nadir to swath edge

Credit: Minnett et al., 2019

https://doi.org/10.1016/j.rse.2019.111366

Change from nadir on ABI sensors
(onboard GOES-R geostationary satellites)

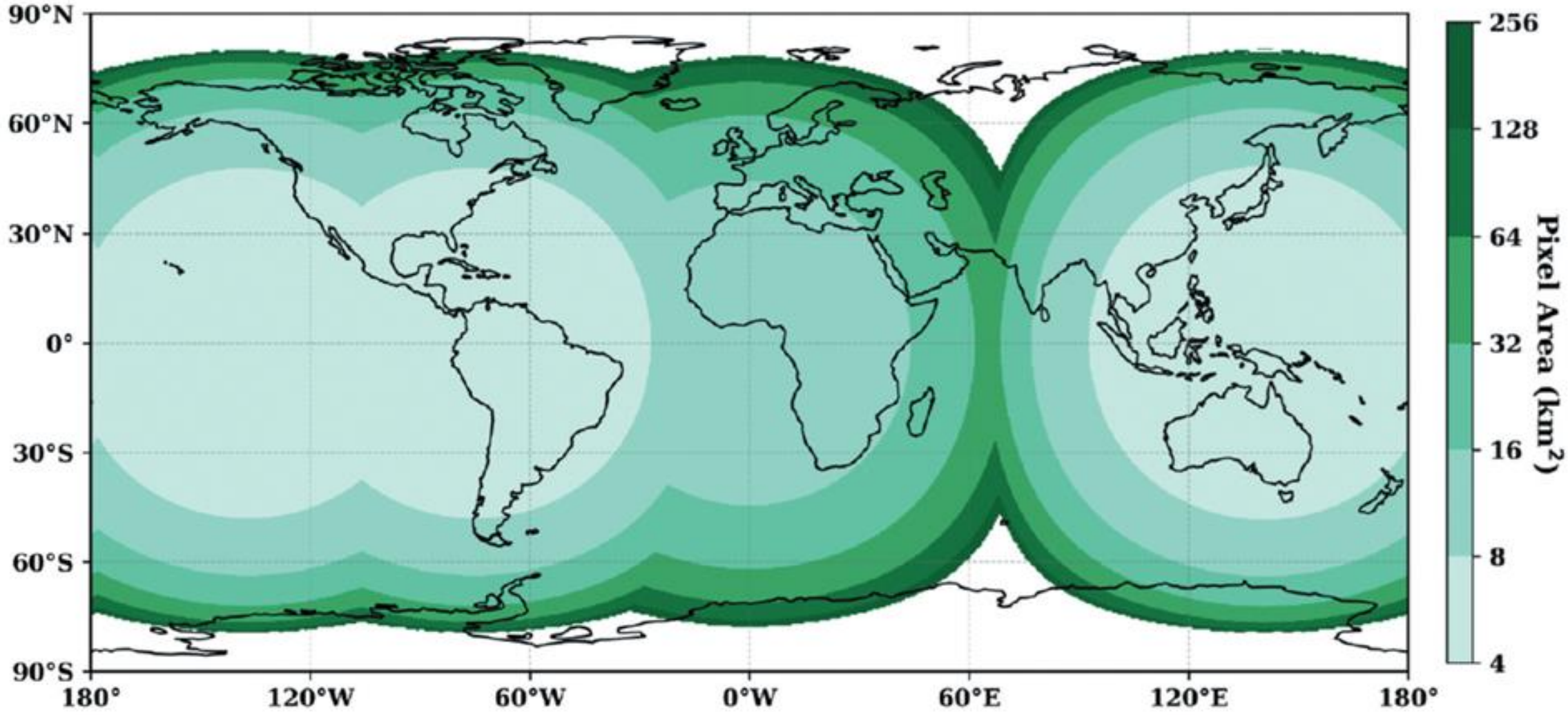


Systematic increase in pixel footprint from sub-satellite point (GOES ABI)

