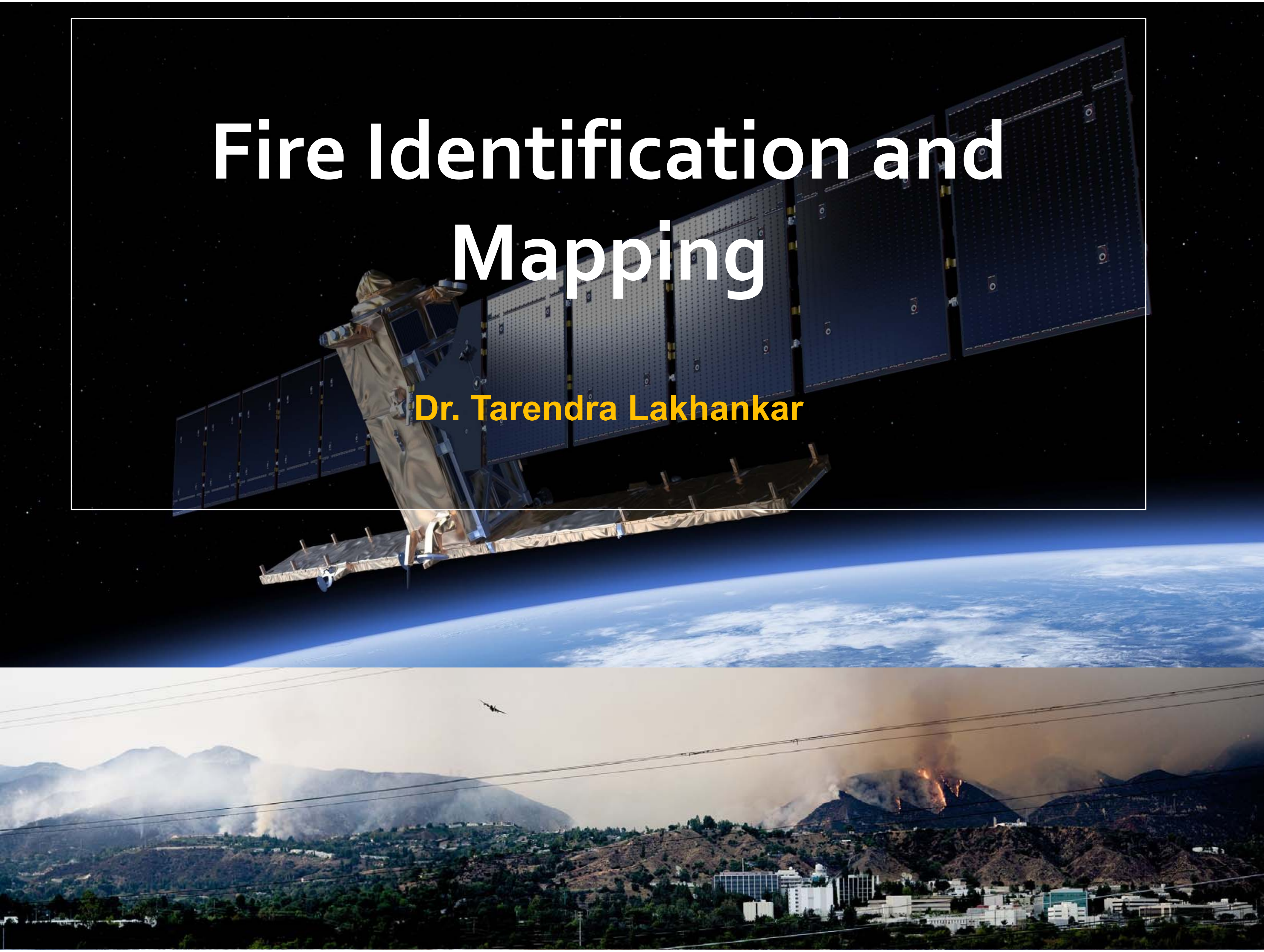
Fire Identification and Mapping

Dr. Tarendra Lakhankar



In this lecture:

Motivation

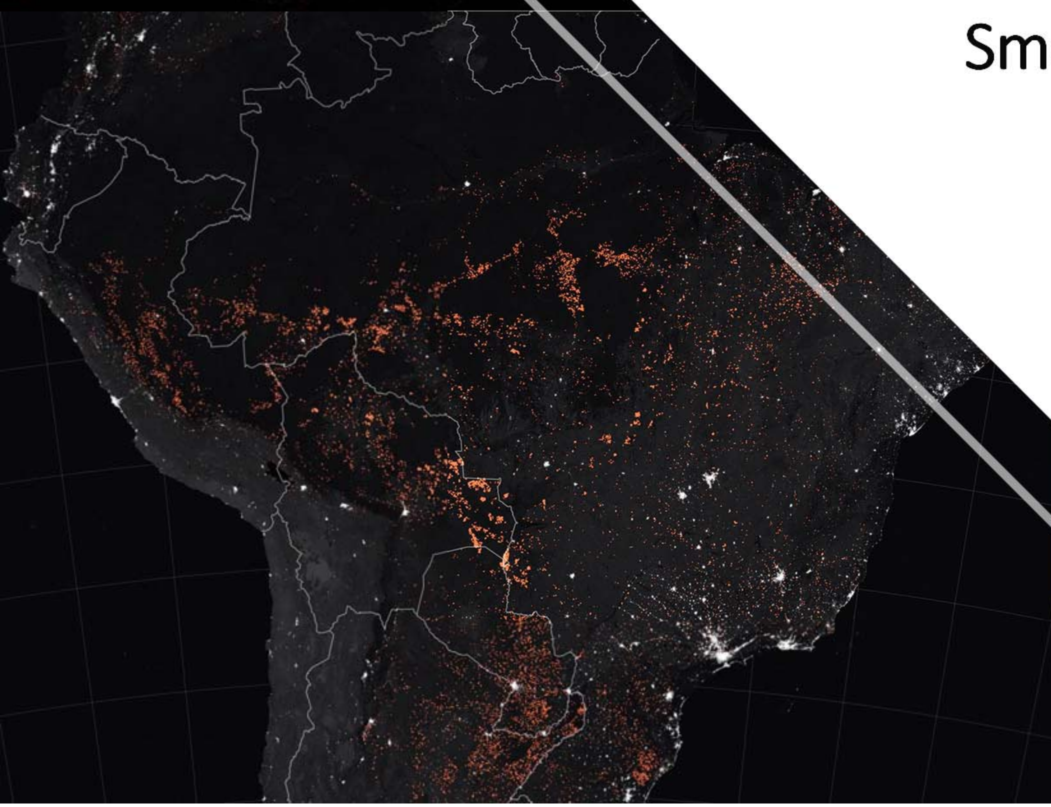
Technique for fire detection

Available Products

Fire damage assessment: burned area

The Devastation of Fire

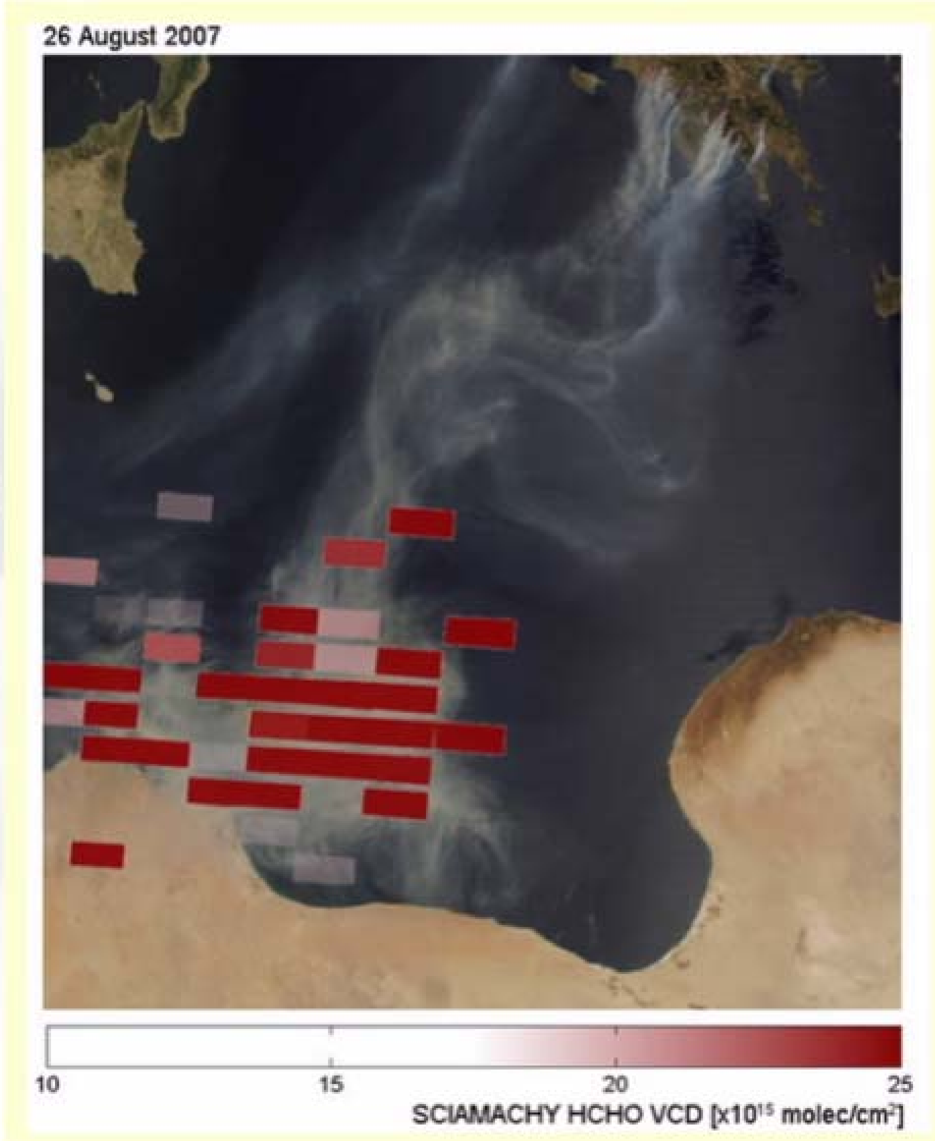

The Dangers of Smoke




Neighboring impacts of Smoke

Formaldehyde concentration from SCIAMACHY:

Poisonous gas released by biomass burning in Greece reaches the coast of Libya.



