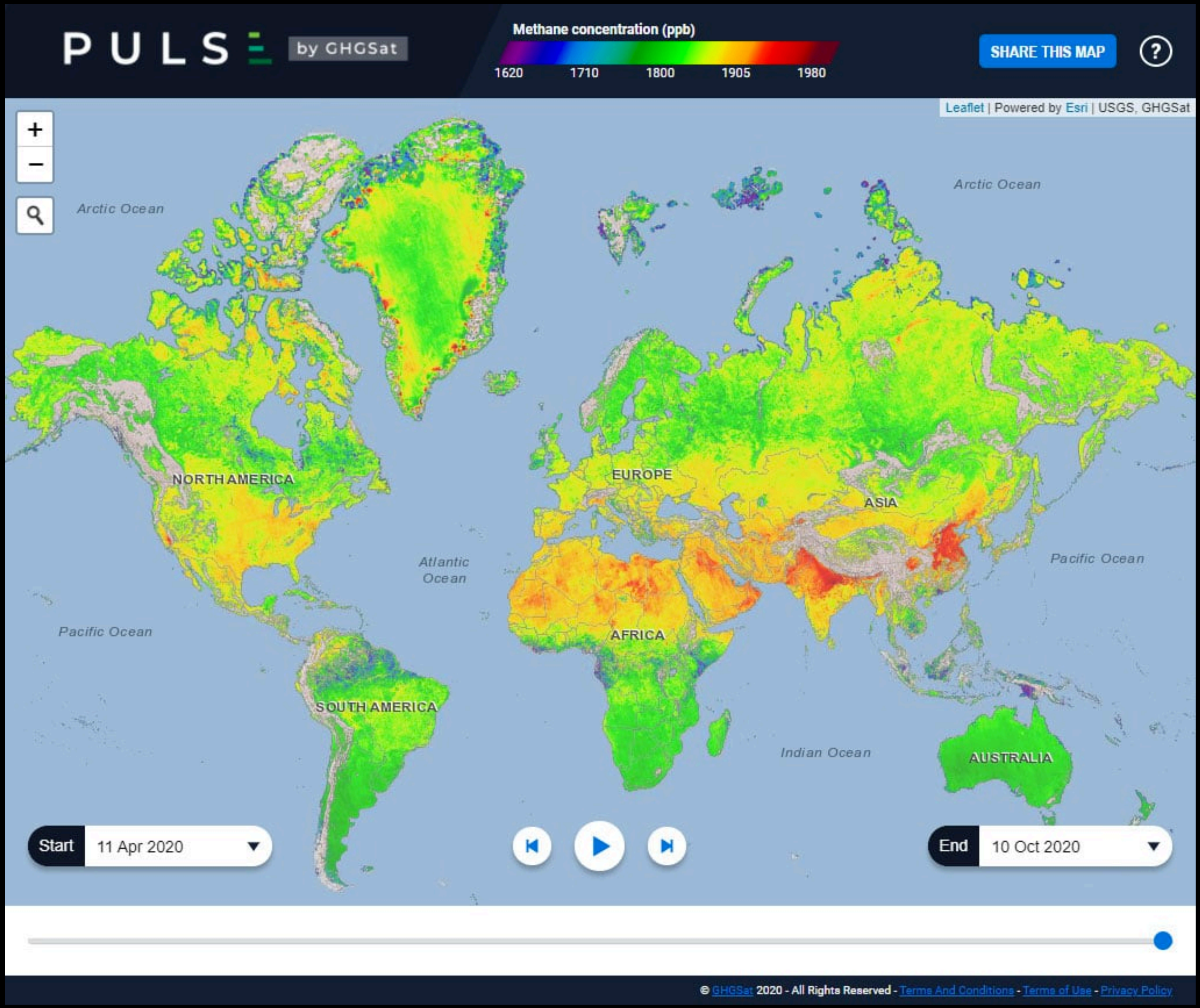
Data of the Week



https://www.ghgsat.com/ghgsat-launches-pulse/

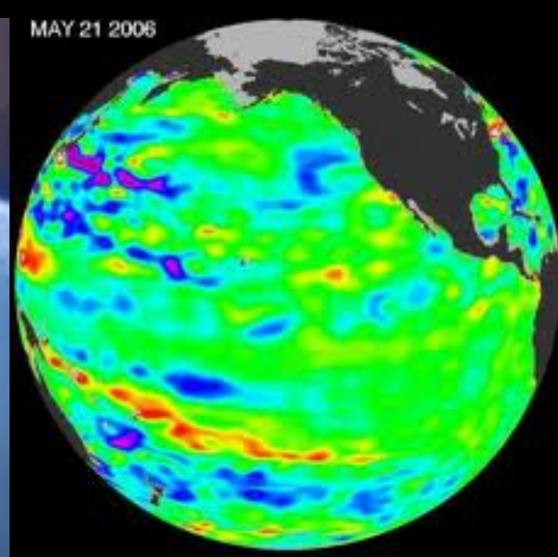
Sentinel-2

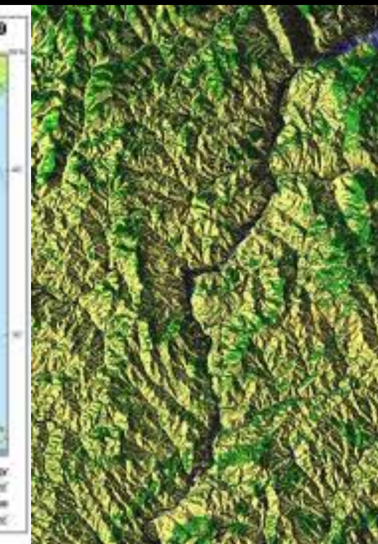
5 days revisit; Twin satellites — 2-3 days;
FOV (swath 290 km); four bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution.