Credit: Losos et al., 2024

https://doi.org/10.1038/s41597-024-03071-z

Spatial Coverage and Systematic increase in pixel area

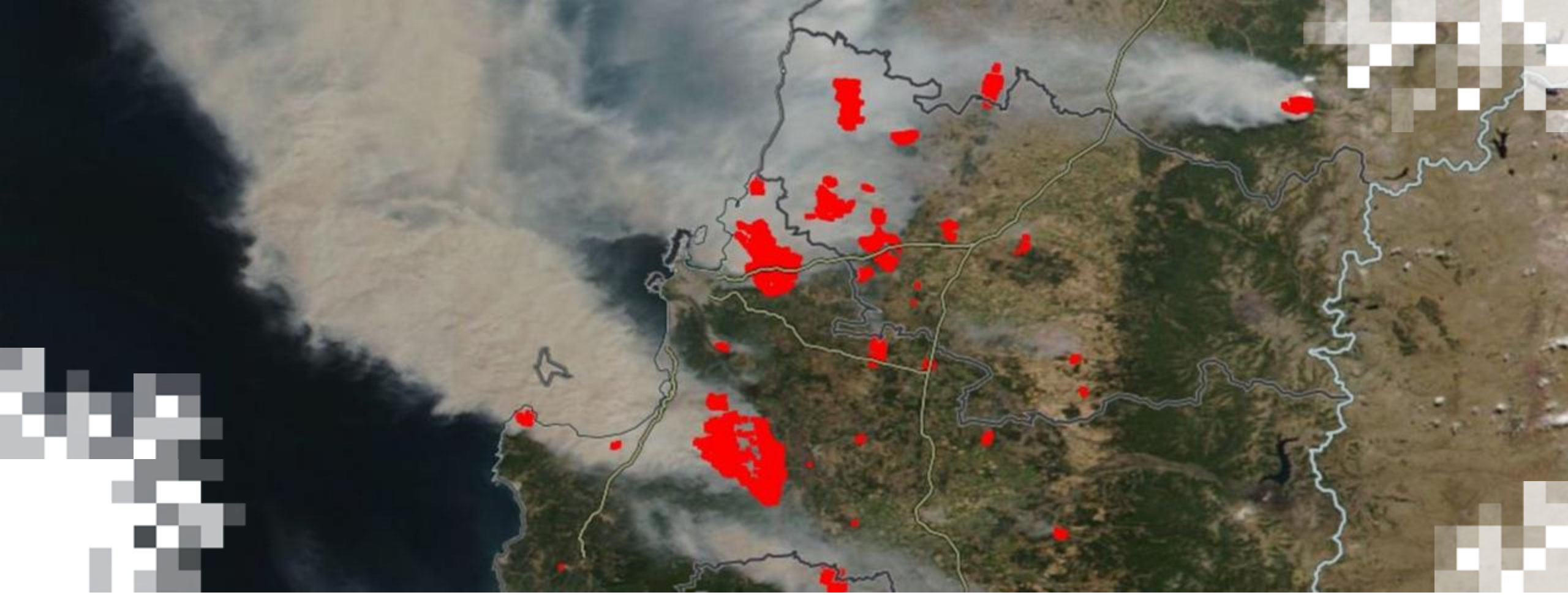


Credit: Hall et al., 2023

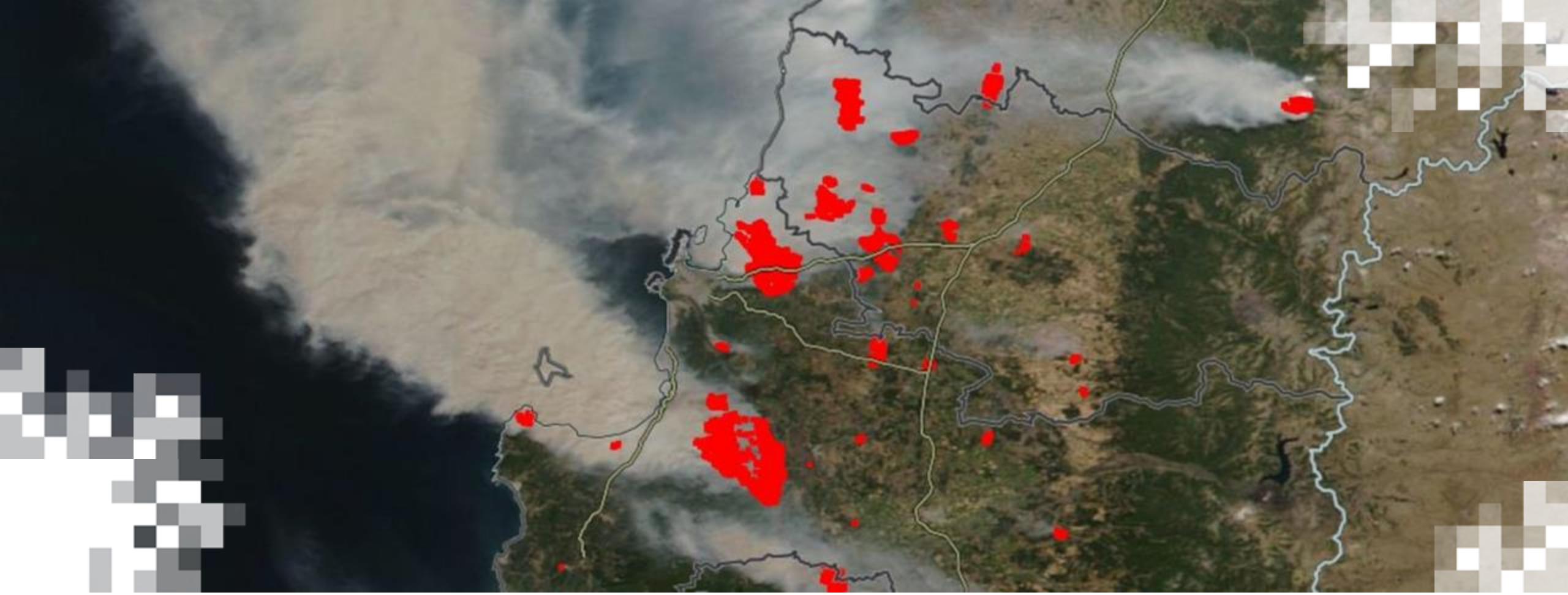
DOI: 10.1080/01431161.2023.2217983

	POLAR-ORBITING SATELLITES	GEOSTATIONARY SATELLITES
STRENGTHS	• Long history of use for active fire detection • Mature algorithm development • Users are familiar with the data • Higher spatial resolution (1km, 375m, 30m, 20m) • Higher spectral resolution • Observations ~2x a day, more towards the poles • Sensors typically optimized to map/monitor environmental phenomena (e.g., fire) • NRT detection data (MODIS/VIIRS) delivered to FIRMS within 3 hours of observation • NRT detection data (Landsat*) delivered to FIRMS within 30 minutes of satellite observation • URT* Detection data for MODIS & VIIRS delivered to FIRMS within 2 minutes of satellite observation *available for CONUS, S. Canada, N. Mexico	• Coverage of entire Earth disk/hemisphere within view • Observations are conducted multiple times hourly (10-15 mins for full disk) • Active fire detections are delivered to FIRMS within 20-30 minutes after satellite observation • Provide frequent sampling of fire activity • Enable earlier detection of new ignitions • Helpful for tracking fast moving fires • Helpful for tracking short-lived/transient fires • Helpful for 'filling-in' (fire tracking/monitoring between overpasses by polar-orbiting satellites) • Fewer satellites needed for complete global coverage

LIMITATIONS	• No continuous coverage of all of Earth at one time
	• Repeat observations vary:
	  • Daily global coverage (MODIS/VIIRS)
	  • Sentinel-2 (a+b+c) 3-4 days, Landsat8+9 (8-9 days)
	• Multiple images acquired of same location on same day are not of the same view geometry
	• Systematic pixel growth from nadir (MODIS)
	• MODIS onboard Terra and Aqua nearing end of life
	• Cloud coverage at time of overpass obscures observation
		• Primarily designed for weather applications
		• Inherent platform/sensor characteristics
		• Increased distortion of field of view with distance from nadir
		• Use of geostationary satellites for active fire detection relatively new
		• Algorithm development/refinement ongoing
		• Coarse Spatial resolution
		• Spectral resolution not-optimized for active fire detection
		• Data accuracy can be inconsistent (false positives)*
		*Harmonized global geostationary product available in FIRMS