Neighboring impacts of Smoke

Satellite image showing burned areas of Greece as a result of several forest fires

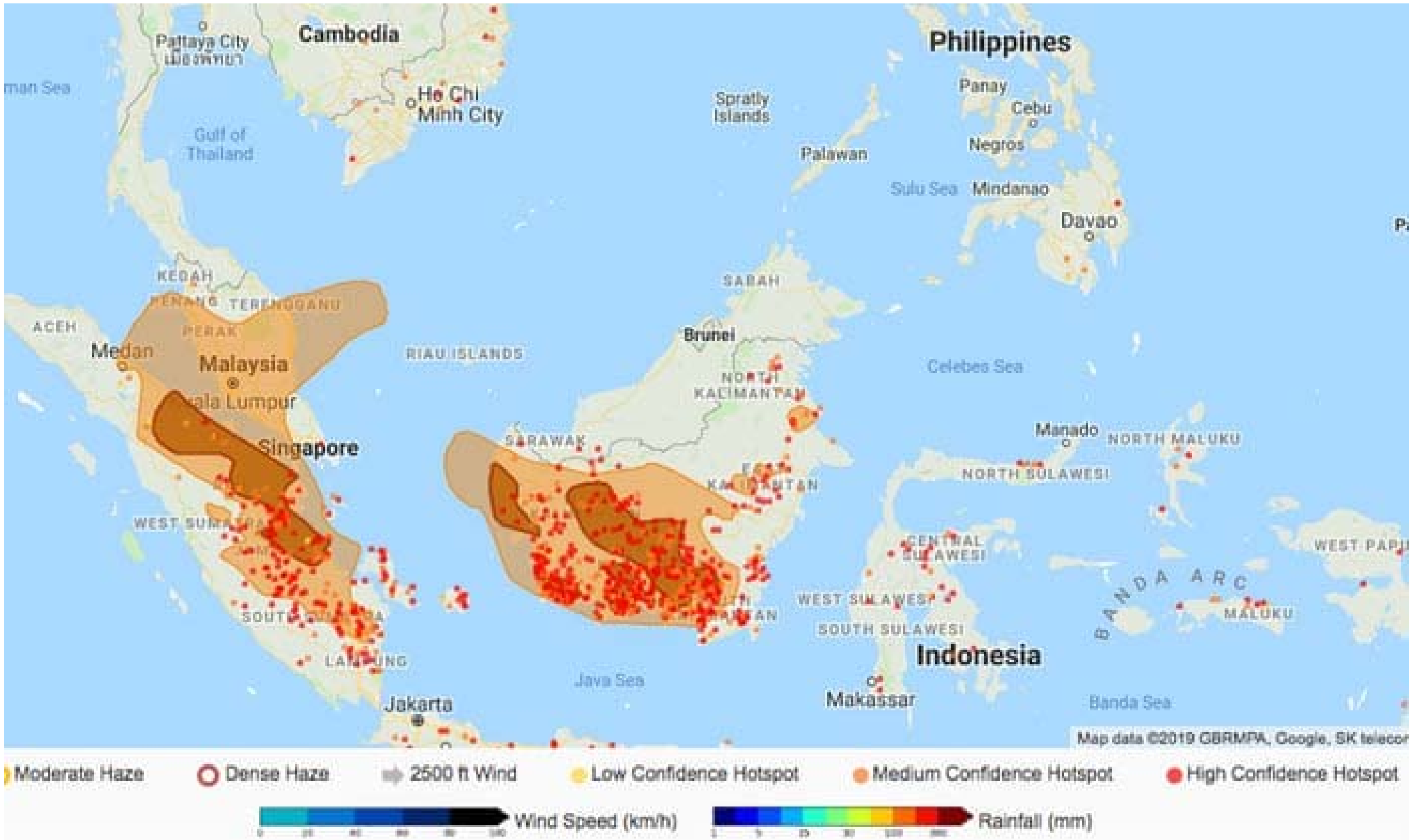
MODIS 28 July 2003

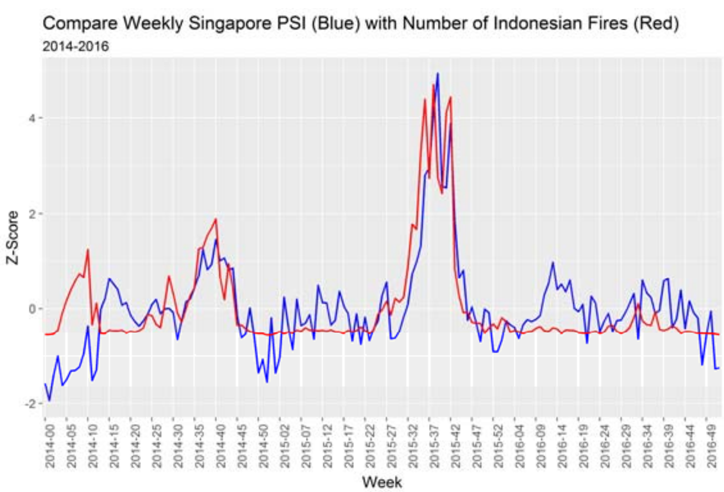
VIS plus IR (0.6; 0.8; 2.1)

The Result of Fire

- Forest fires increase carbon dioxide levels in the atmosphere, contributing to the greenhouse effect and climate change.
- In addition, ashes destroy much of the nutrients and erode the soil, causing flooding and landslides.

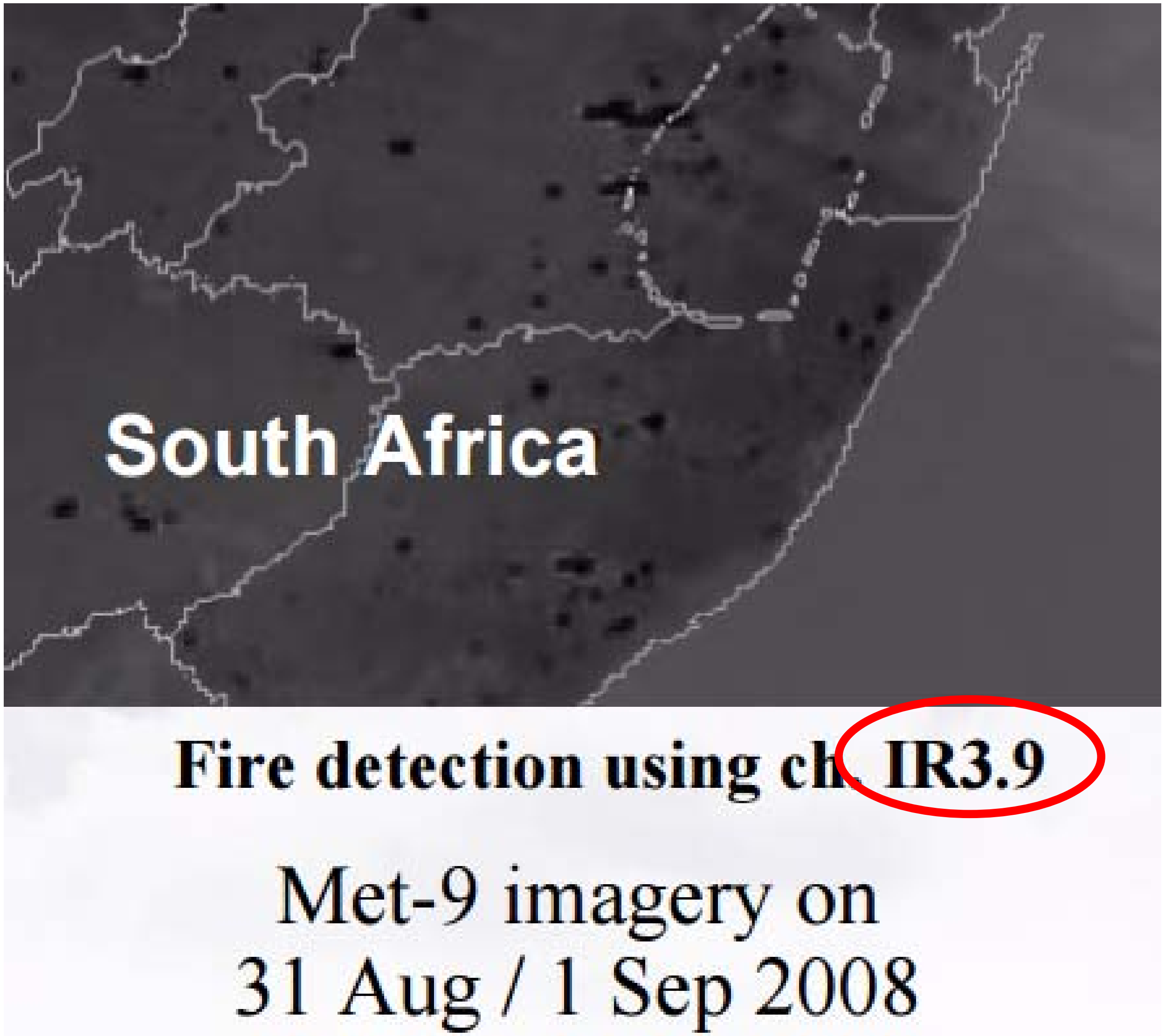
Indonesian forest fires affect Singapore's Air Quality





October 14, 2015: MODIS TERRA satellite imagery reveals smoke plumes from massive peat fires on Kalimantan

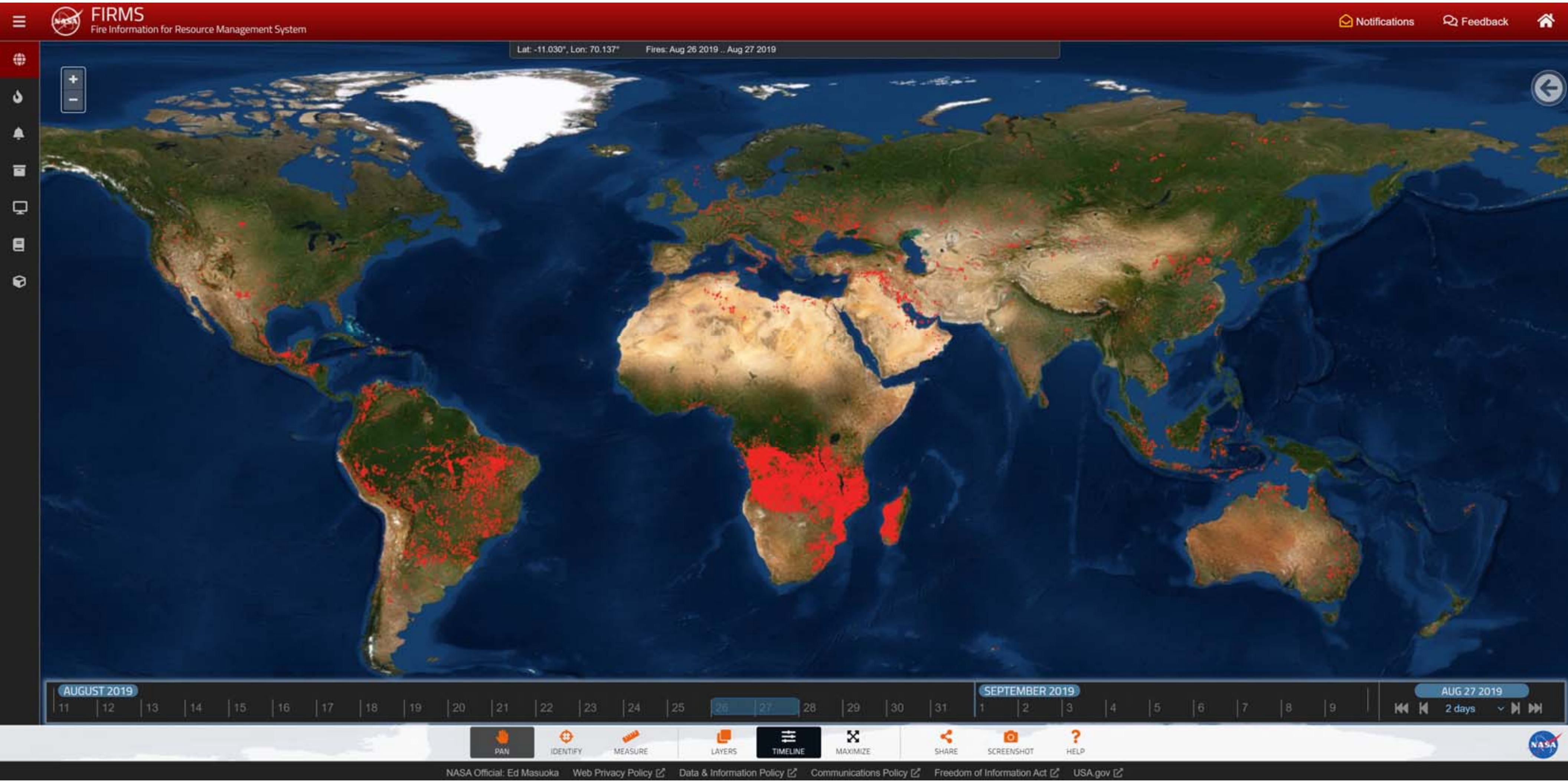
PHOTO: WORLDVIEW



Fires can be seen in satellite imagery

Image taken in 3.9µm band of Meteosat SEVIRI sensor

Fire Information for Resource Management System (FIRMS)