https://www.sentinel-hub.com/explore/sentinel-playground

https://landsatlook.usgs.gov/sentinel2/viewer.html

https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-2-msi/msi-instrument

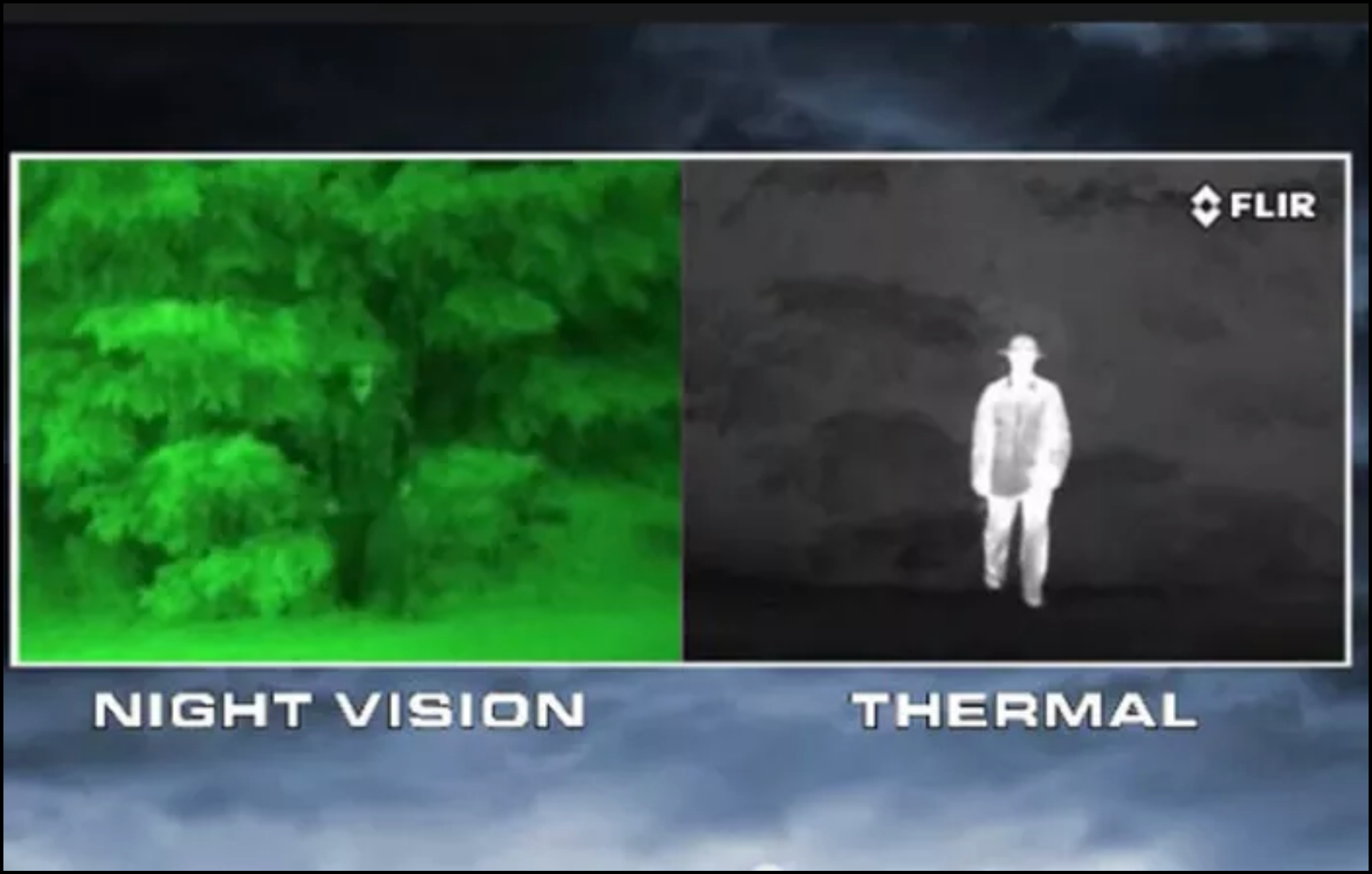



Thermal remote sensing

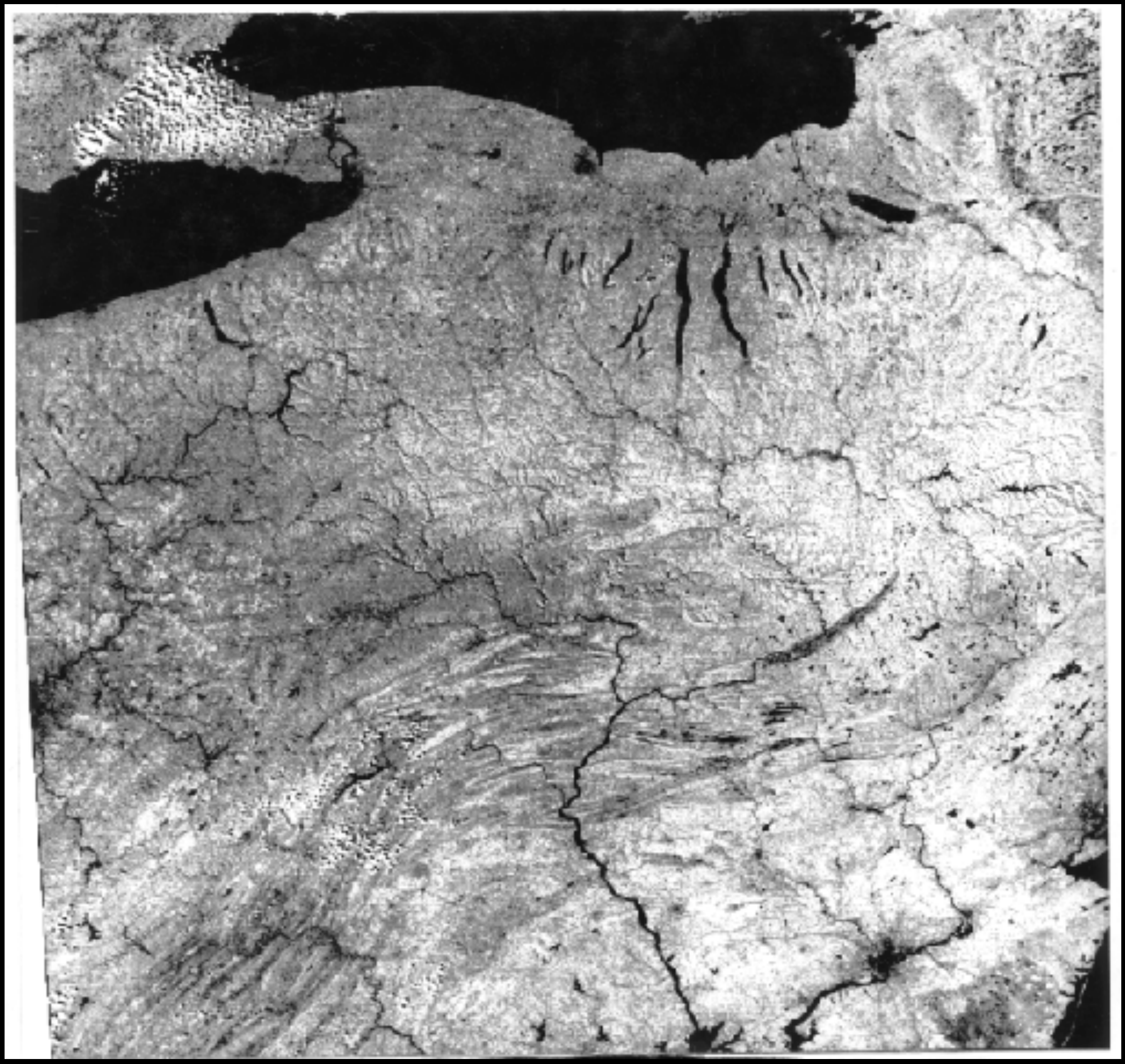
Xi Yang
Department of Environmental Sciences
University of Virginia
xiyang@virginia.edu
390 Clark Hall

EVSC 4010/7010 Week 9

A new way of looking



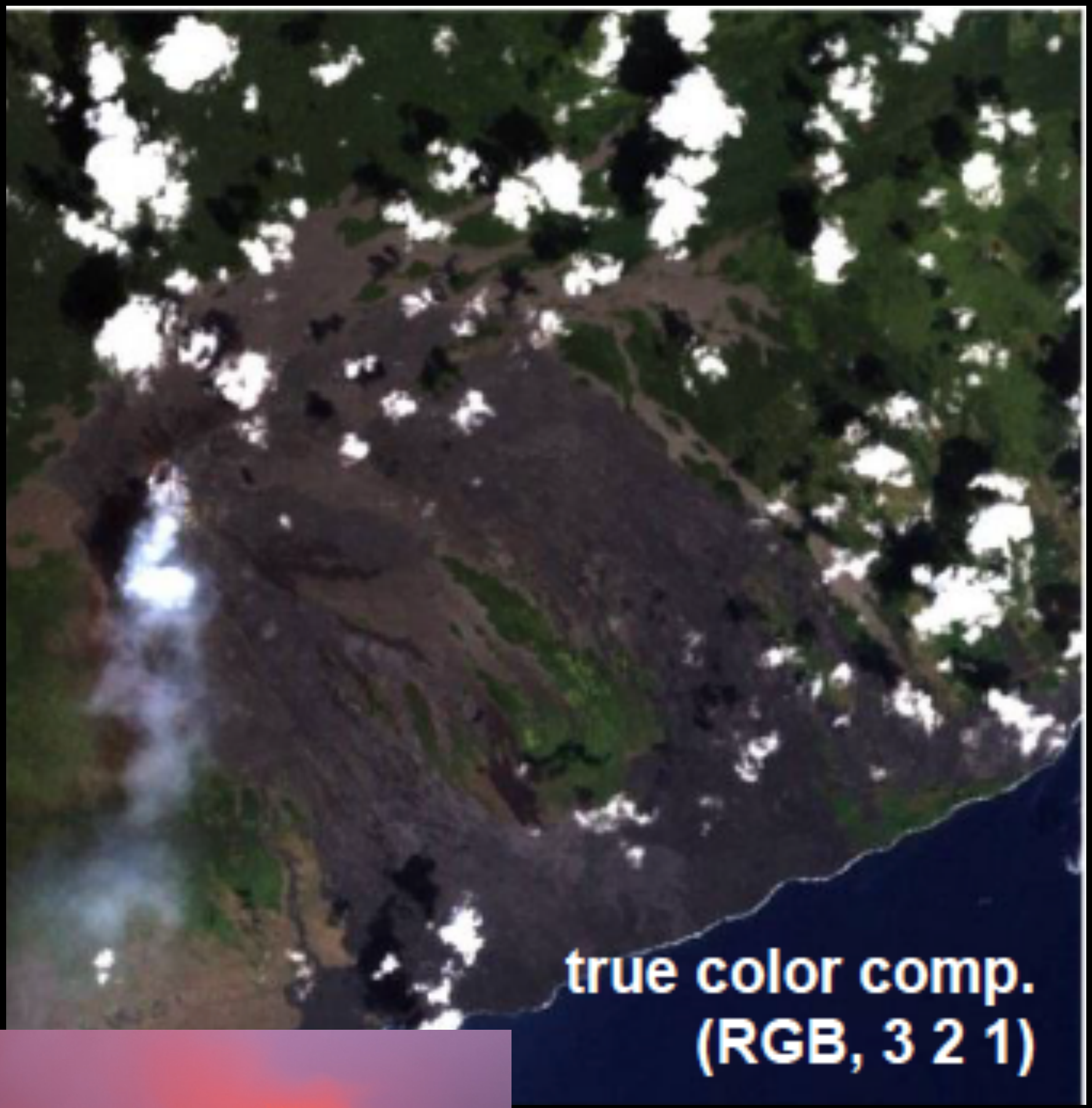
Satellite RS of land surface temperature

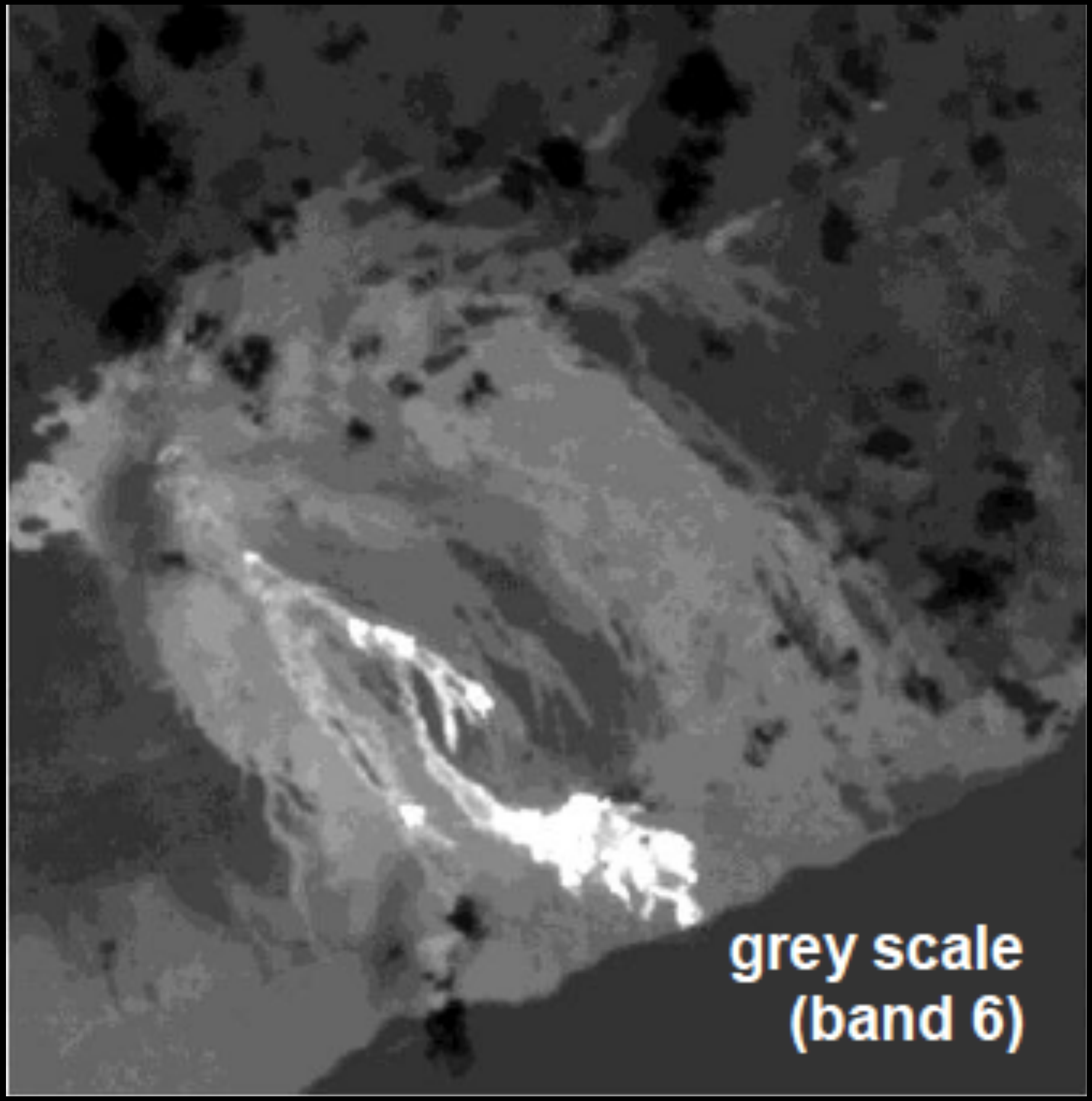


Day Time Visible (0.5 um)

Day Time Thermal (10 um)