Considerations for Using Active Fire Detections Demo



Part 1:
Summary

Summary

- Introduction to FIRMS: FIRMS US/Canada and FIRMS Global
- Satellite-based detection of fires
  - Active fire detection represents the center of a pixel that has been flagged as containing one or more fires
  - Size of the pixel varies with the spatial resolution of the satellite sensor (30m to 3 km)
- Overview of data available in FIRMS
  - 16 sensors, active fire detections, composite imagery, burned area, and other indices
  - Demo: FIRMS Navigation, active fire information, available imagery, and location, measuring and sharing capabilities
- Strengths/limitations of different satellite-based active fire detection data products
  - **Polar sensors**: mature detection algorithms, higher spatial resolution, repeat frequency varies (daily to 8-9 days)
    - Higher spatial resolution is helpful for observing smaller fires, fires within a fire perimeter
  - **Geostationary sensors**: lower spatial resolution, cover entire hemisphere, multiple observations per hour
    - Helpful for tracking fast-moving fires or proving information between polar observations
  - Demo: Impacts of swath width, spatial resolution, and higher view angles on fire detection

Looking Ahead to Part 2

- Use FIRMS to monitor the evolution and growth of wildfires
- Identify factors that can impact wildfire detection

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 04/31/2025
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 05/14/2025**

- **Certificate of Completion:**
  - Attend all three live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

Trainers:

- Jenny Hewson
  - jennifer.h.hewson@nasa.gov
- Brad Quayle
  - brad.quayle@usda.gov
- Diane Davies
  - diane.k.davies@nasa.gov
- Melanie Follette-Cook
  - melanie.cook@nasa.gov

- ARSET Website
- Follow us on Twitter!
  - @NASAARSET
- ARSET YouTube

Visit our Sister Program:

- DEVELOP

Resources

- Active Fire Detection
  - Giglio et al., 2003 - https://doi.org/10.1016/S0034-4257(03)00184-6
  - Giglio et al., 2016 - https://doi.org/10.1016/j.rse.2016.02.054
  - Wooster et al., 2021 - https://doi.org/10.1016/j.rse.2021.112694
- Scan View Angle Graphic
  - Schueler and Barnes, 1998 - https://doi.org/10.1175/1520-0426(1998)015%3C0430:NGMFPO%3E2.0.CO;2
  - Schueler et al., 2013 - https://doi.org/10.1080/01431161.2013.796102
- Sizes and Types of Fires that can be Detected:
  - Schroeder et al., 2014 - https://doi.org/10.1016/j.rse.2013.12.008
  - Schroeder et al., 2016 - https://doi.org/10.1016/j.rse.2015.08.032
  - Schroeder and Giglio, 2017 - https://viirsland.gsfc.nasa.gov/PDF/VIIRS_activefire_750m_ATBD.pdf
- Satellite Data Products
  - GOES ABI - https://www.goes-r.gov/products/overview.html
  - Meteosat SEVIRI - https://navigator.eumetsat.int/search?query=seviri&filter=satellite__MSG
  - Himawari AHI - https://www.eorc.jaxa.jp/ptree/userguide.html

Resources

- Polar-Orbiting and Geostationary Animations
  - https://spaceplace.nasa.gov/orbits/en/
- Geographic Coverage by GOES-18, GOES-16, Meteosat-9 (IODC), Meteosat-11 (MSG) and Himawari-9
  - Ceamanos, et al., 2021; https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JD034906
- MODIS Pixel Growth from Nadir to Swath Edge
  - Minnett et al., 2019; https://doi.org/10.1016/j.rse.2019.111366
- Systematic Increase in Pixel Footprint from Sub-Satellite Point (GOES ABI)
  - Losos et al., 2024; https://doi.org/10.1038/s41597-024-03071-z


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!