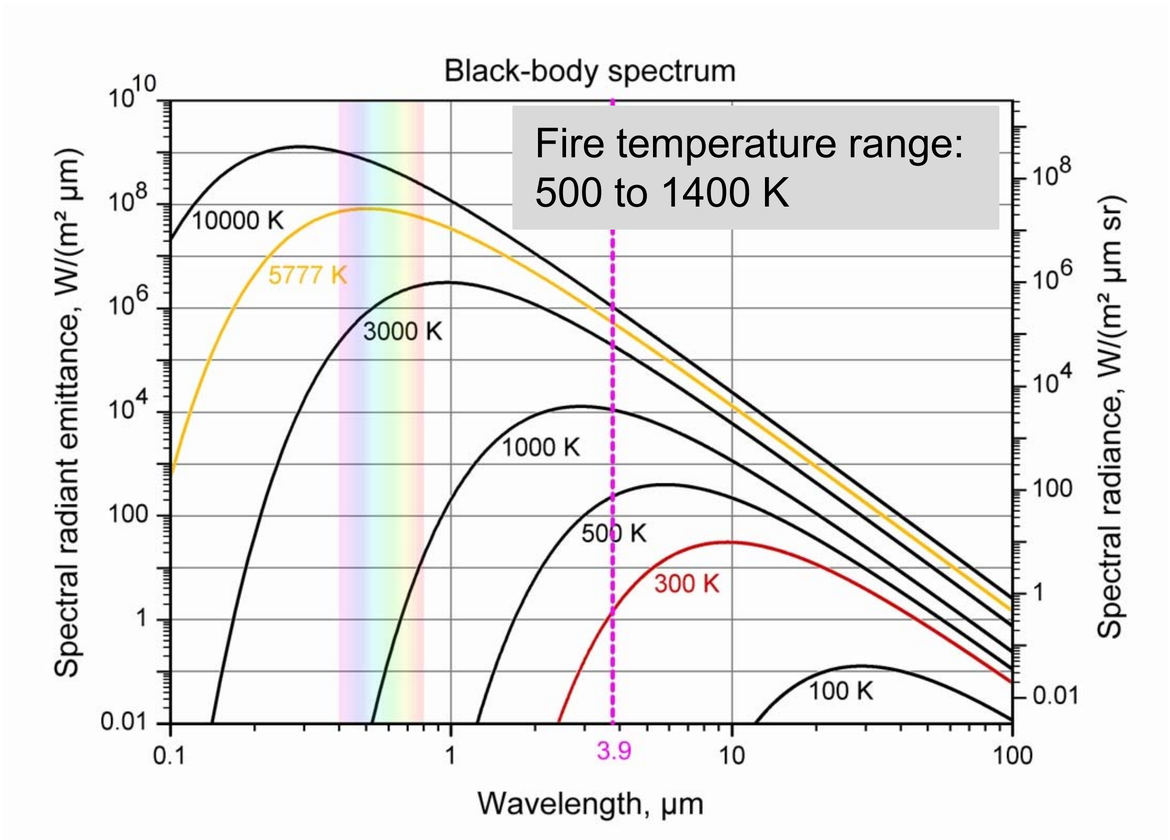
Fire Detection : Theory

Planck's Radiation Law and Fire Temperature

Planck's law gives the amount of electromagnetic energy radiated by a black body at given temperature for different wavelengths.

Temperature of fires ranges from ~ 500 K (weak smoldering) to ~ 1400 K (intense flaming).

For these temperature emission mission peaks in the middle-infrared spectral region (2-6 μm)

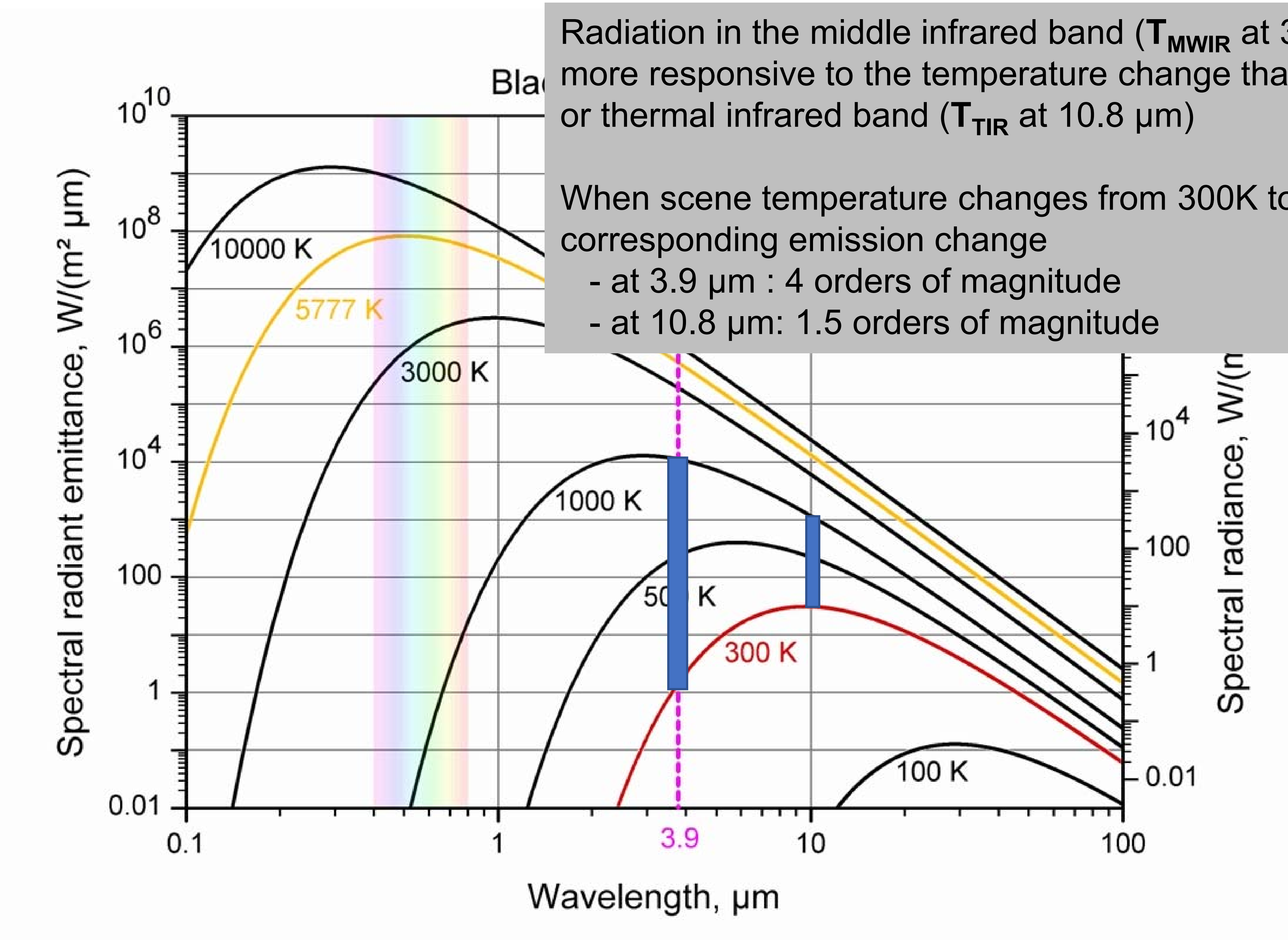


For fire detection most often observations in the 3.7-3.9 μm are used since
(1) This is an "atmospheric window" band: you can see land surface
(2) Most weather satellite sensors have a corresponding spectral channel

Sensitivity to fire: 3.9 vs 10.8 µm

Radiation in the middle infrared band (**T**$_{MWIR}$ at 3.9 µm) is more responsive to the temperature change than in the far or thermal infrared band (**T**$_{TIR}$ at 10.8 µm)

When scene temperature changes from 300K to 1000K corresponding emission change
- at 3.9 µm : 4 orders of magnitude
- at 10.8 µm: 1.5 orders of magnitude

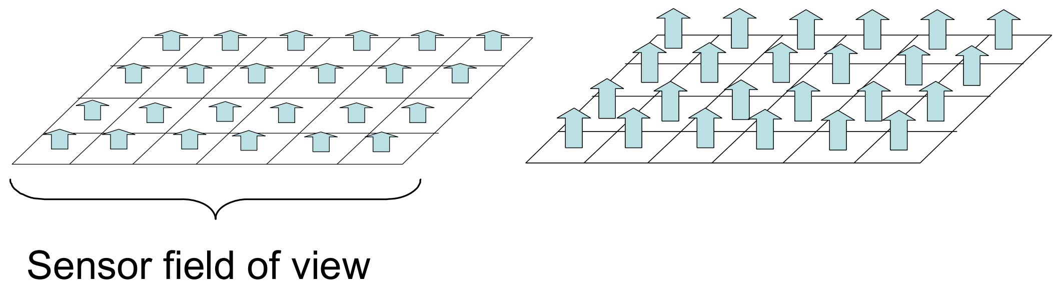


T(3.9) vs T(10.8): No fire

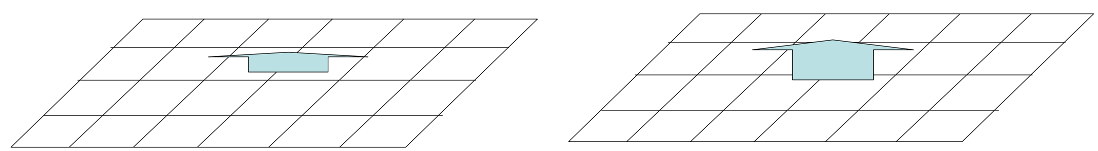
T=**300K** across the whole pixel

3.9 µm | **10.8 µm**

No fire: Emission is distributed evenly across the pixel



Pixel radiance measured by satellite sensor



Convert radiance to temperature

$$T = c_2 / [\lambda \ln(c_1 / (\lambda^5 B)+1)]$$

Observed brightness temperature

300 K | **300 K**

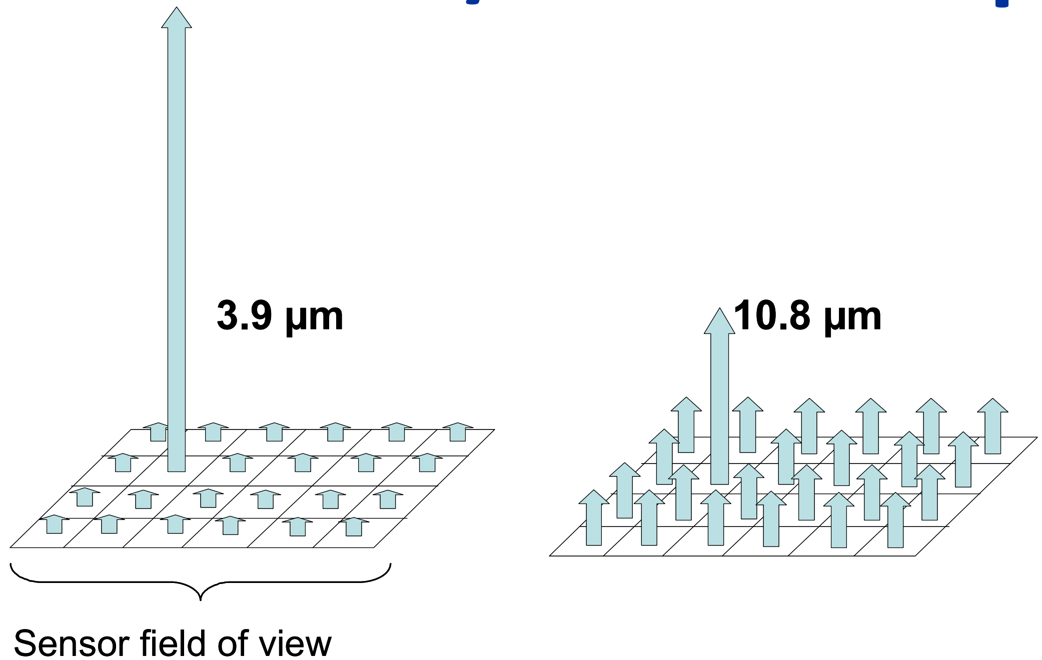
Brightness temperature difference

T(3.9) – T(10.8) = 0K

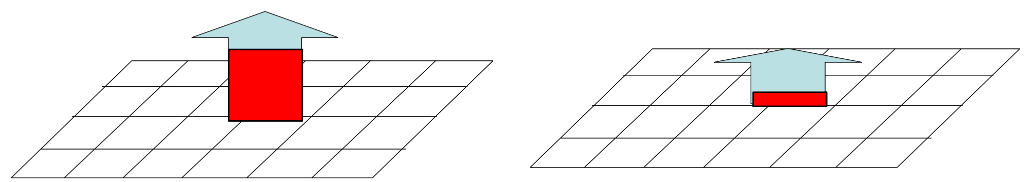
T(3.9) vs T(10.8): Fire over 1/24th of the pixel