Satellite RS of land surface temperature

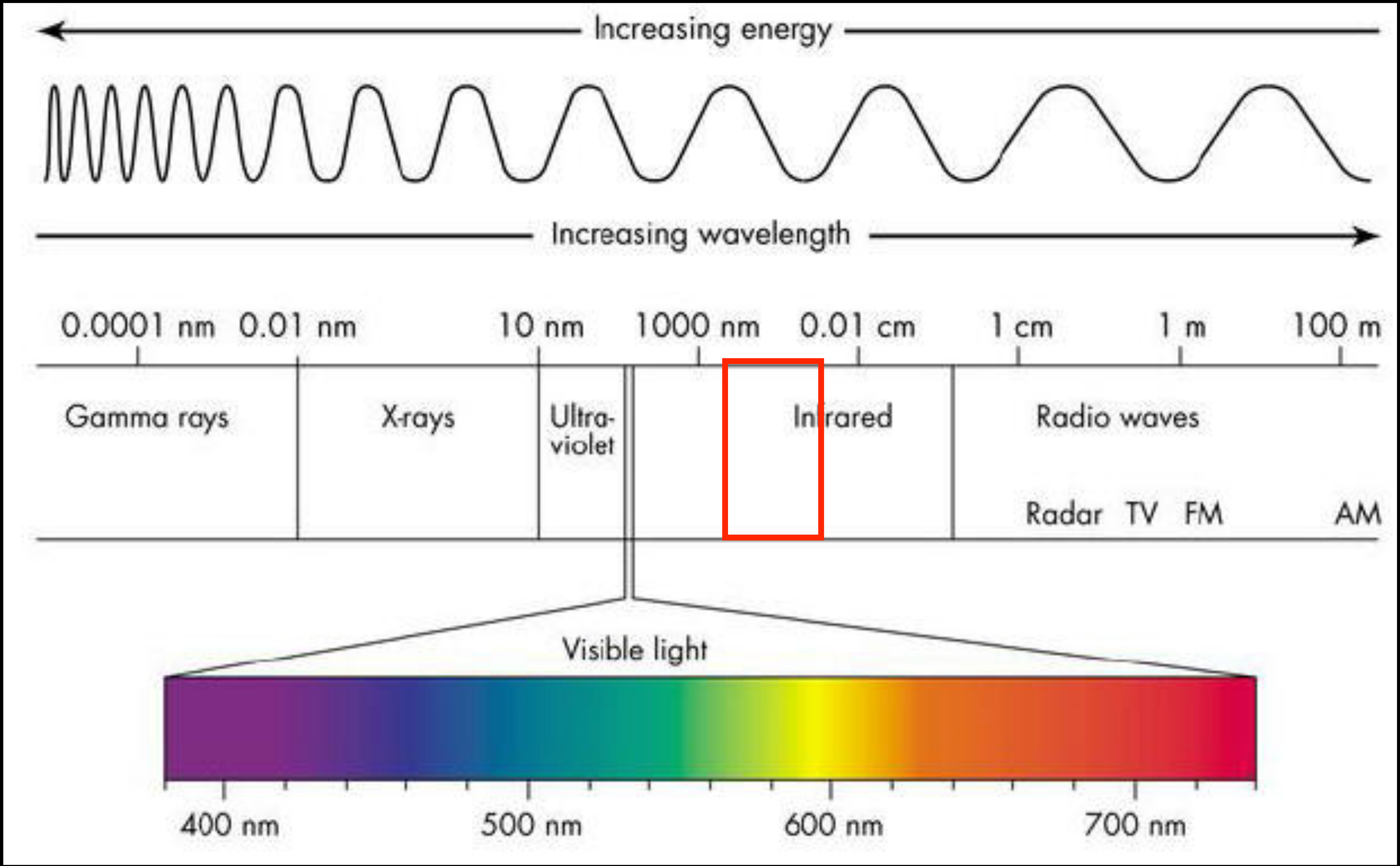




Kilauea Volcano, HI

Landsat 7 ETM+
February 14, 2000

Thermal infrared radiation: 3-14 um



EMR laws: Recap

- Stefan-Boltzmann Law (Blackbody)

$$M = \sigma T^4$$

$\sigma = 5.6697 \times 10^{-8}$ W m^{-2} K^{-4}

- Gray body situation:

$$M = \varepsilon \sigma T^4$$

$\varepsilon = 0\text{-}1$
$\sigma = 5.6697 \times 10^{-8}$ W m^{-2} K^{-4}

  - To be more precise, Kirchhoff's law is actually

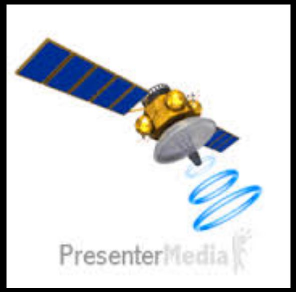
$$\alpha = \varepsilon$$

- Wien's Displacement Law: $\lambda_{\max} = \dfrac{2898}{T}$

Satellite sensors measure the radiance

A constant

$$M = \varepsilon\sigma T^4$$



Radiance

Kinetic temperature

Emissivity

Brightness temperature (unit: K): the apparent temperature of a surface assuming epsilon = 1

Kinetic temperature: true temperature as measured by a thermometer

Same Kinetic Temperature, different emissivity

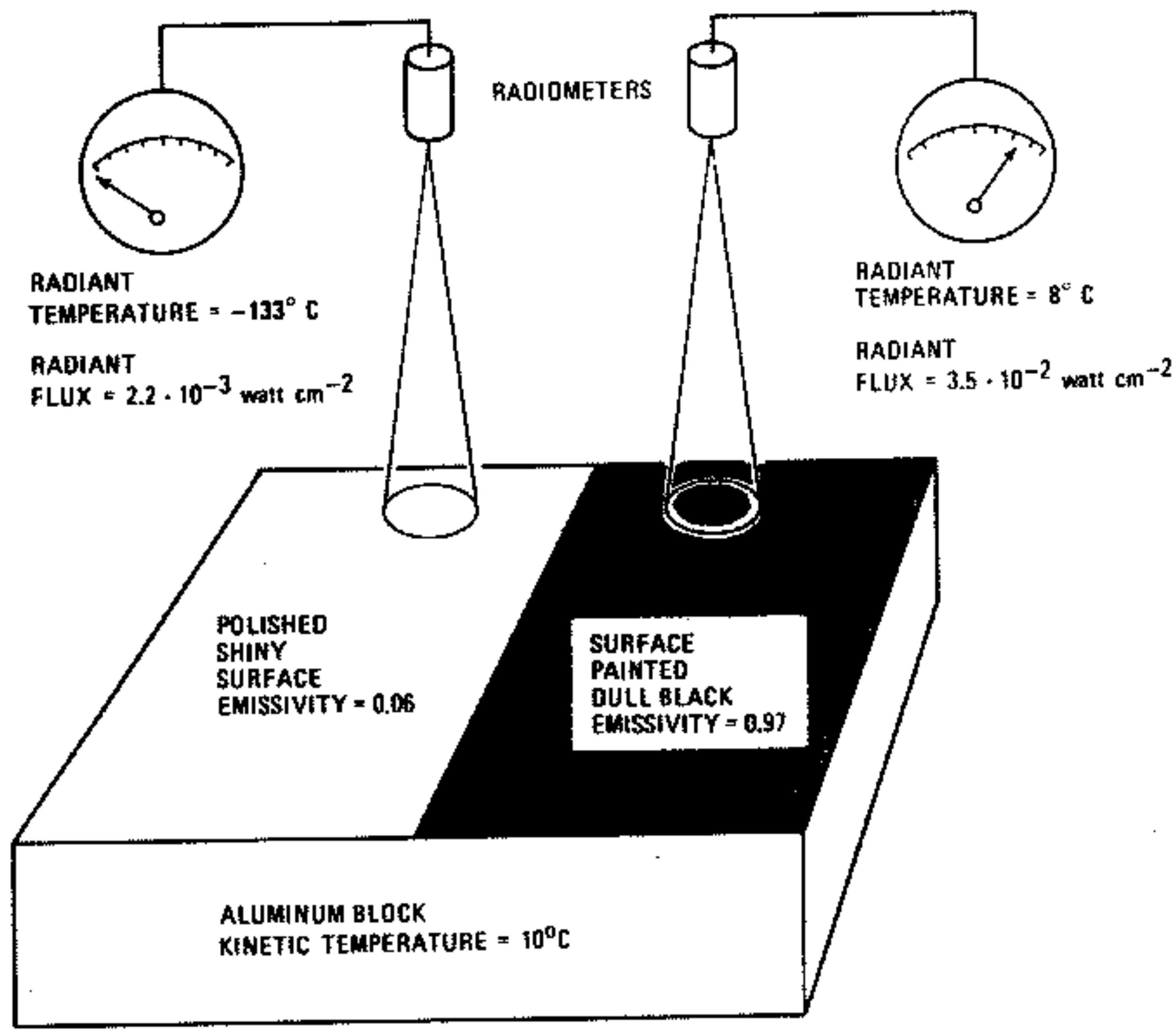


FIGURE 5.1
Effect of emissivity differences on radiant temperature. Kinetic temperature of aluminum block is uniformly 10°C. Different emissivities cause different radiant temperatures that are measured with radiometers.

Emissivity of typical land cover

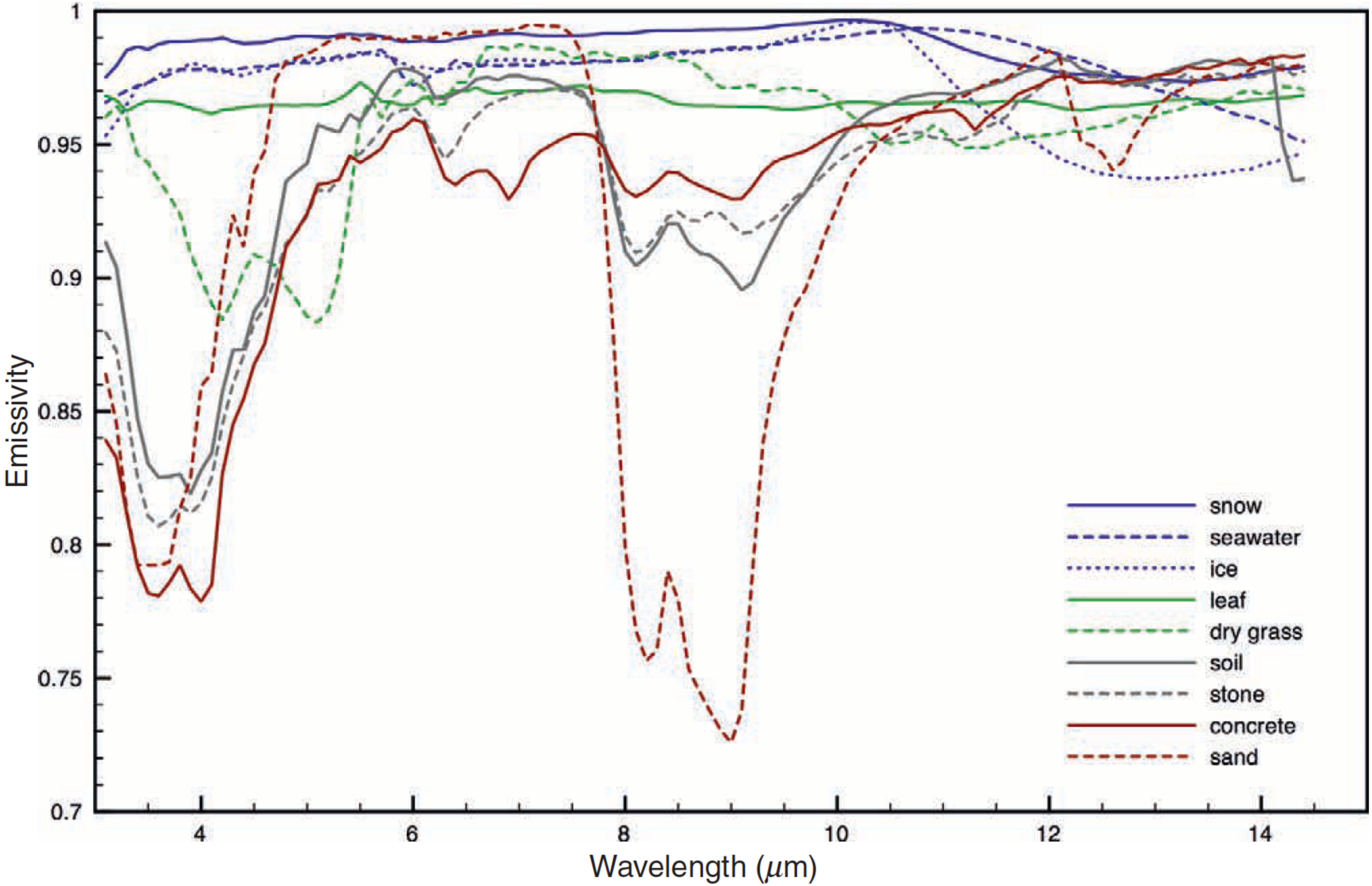
For thermal infrared radiation, there is little transmission. Thus we have:

$$\varepsilon + \rho = 1$$

Emissivity is usually a function of the material itself and the wavelength:

$$\varepsilon = f(material, \lambda, viewing\_angle)$$

Emissivity of typical land cover

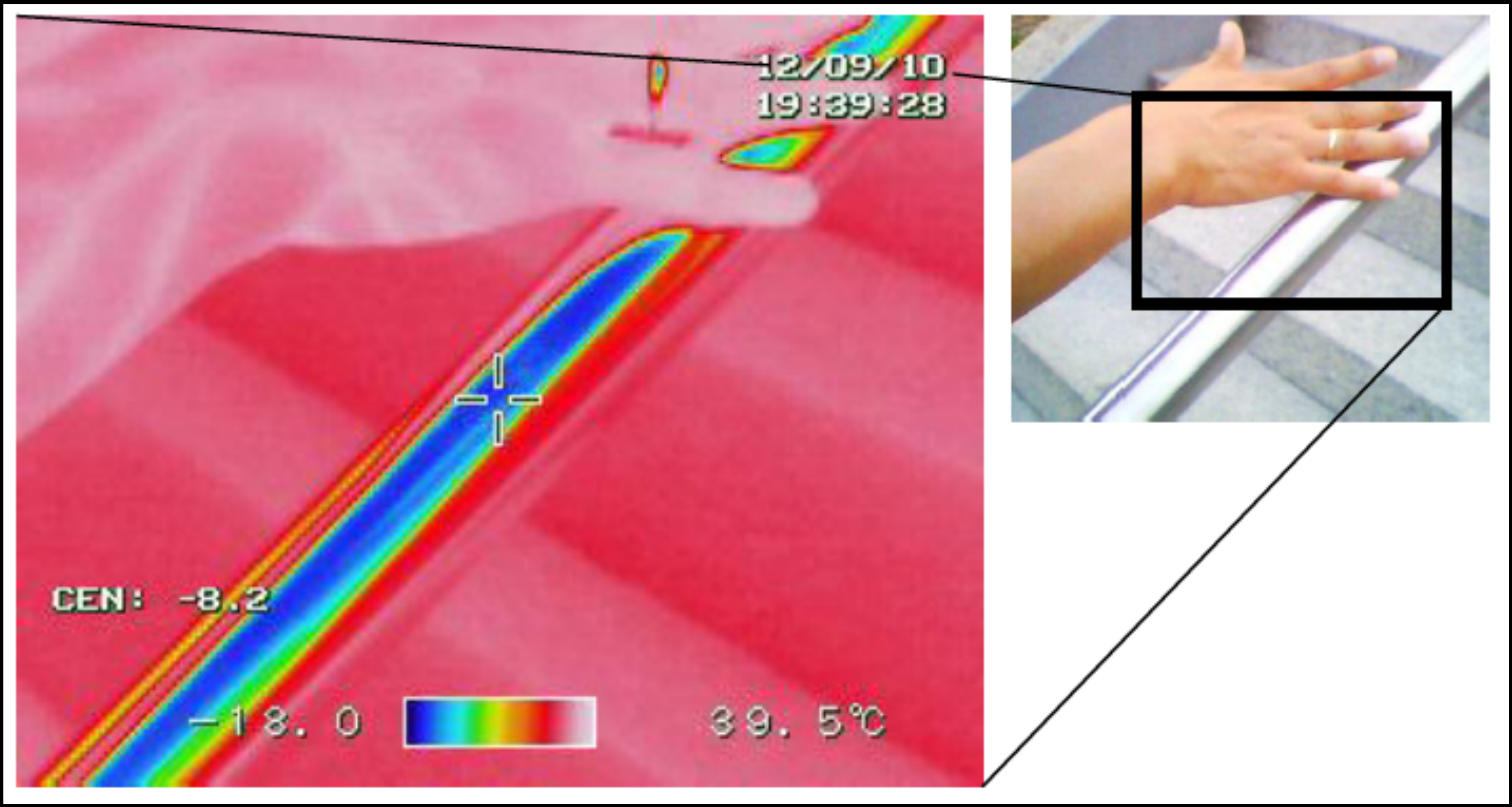


Emissivity of typical land cover

Table 1.1 Emissivity of different surfaces in the 8-14 μm wavelength range as compiled from different sources (own measurements, Lillesand et al. 2008, Sabins 1996)

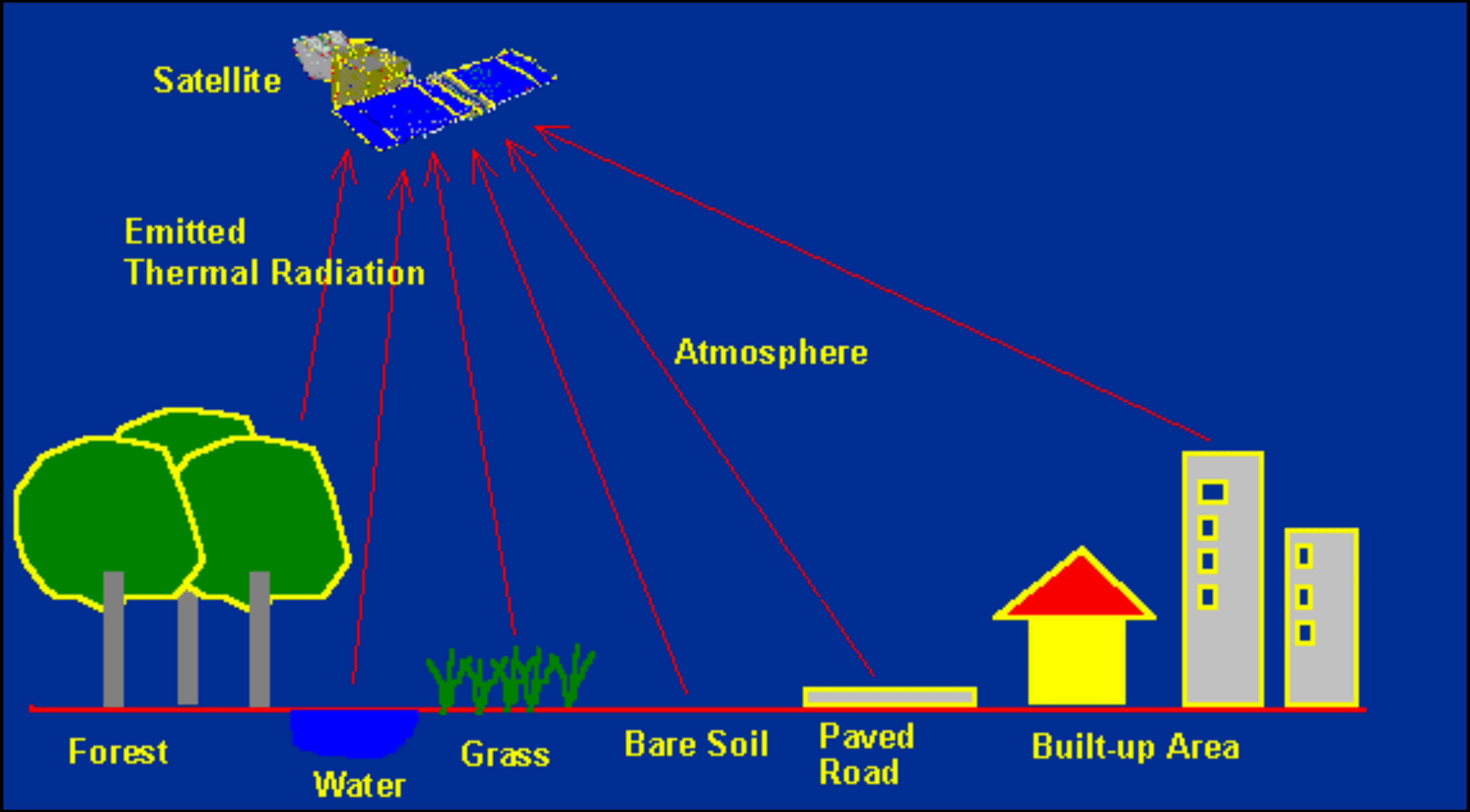
Surface	Emissivity at 8-14 μm
Carbon powder	0.98-0.99
Water	0.98
Ice	0.97-0.98
Plant leaves, healthy	0.96-0.99
Plant leaves, dry	0.88-0.94
Asphalt	0.96
Sand	0.93
Basalt	0.92
White paper	0.90
Wood	0.87
Granite	0.83-0.87
Polished metals, averaged	0.02-0.21
Aluminium foil	0.036

The importance of emissivity

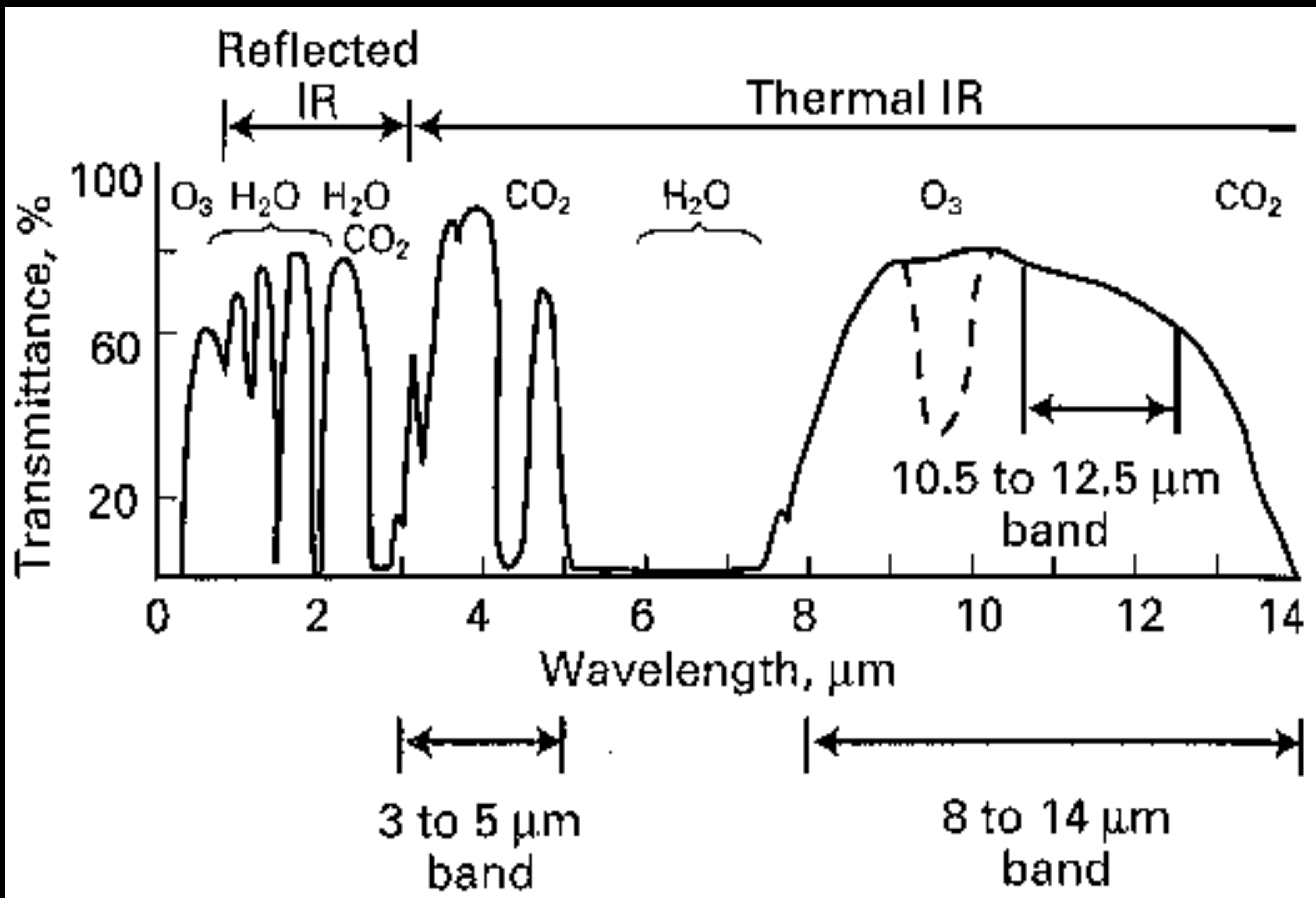


Brightness temperature or kinetic temperature?