Fire T=**1000K**
Background **T=300K**

Fire: Emission increases in a small portion of a pixel



Pixel radiance measured by satellite sensor



Convert radiance to brightness temperature

$$T = c_2 / [\lambda \ln(c_1 / (\lambda^5 B) + 1)]$$

Observed brightness temperature

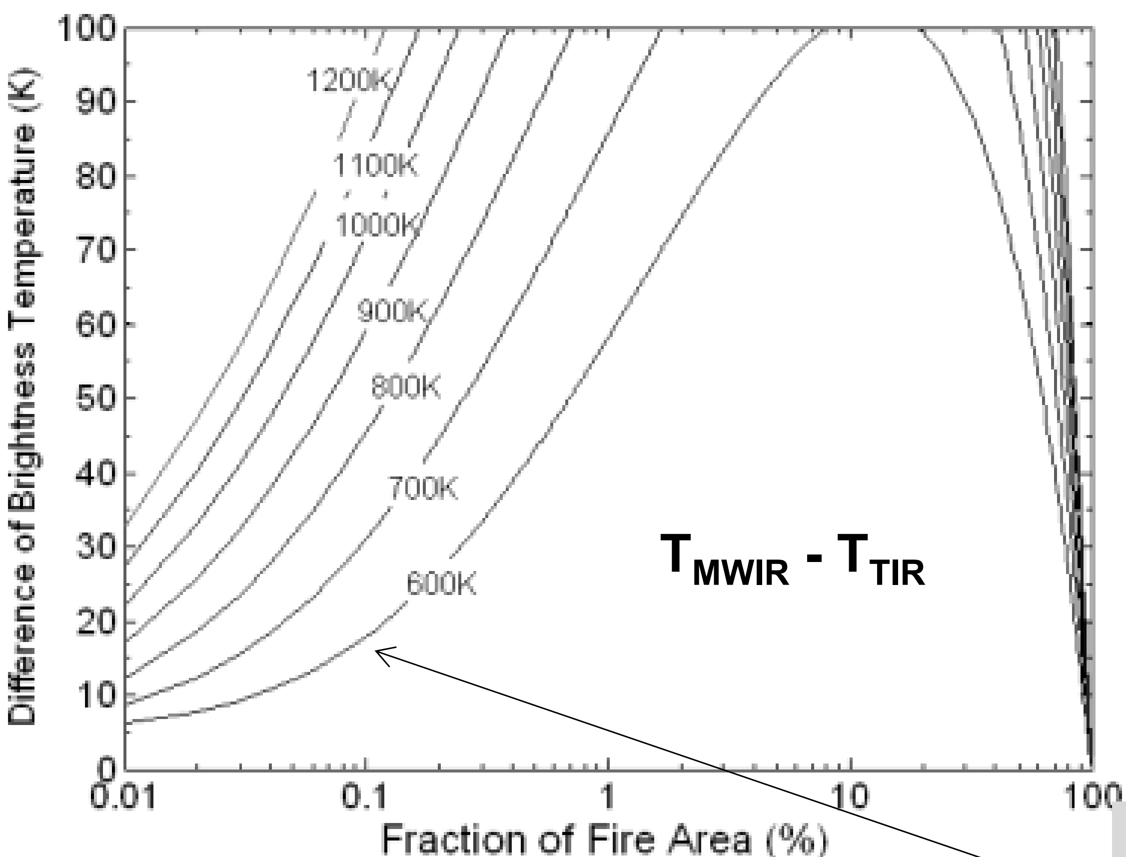
320 K **301 K**

Brightness temperature difference

T(3.9) – T(10.8) = 19K

Power of the T(3.9) – T(10.8) Difference

As a result, when a fire covering a small fraction of the pixel begins, the observed pixel brightness temperature at 3.9 µm (**T_{MWIR}**) would noticeably exceed the brightness temperature observed at 10.8 µm (T_{TIR}).



Large difference

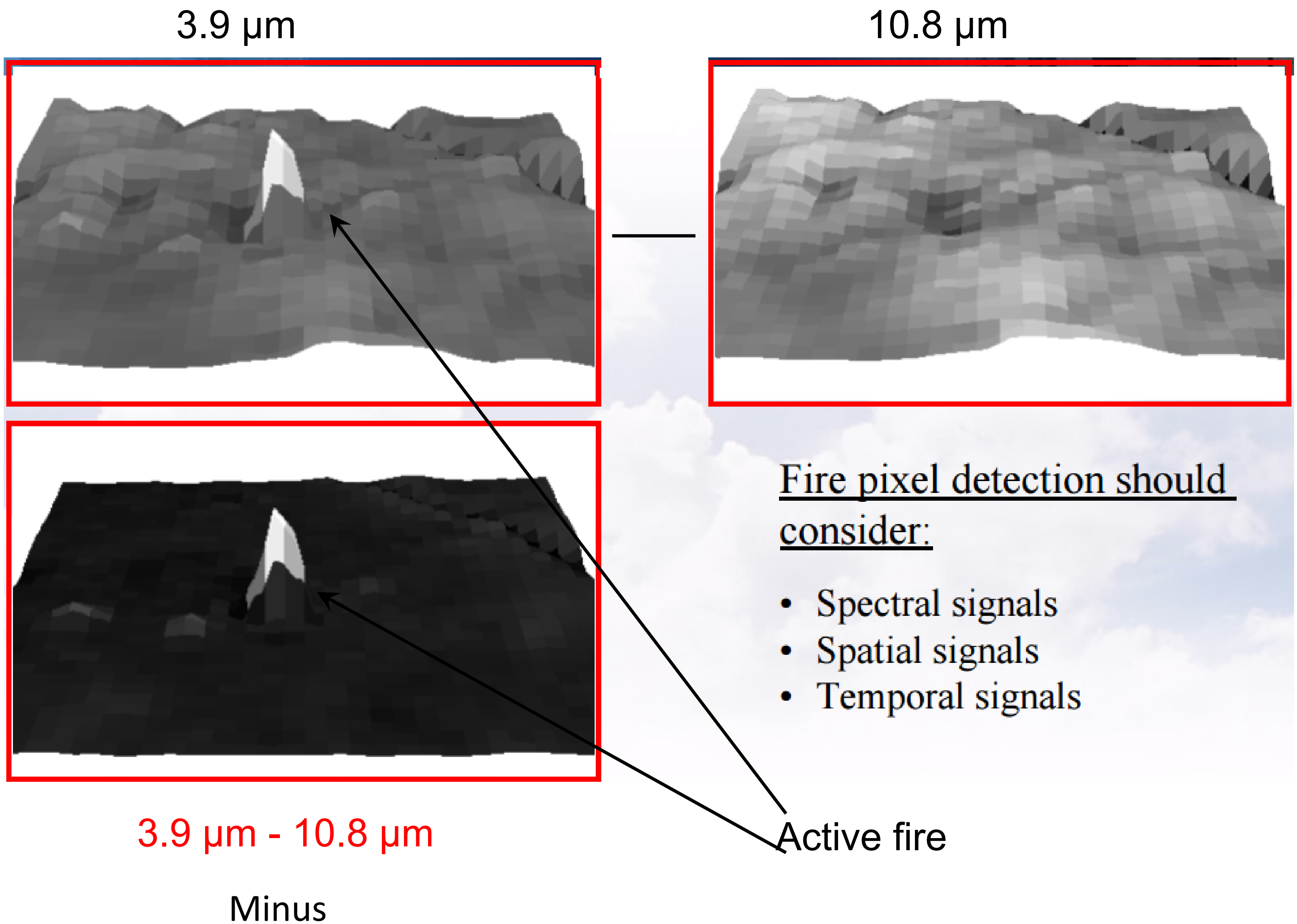
T_{MWIR} - T_{TIR}

is the primary indicator of the fire within the sensor field of view

This spectral feature is actively used in satellite-based fire identification algorithms

Substantial increase of the difference occurs even when the burning area is less than 0.1% of the pixel area

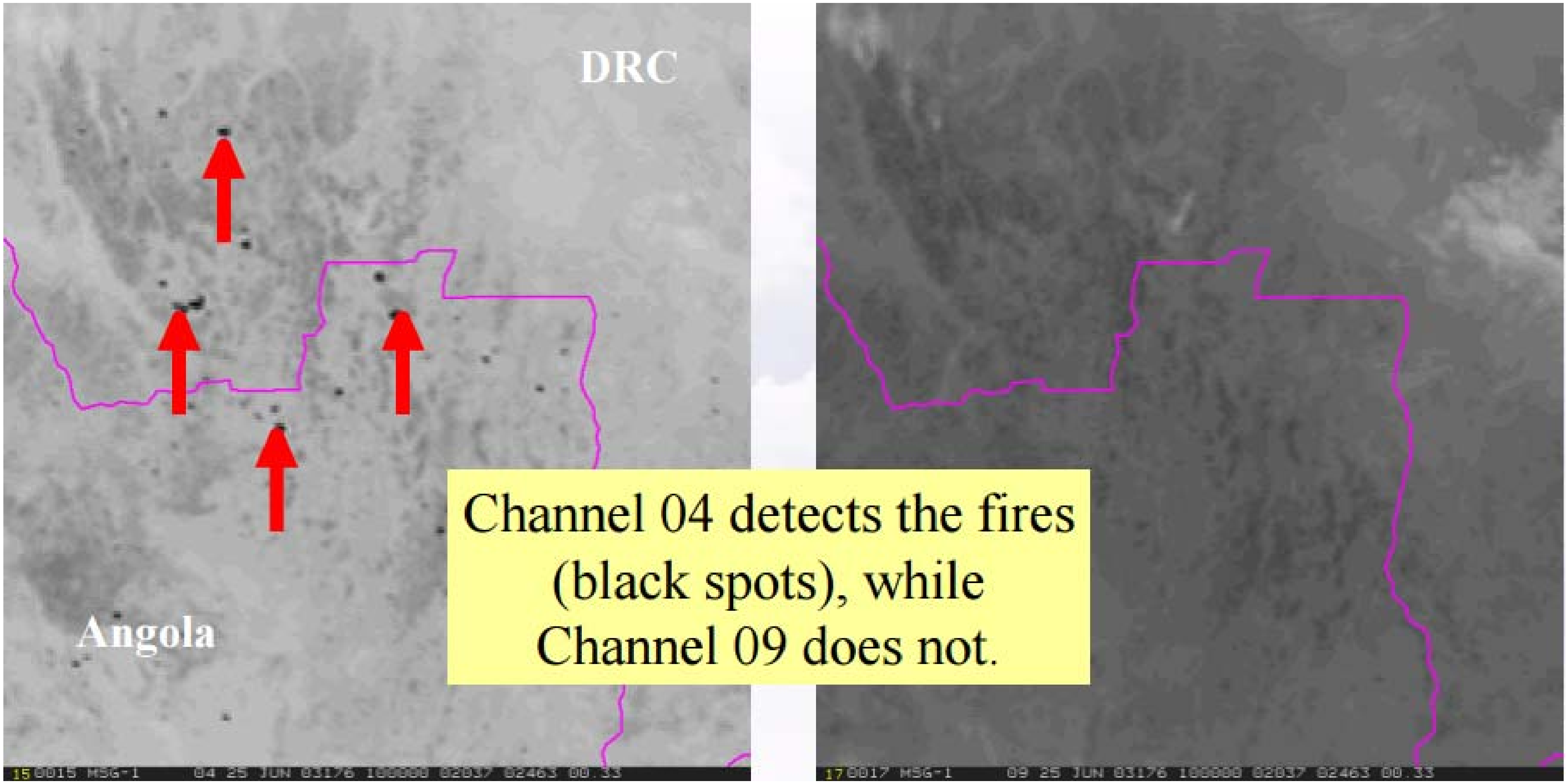
Power of the T(3.9) – T(10.8) Difference



Fire pixel detection should consider:

- Spectral signals
- Spatial signals
- Temporal signals

Example of Fires in Meteosat Imagery



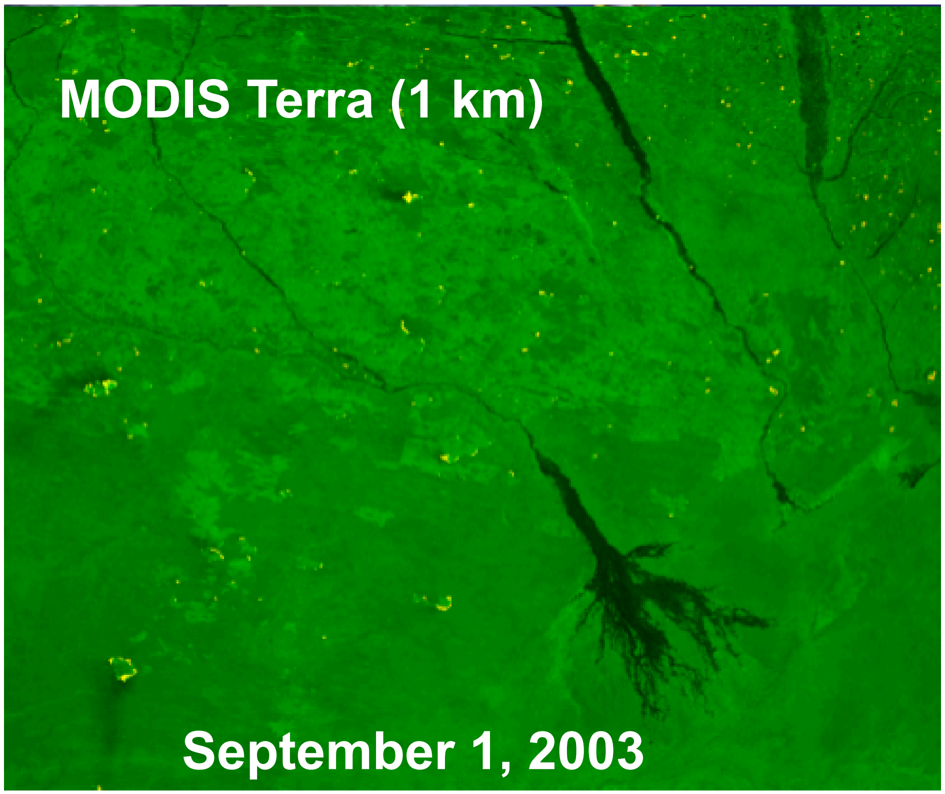
Meteosat SEVIRI, ch.4 (3.9 μm)

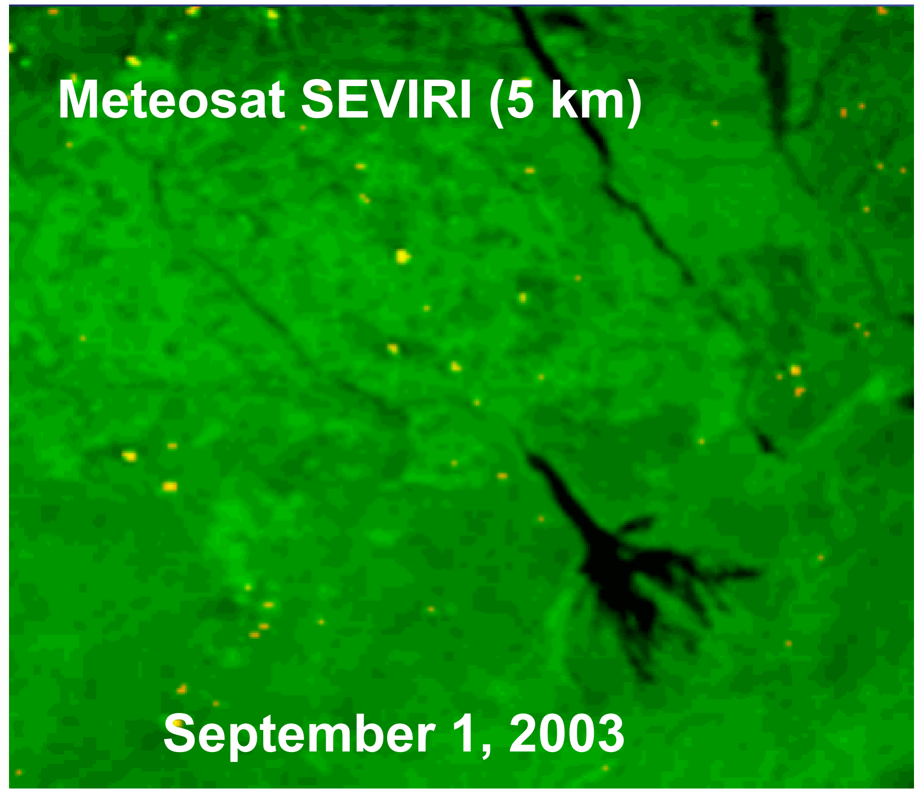
Meteosat SEVIRI, ch.9 (10.8 μm)

June 25, 2003 10:00UTC

Spatial Resolution Matters

- Higher spatial resolution sensors allow for a much more precise detection and more detailed mapping of active fires.
- At the same time, frequent observations from geostationary satellite provide information on the fire temporal dynamics and spread and sometimes allow for earlier fire identification.