Thermal radiation received by the satellite sensor



Atmospheric windows in the TIR region

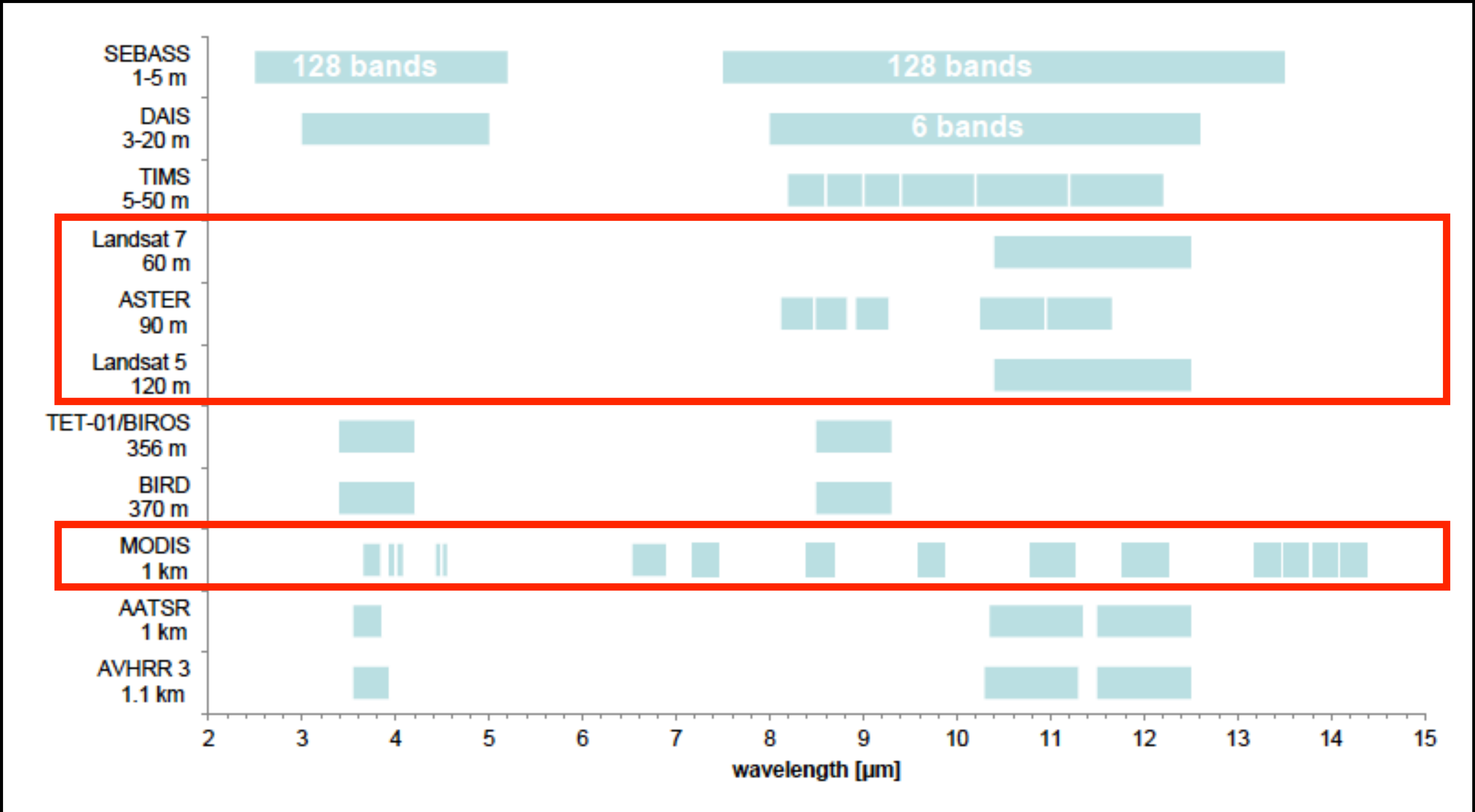


Where are the atmospheric windows in the TIR?

3-5 um & 8-14 um

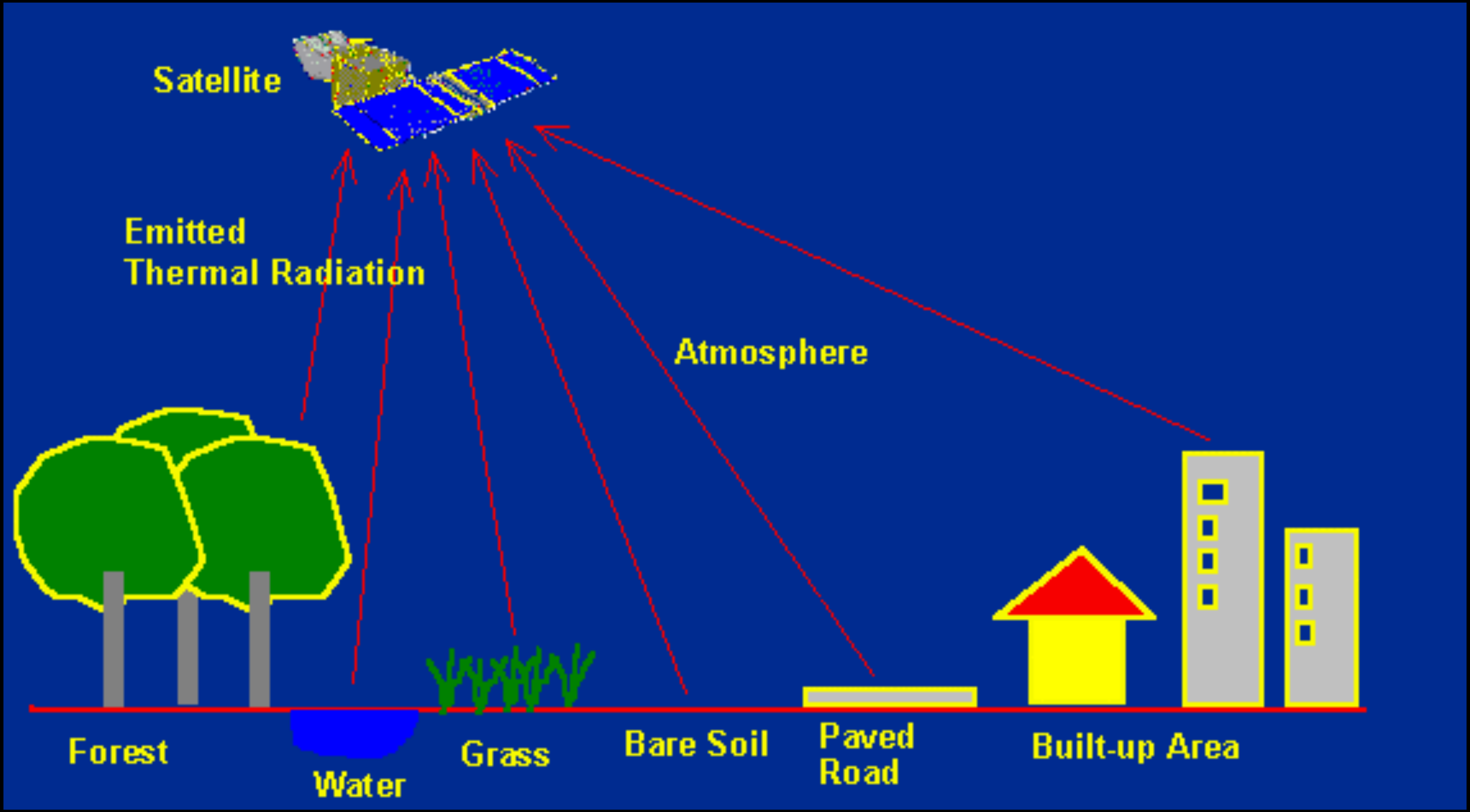
Ozone absorption around 9-10 um

Satellites that measure TIR radiation



Sacramento, CA

What contribute to the radiation received by the satellite sensors?



Radiative Transfer in the TIR

$$L_{sat} = \boxed{L_p} + \boxed{T_v \times \varepsilon \times L_{surf}(T)} + \boxed{T_v \times (1-\varepsilon) \times F_d / \pi}$$

Path Radiance

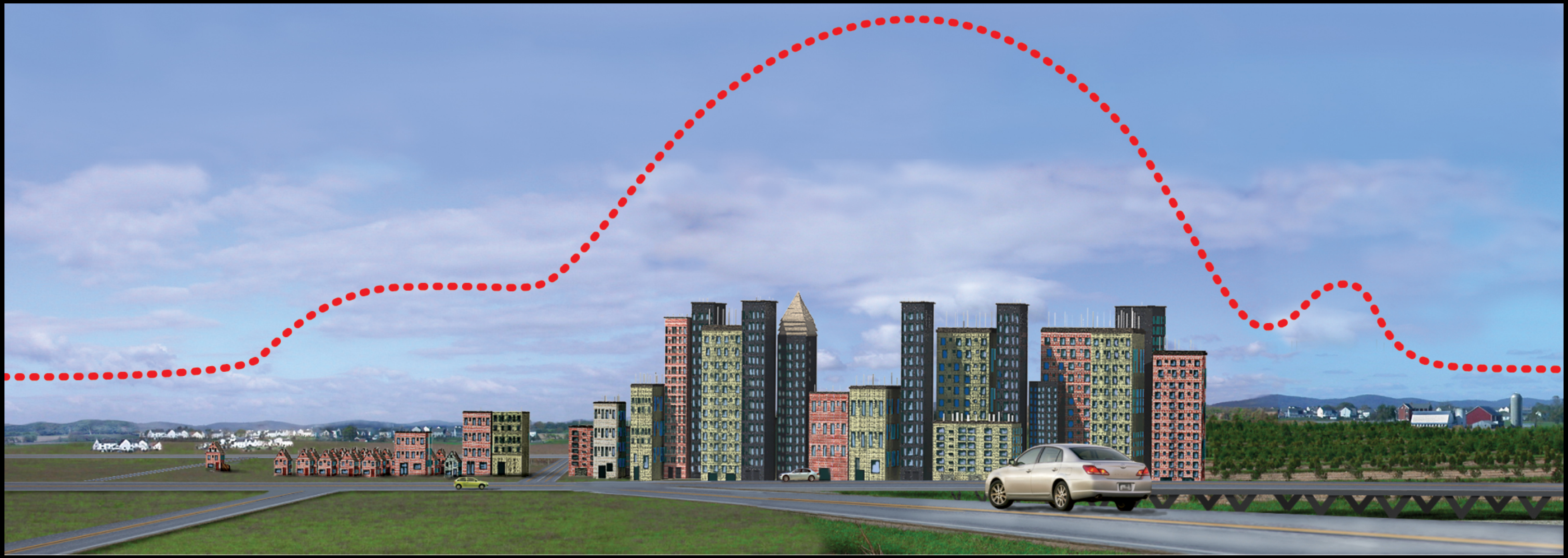
Radiance emitted from the surface

Radiance emitted from the atmosphere and then reflected by the surface

- Lp: thermal path radiance;
- Tv: transmittance of the atmosphere to thermal radiation;
- ε: emissivity of the land surface;
- $L_{surf}(T)$: surface radiation;
- F_d: downwelling thermal radiation