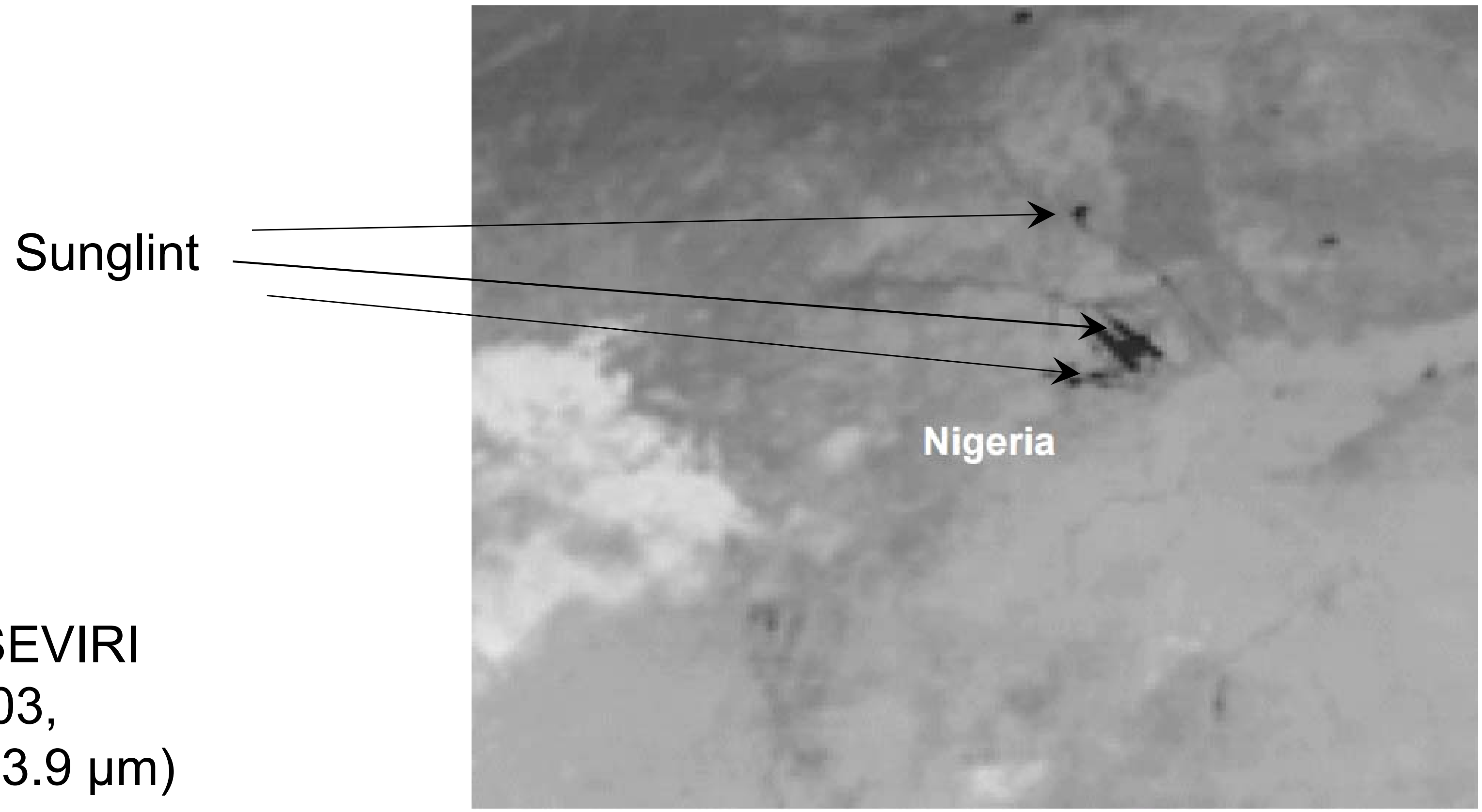




Yellow: Detected active fire pixels
Green: Brightness temperature at 3.9 µm

Not All Detected Fires Are Fires…

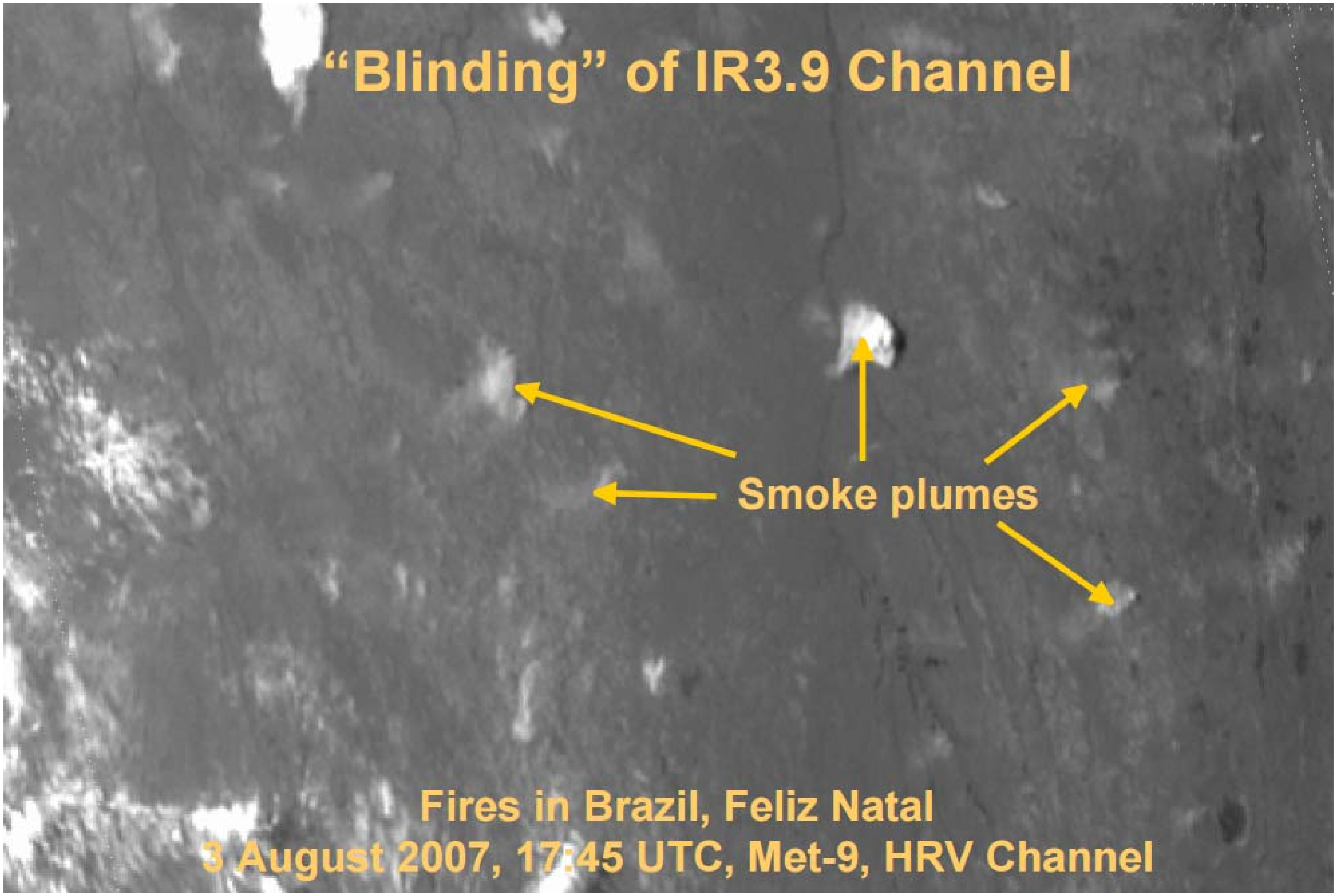
- During daytime sun glint may increase brightness temperature observed in the middle infrared. As a result sun glint on small lakes and rivers may be confused with fires.
- Sometimes very hot land or rocks may also cause false fire identification. Therefore fire detection algorithms usually are not run over deserts or other non-vegetated land types



Meteosat SEVIRI
June 5, 2003,
channel 4 (3.9 μm)

Not All Fires Are Detected…

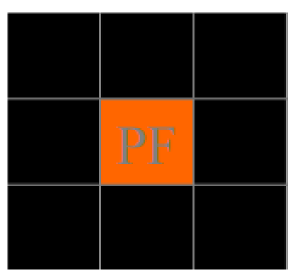
Fires may not be properly detected and mapped due to clouds and smoke plumes masking the fire

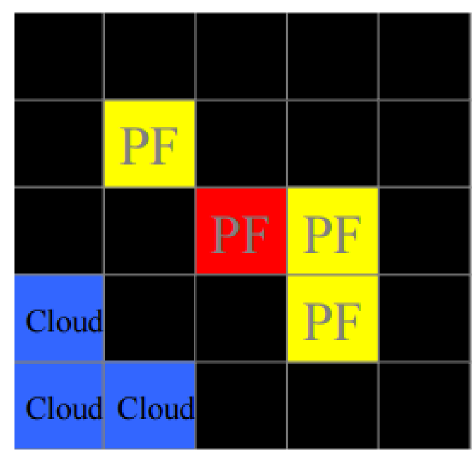


Typical Algorithm for Fire Detection

Stage 1: Potential Fire Detection: based on 3.9 μm and 10.8 μm temperatures and their difference

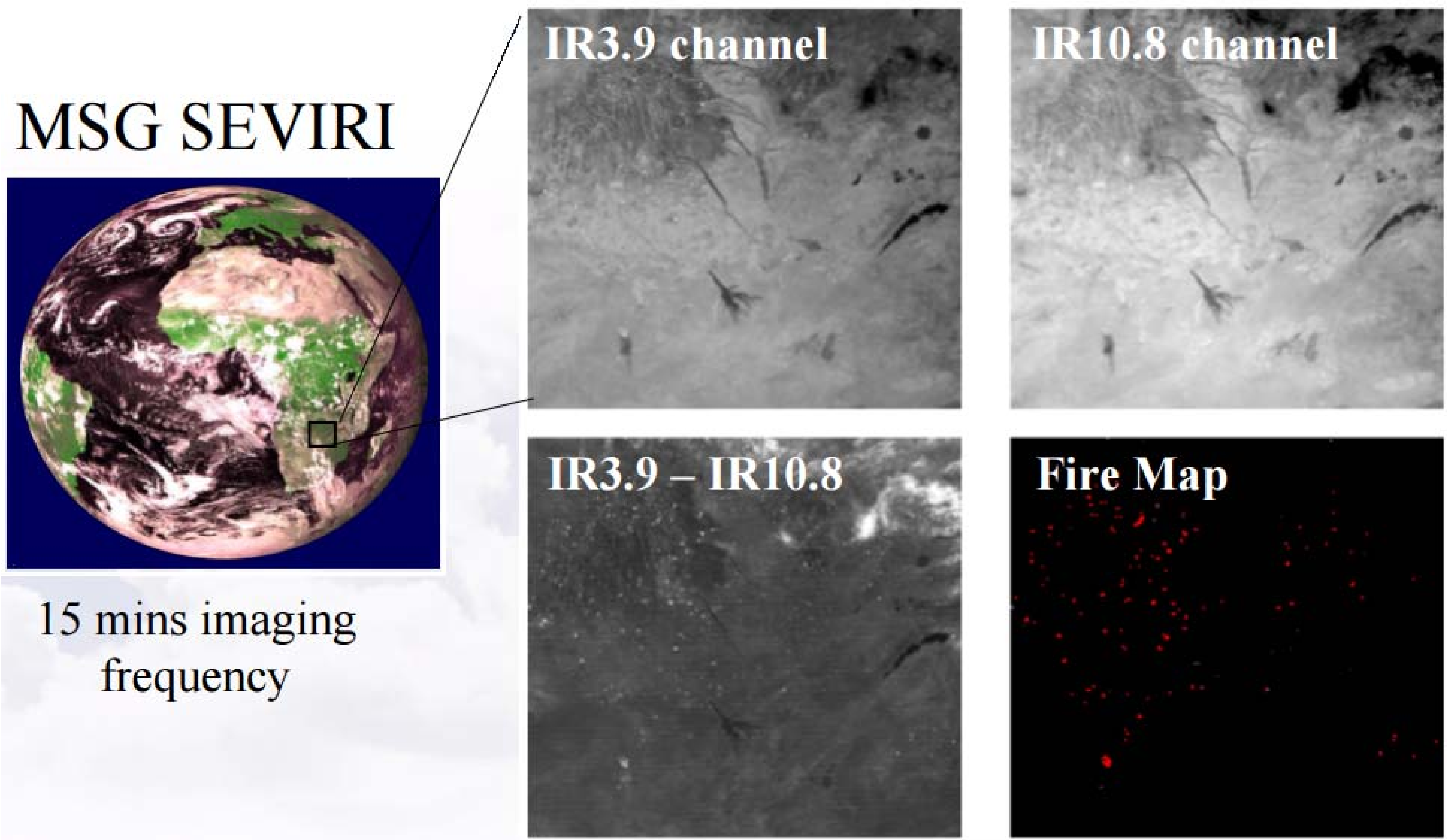
Stage 2: Textural analysis of brightness temperatures within a 3x3 or a larger window centered at the potential fire pixel. Identify whether potential fire pixel is isolated or is part of a small cluster of fire pixels





Stage 3: Filtering of false fire identifications (e.g., remove identified fires in deserts)

Example of Active Fire Retrieval: Meteosat



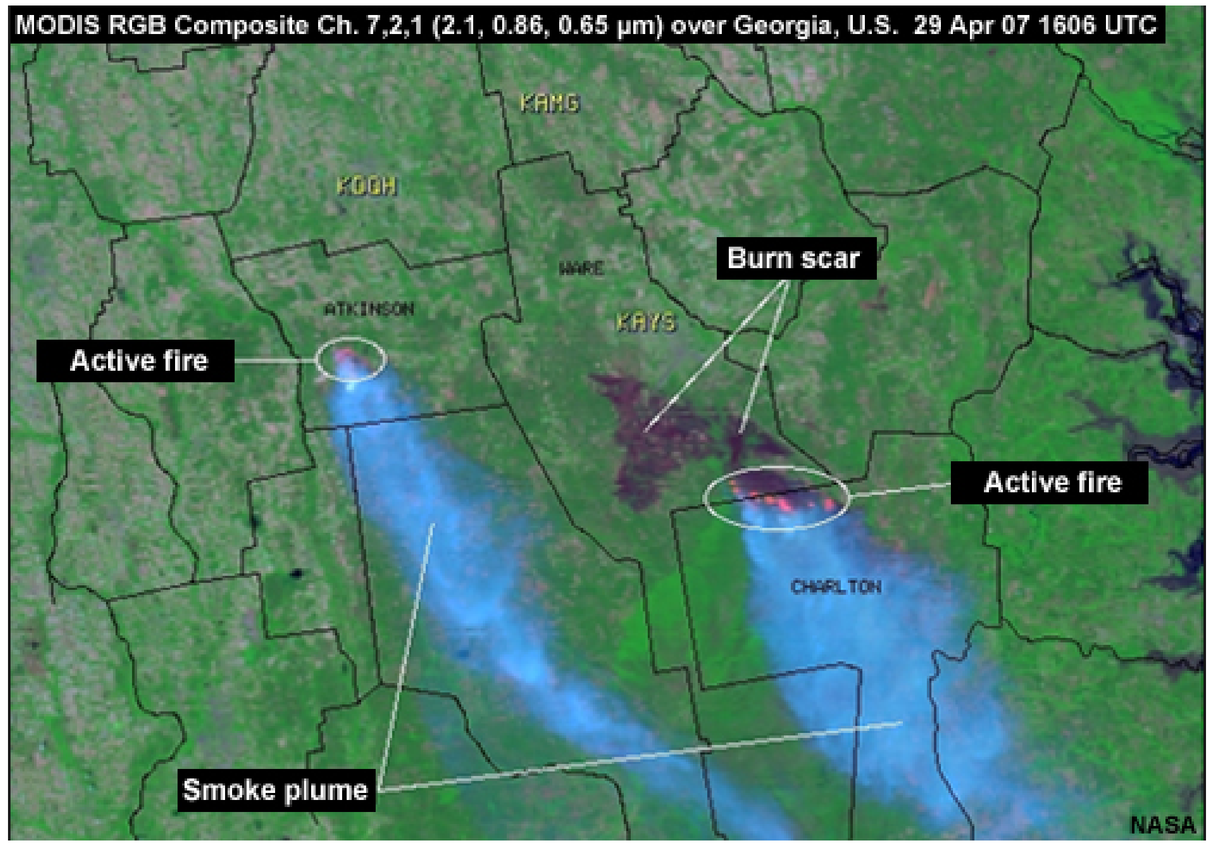
Fire RGB

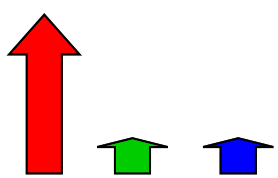
MWIR (3.7 µm)

NIR (0.8 µm)

VISIBLE (0.6 µm)

To show fires in the imagery false color combination of bands MWIR, NIR and visible may be used. With properly tuned color contrast active fire location may be clearly seen: No need to run an automated algorithm



Fire:  → Appears as red in the RGB image

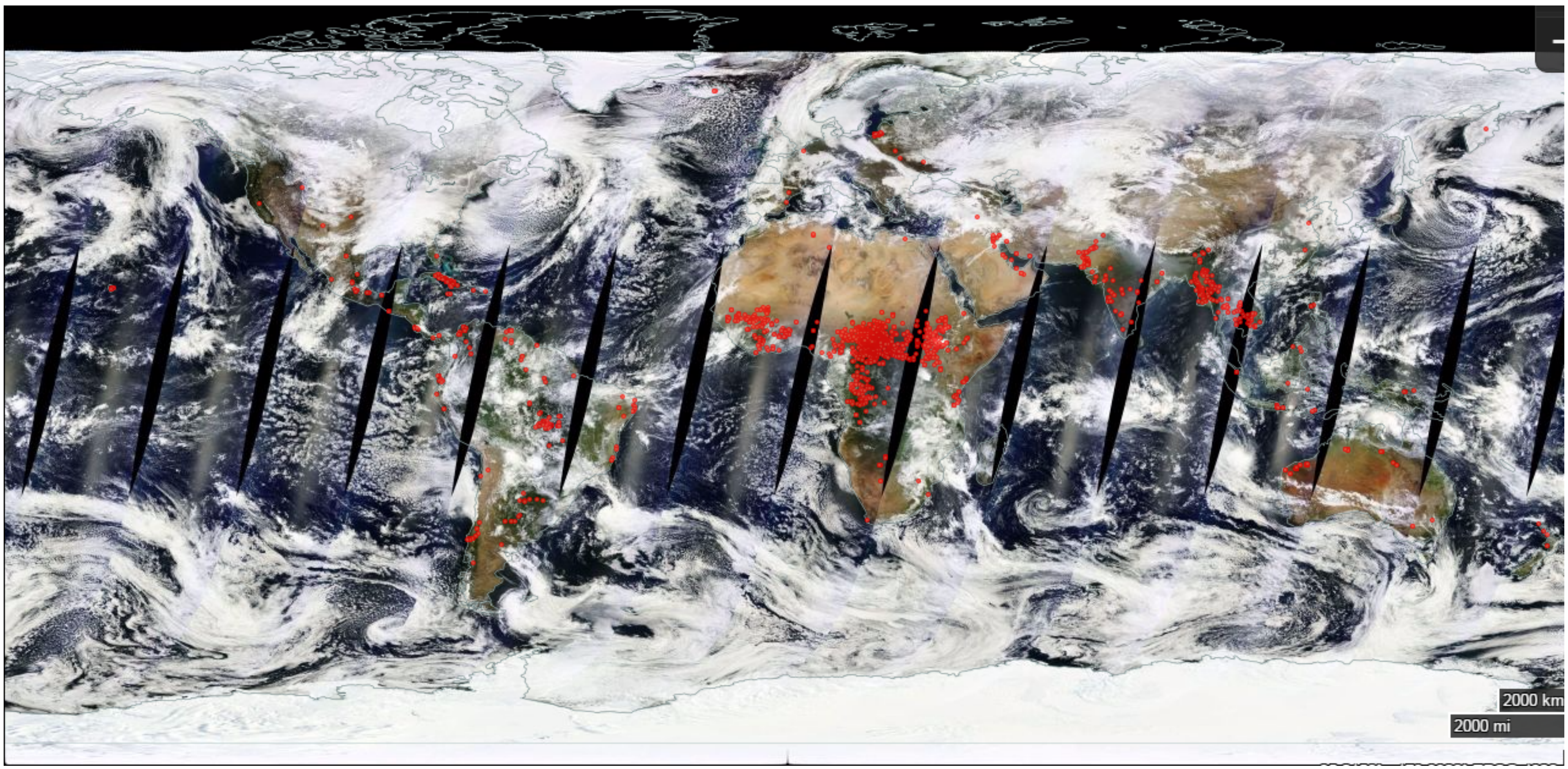
Example of Active Fire Retrieval: MODIS

To make the visual presentation of identified active fires more appealing fire locations may be drawn on top of a true color image as red dots.

Identified fires

Example of Active Fire Retrieval: MODIS

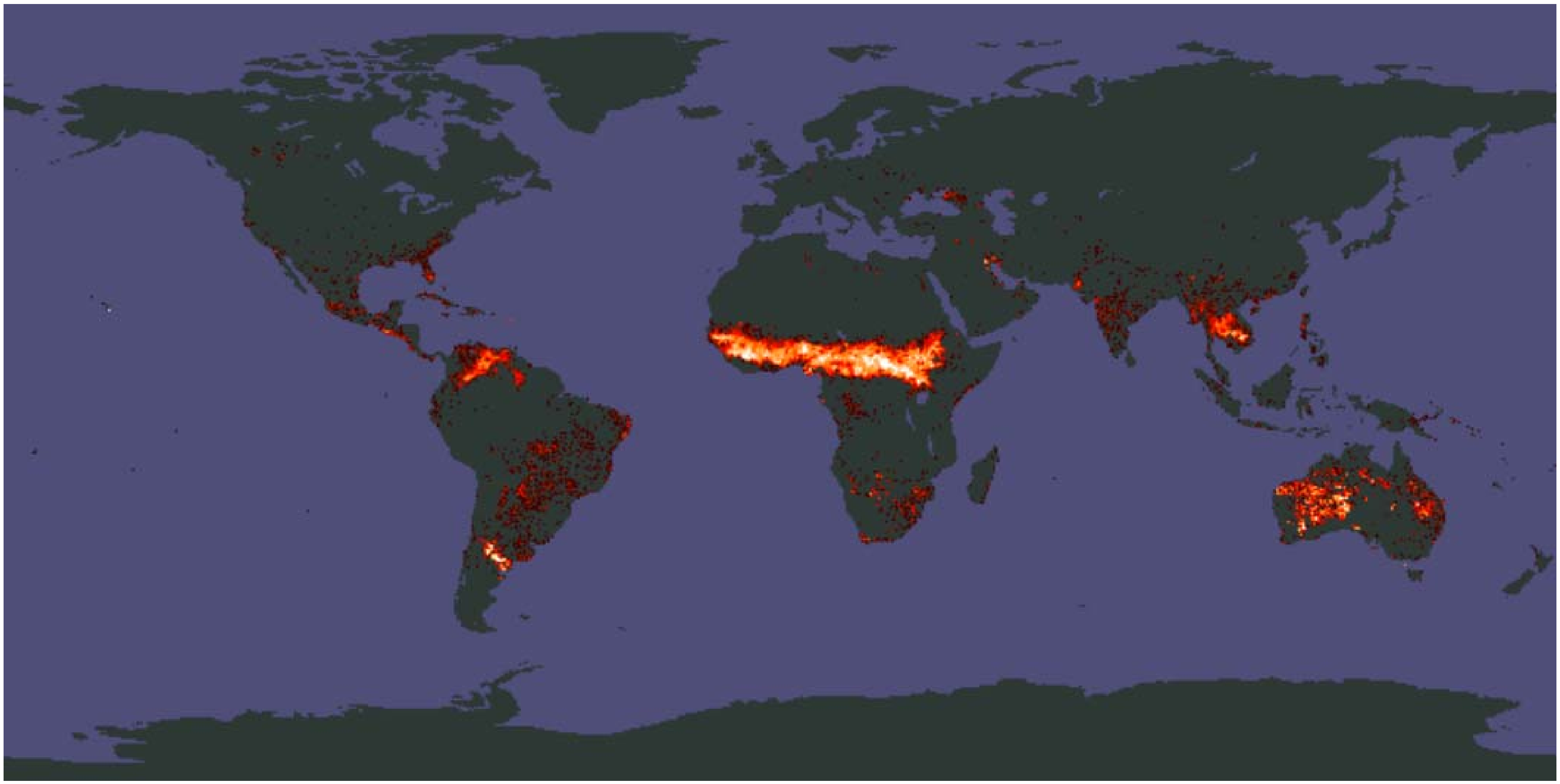
Fire monitoring is conducted globally using observations from polar orbiting satellites. Fire identification algorithm works day and night. Daily global fire products are available from NASA, NOAA, EUMETSAT. Many products are available in near real time.



Daily map of active fire locations derived with MODIS data.

MODIS Fires: Monthly Statistics

Daily fire identifications are aggregated into monthly maps. These maps are needed primarily for climatological purposes: To understand the trends in fire occurrence and to estimate the total amount of carbon emissions from fires.



Daily map of active fire locations derived with MODIS data.

Satellite Fire Products

To save space, rather than maps the results of fire identification are typically provided as the list of geographical locations (pixel coordinates) where active fires were detected.

Active fire products are available from most weather satellites, both polar orbiting and geostationary.

This includes

<u>Polar orbiting</u>
AVHRR (all operational platforms)
MODIS (both Terra and Aqua satellites)
VIIRS

<u>Geostationary</u>
GOES (two satellites cover western Hemisphere)
Meteosat (Europe, Africa)
MTSAT (covers Eastern Asia and Australia)

Immediate Consequences of Fires:

- Aerosols
- Burned Areas

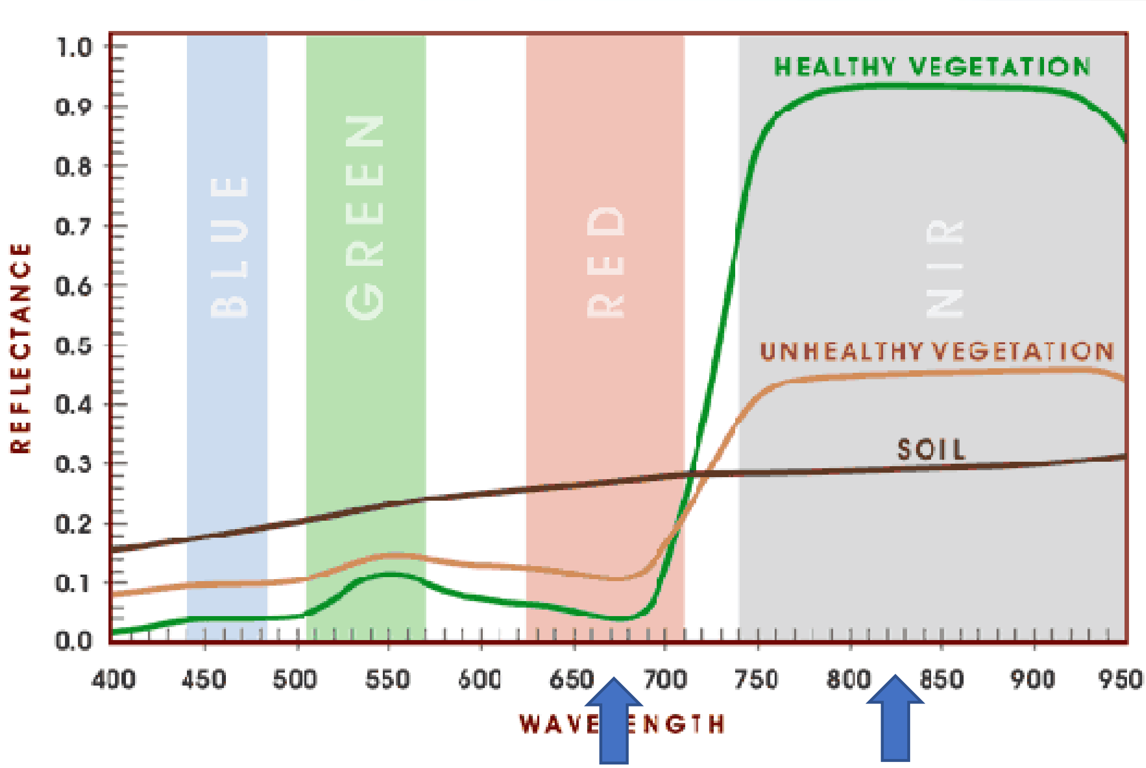
Burned Areas (Burned Scars)