Case studies

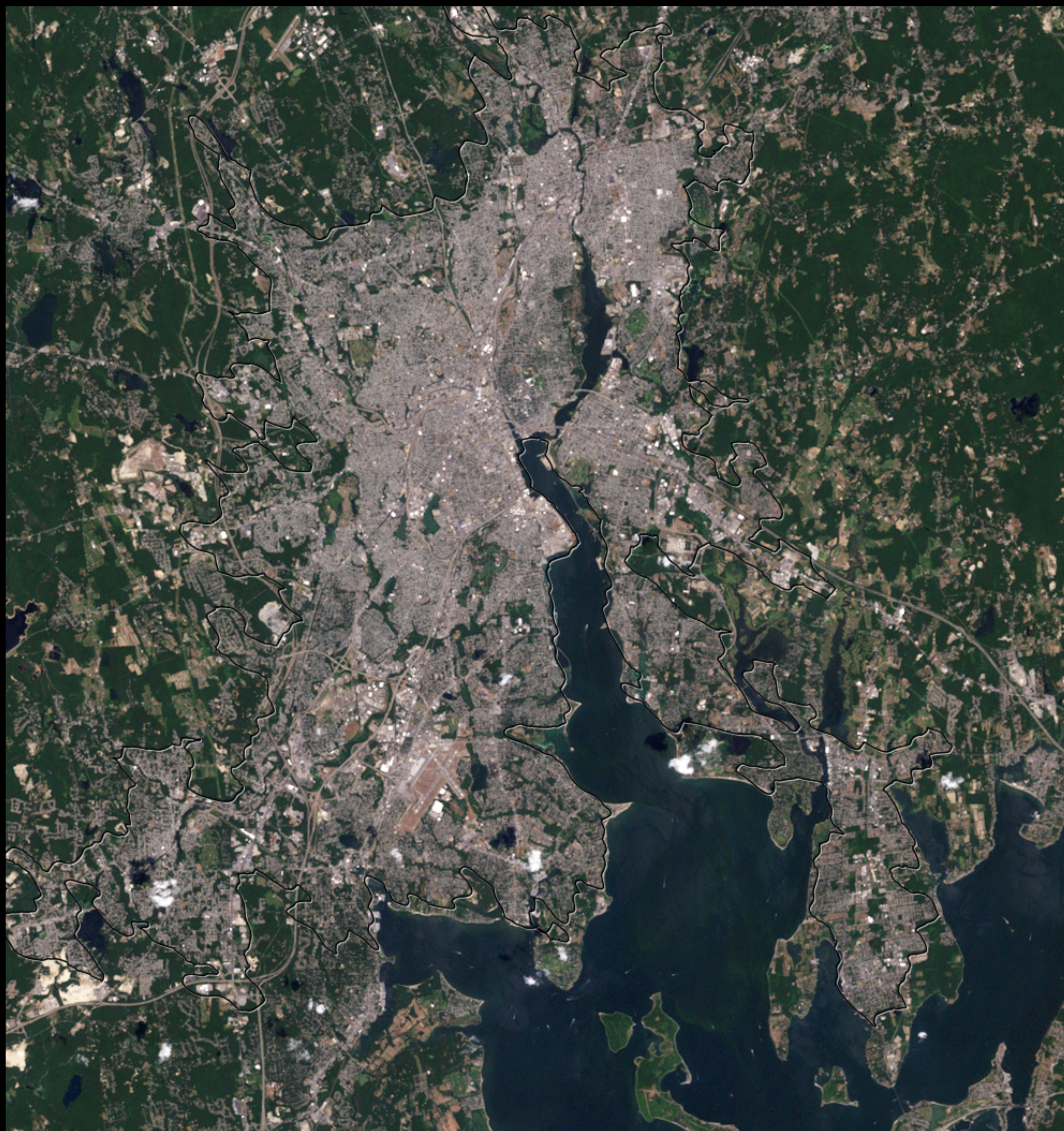
- Urban Heat Island and TIR Change Detection
- Remote Sensing of Fire