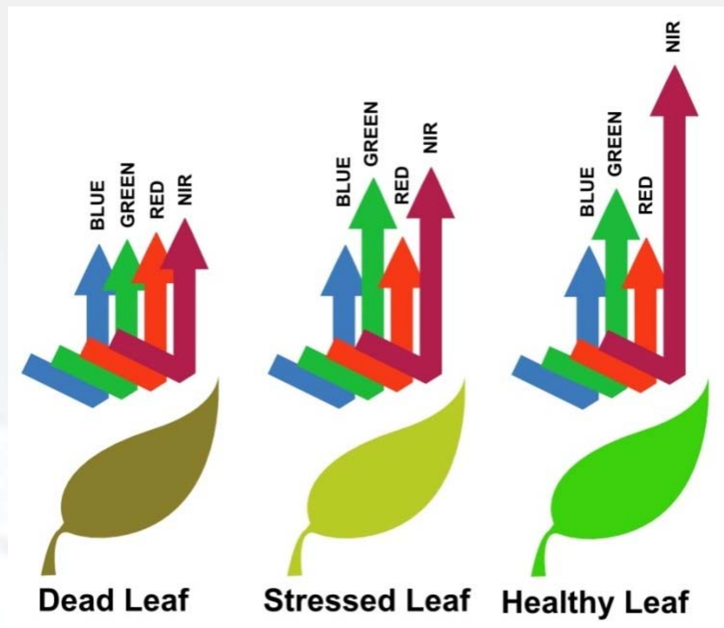
Burned areas may be identified visually and delineated interactively in true color images or in false color RGB images involving near infrared reflectance

Automated identification is based on the analysis of vegetation-related spectral indices and their **change** in the areas were active fires were previously detected.

Most often Normalized Difference Vegetation Index (NDVI) is used.

Basics of Vegetation Monitoring





Primary bands in vegetation cover observations

When moving from non-vegetated to vegetated land most substantial changes in the surface reflectance occur in the visible and near infrared spectral bands.

Therefore observations in the red and NIR spectral bands are most efficient for monitoring vegetation cover and vegetation state from space

NDVI

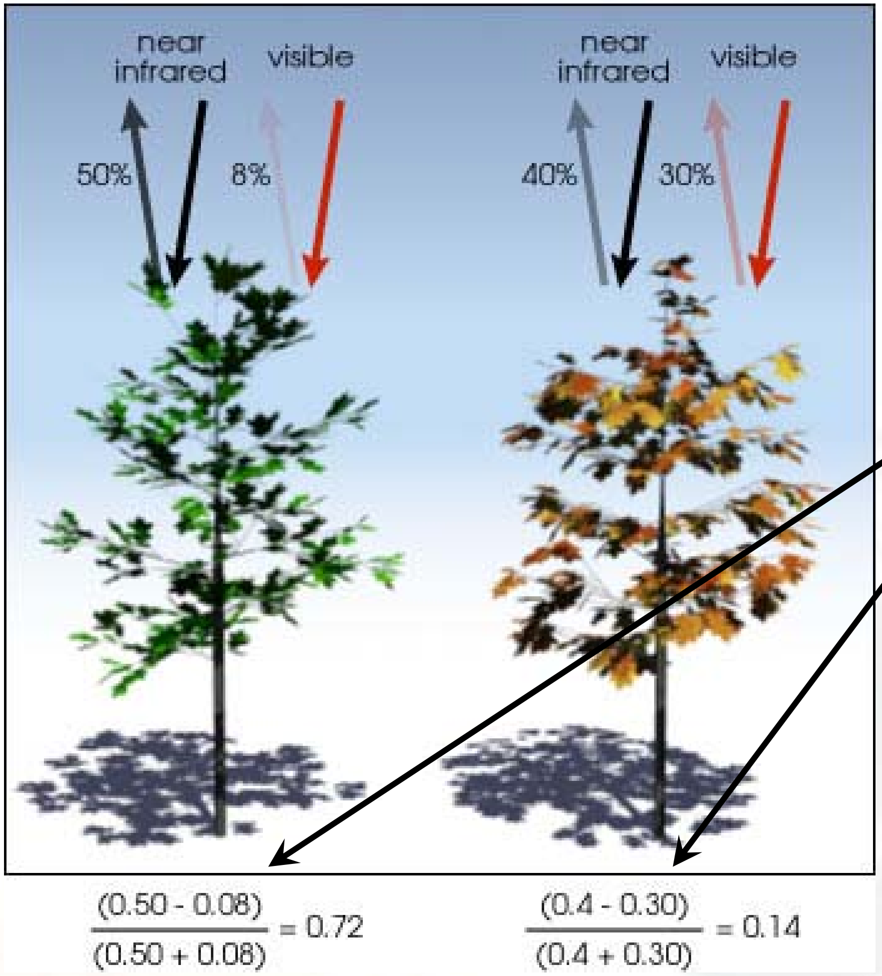
Normalized Difference Vegetation Index **(NDVI) :**

$$\mathbf{NDVI = (R_{NIR} - R_{RED}) / (R_{NIR} + R_{RED})}$$

$\mathbf{R_{NIR}}$: reflectance in the near infrared (~0.8 µm)
$\mathbf{R_{RED}}$: reflectance in the "red" part of spectrum (~0.6 µm)

All imaging sensors onboard polar orbiting weather satellites since early 1980s and many geostatonary satellite sensors provide observations in the visible and near infrared. This allows for using their data to derive NDVI.

NDVI: Typical Values



NDVI theoretical range: -1.0 to +1.0

NDVI=0.4-0.7 : healthy green vegetation,

NDVI=0.1-0.2: stressed or sparse vegetation

NDVI= 0.0-0.1: Bare rock or soil

NDVI of snow and clouds is zero or negative

NDVI is the most popular spectral index vegetation cover and density
NDVI is technically very easy to implement
NDVI characterizes the "greeness" of a scene being observed
NDVI is closely related to biomass volume

Typical Algorithm to Identify Burned Areas (Burned Scars)

Pixel is clear of clouds → no → **No data or area is not burned**

↓ yes

Active fires were earlier identified within a certain area around the pixel → no → **No data or area is not burned**

↓ yes

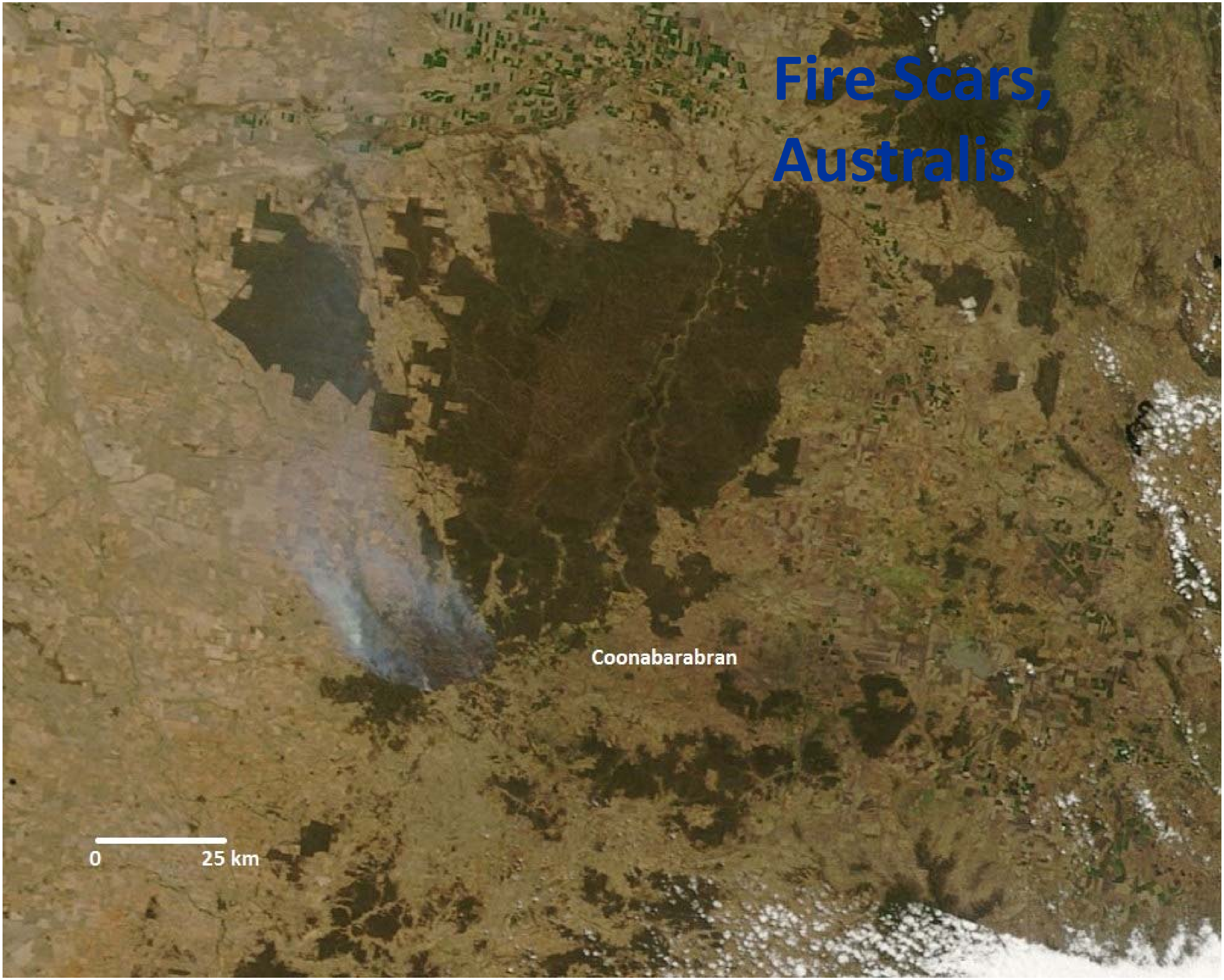
NDVI considerably decreased since the previous observation → no → **No data or area is not burned**

↓ yes

Burned area

Fire scars are best seen in the true color images or false color images involving near infrared spectral band (0.8 µm)

Fire Scars, Siberia


Fire Scars,
Australis
Coonabarabran
0
25 km

SUMMARY

- Meteorological satellites present an efficient tool to identify and monitor active fires. Fires can be identified in the satellite imagery interactively through its visual analysis and with automated active fire detection techniques.

- Fire identification algorithms are based on observations in the middle infrared and far (or thermal) infrared spectral bands. The primary feature used to distinguish fires is a large positive difference between brightness temperature in these spectral bands. Automated fire detection can be performed day and night.

- Automated fire detection and mapping algorithms are applied routinely with operational weather satellite data. Information on active fires is provided globally. Some fire products are available in near real time.

- Identification of burned areas or burn scars is based on the analysis of the change of vegetation-related indices (most often, NDVI). Typically his analysis is conducted in the areas which earlier were affected by fires.

Reading

1. EUMETSAT Tutorial on Remote Sensing, Chapter 5: Forest Fires
http://www.eumetrain.org/data/3/30/print_5.htm

2. EUMETSAT: Use of SEVIRI and AVHRR channels for remote fire/smoke detection
http://www.eumetsat.int/website/wcm/idc/idcplg?IdcService=GET_FILE&dDocName=PDF_TL_09_11_02&RevisionSelectionMethod=LatestReleased&Rendition=Web