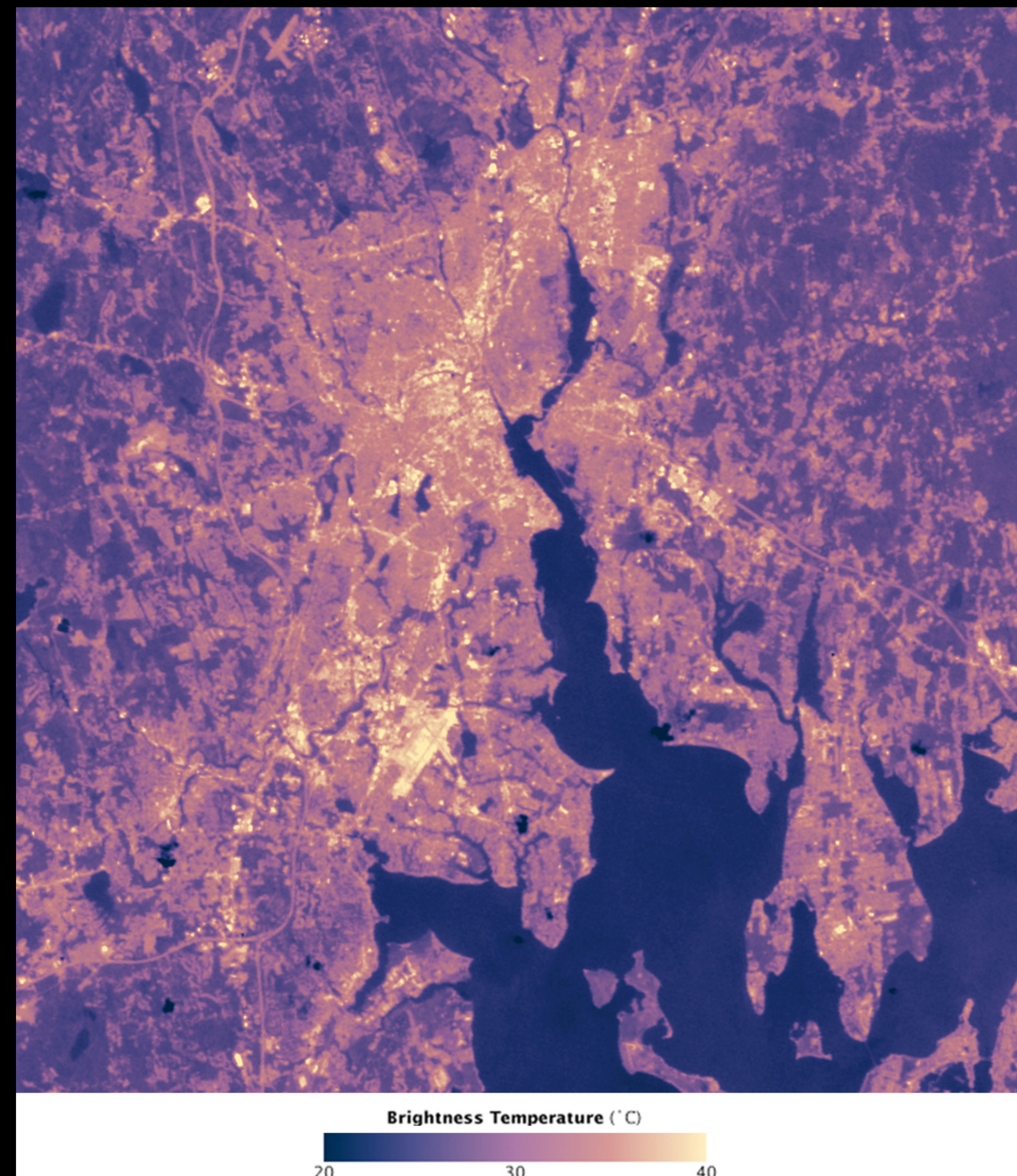
NASA

Urban Heat Island

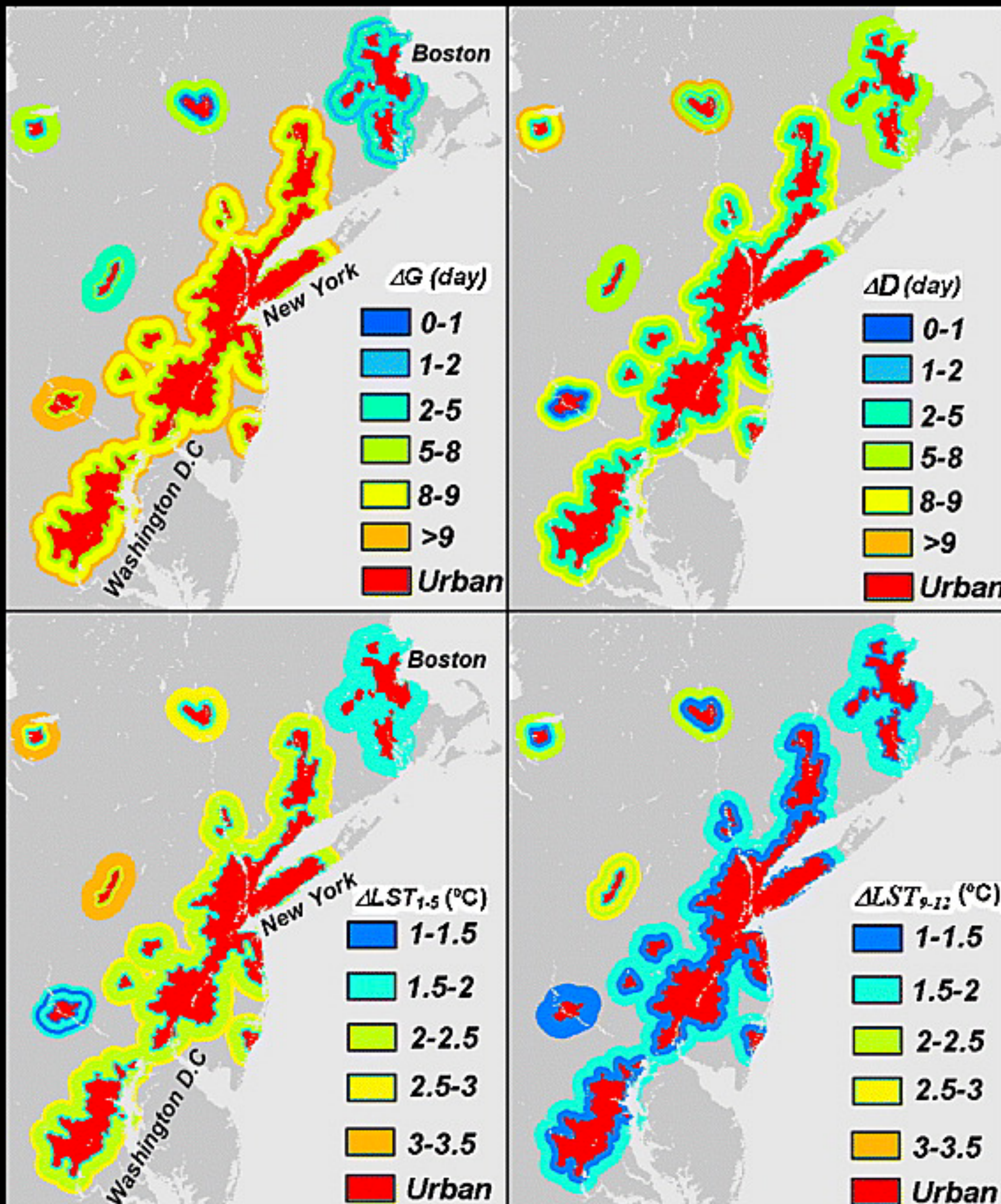
Visible



LST



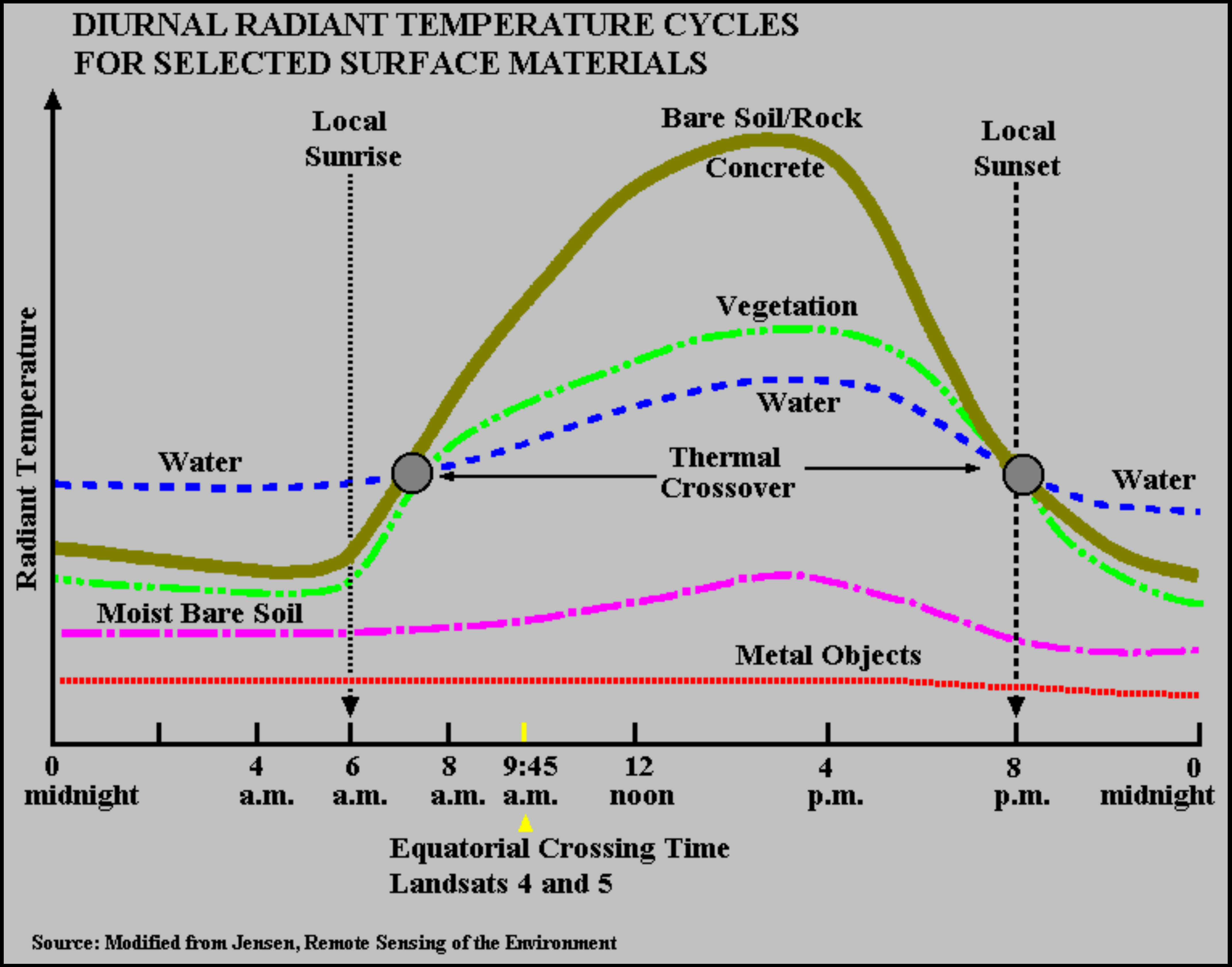
Urban Heat Island and its impact on vegetation



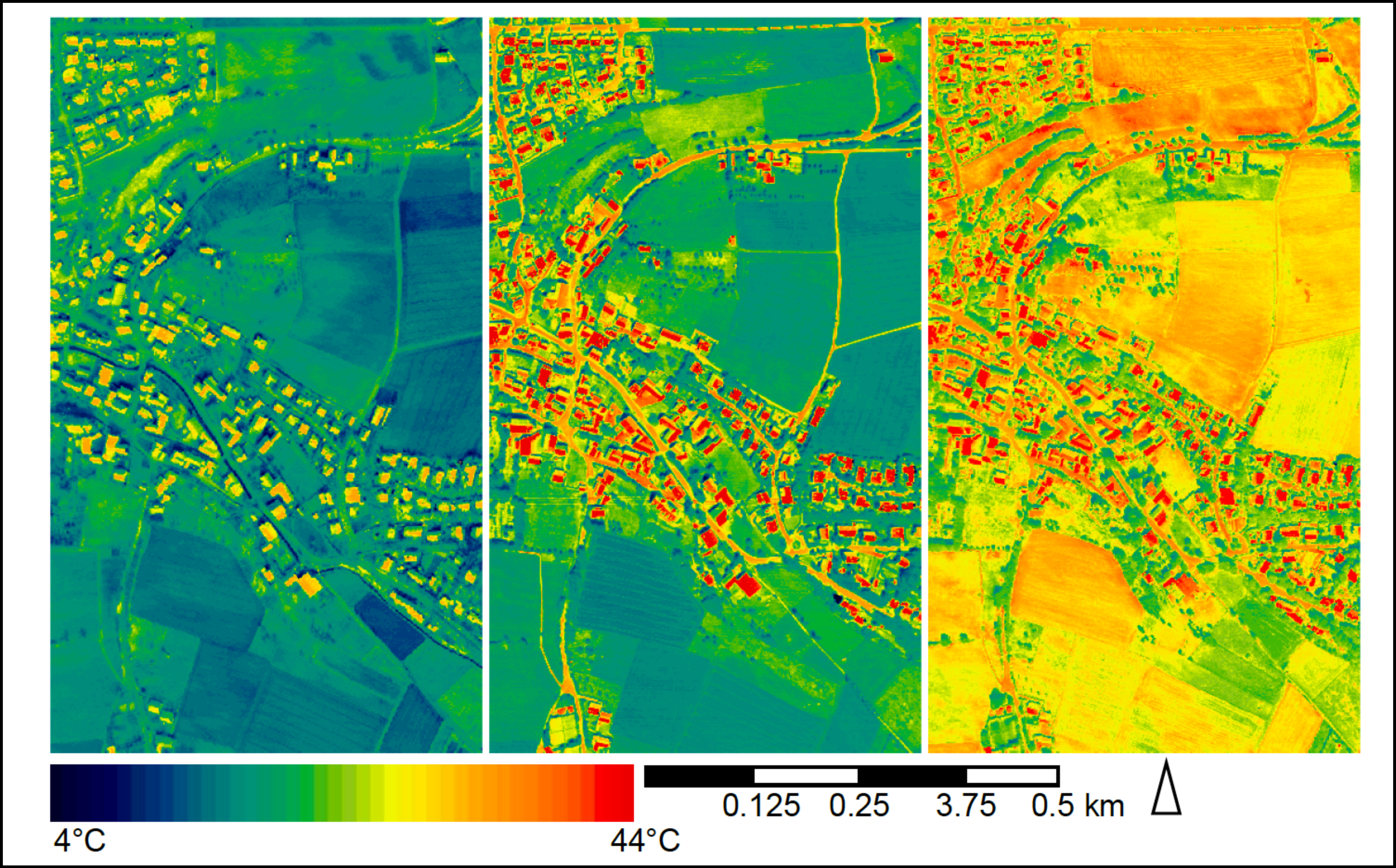
Spring season Urban - Rural	Fall season Rural - Urban
Spring LST Urban - Rural	Fall LST Rural - Urban

Zhang et al. 2004

Diurnal patterns of surface temperature

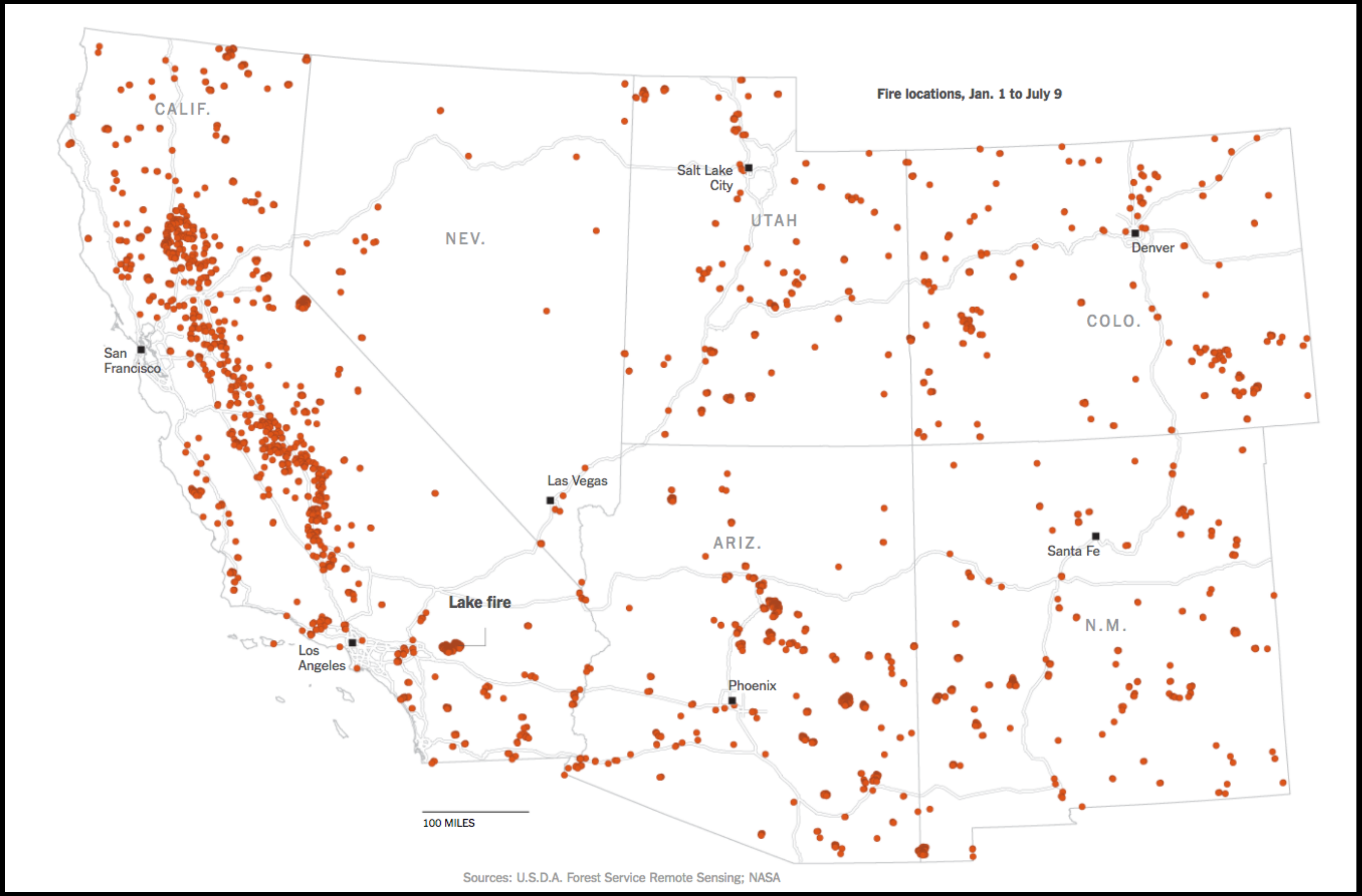


TIR for change detection



Winter Spring Summer

Forest Fire

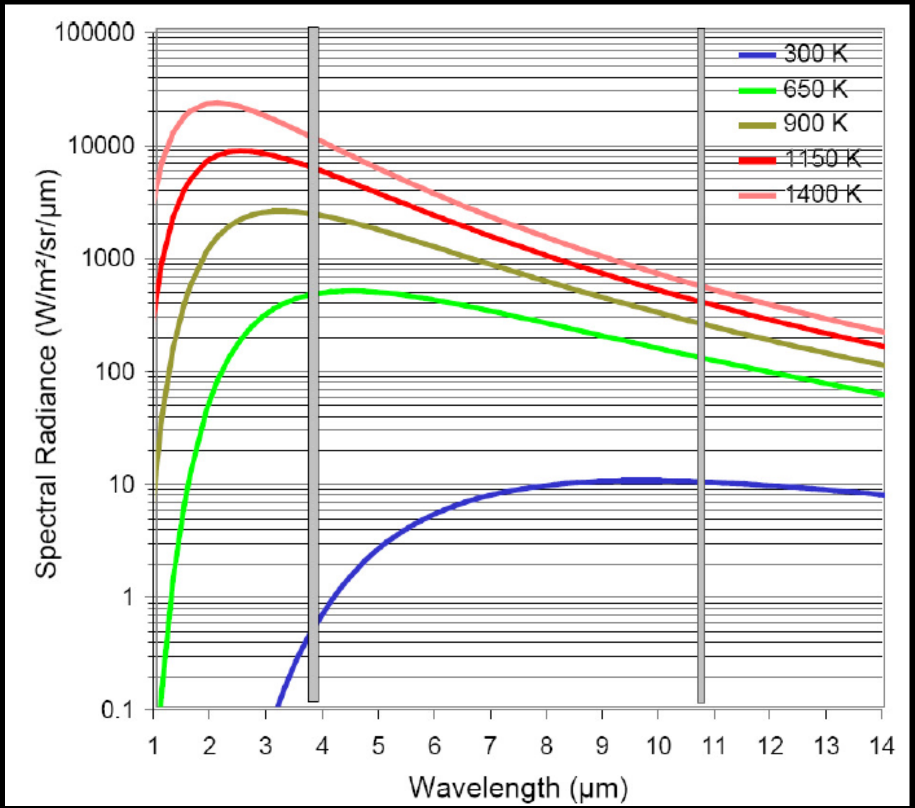


- Costly: the largest 10 fires in the U.S. last year costs $320 million dollars
- Carbon emitter
- Difficult to monitor

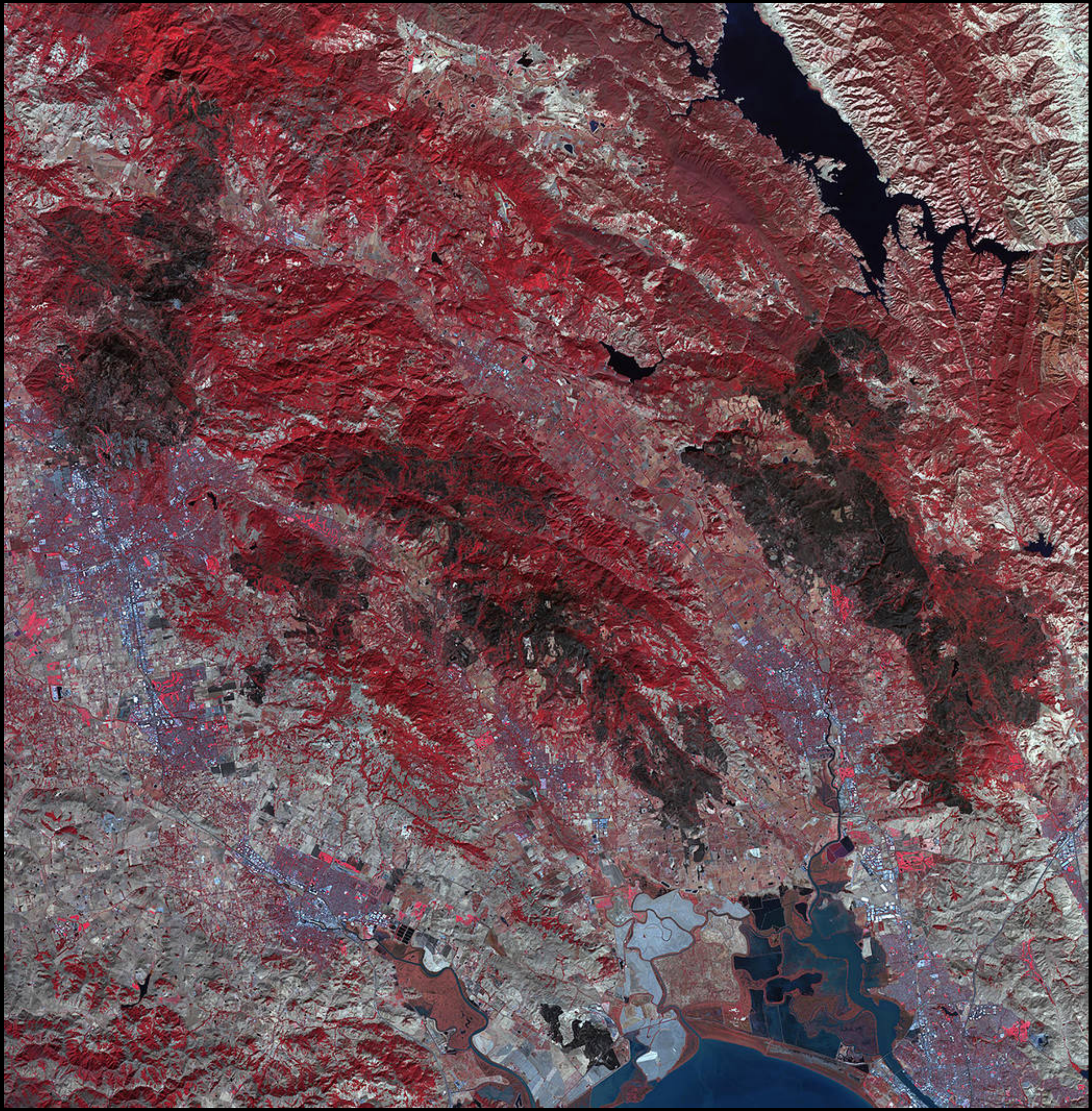
https://firms.modaps.eosdis.nasa.gov/firemap/

Remote Sensing of Forest Fire

- What aspects of fire are observable with remote sensing?
  - Direct optical signals (Light)
  - Thermal signals (heat) — which wavelengths do we consider?
  - Aerosols & smoke
  - Residue (char & ash)
  - Altered vegetation structure (burn scar)
- Active fire vs. Burned area



ASTER image (post-fire California)

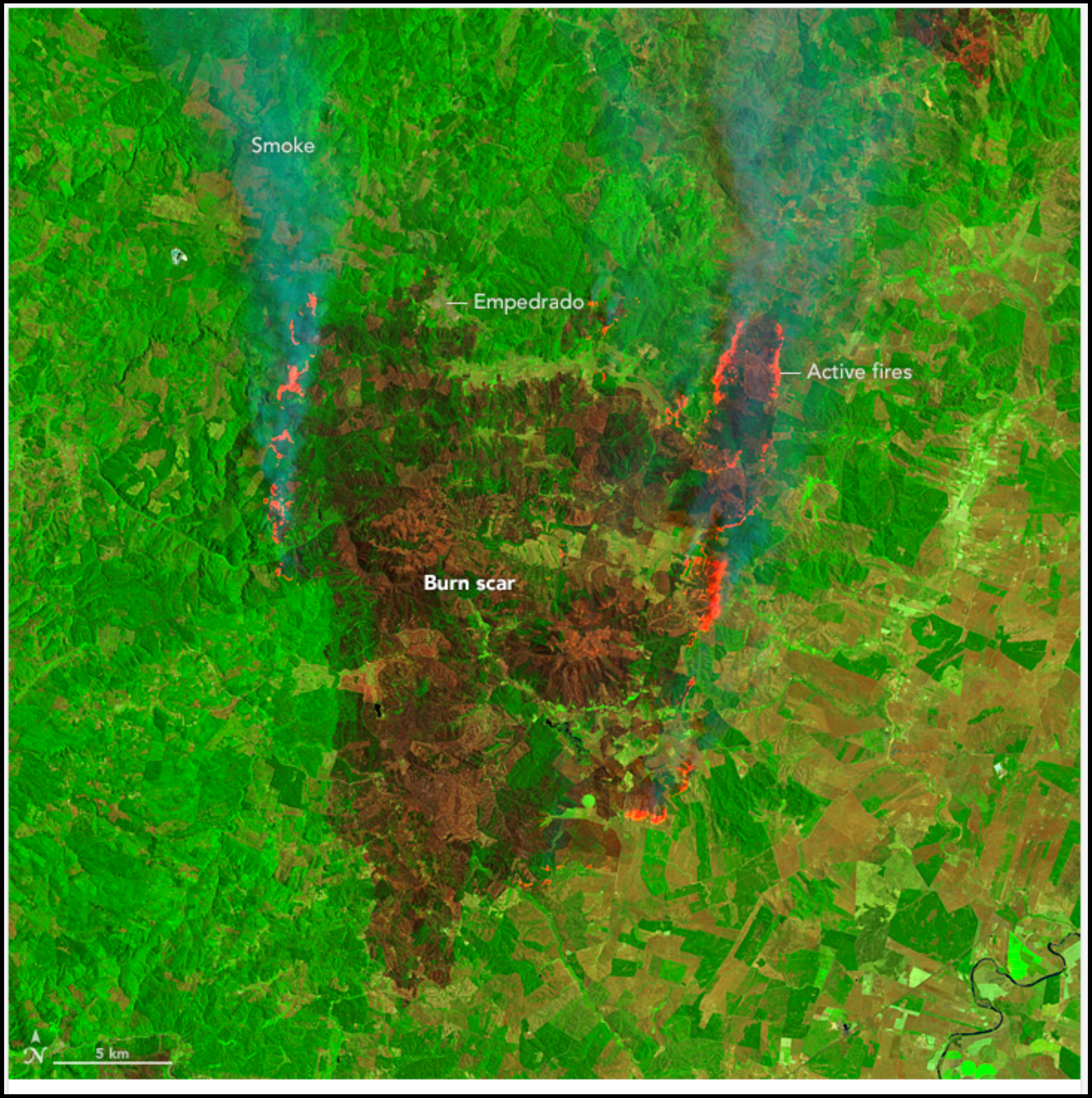


MODIS image

Landsat 8 OLI true color

Landsat 8 OLI Thermal Infrared + Visible

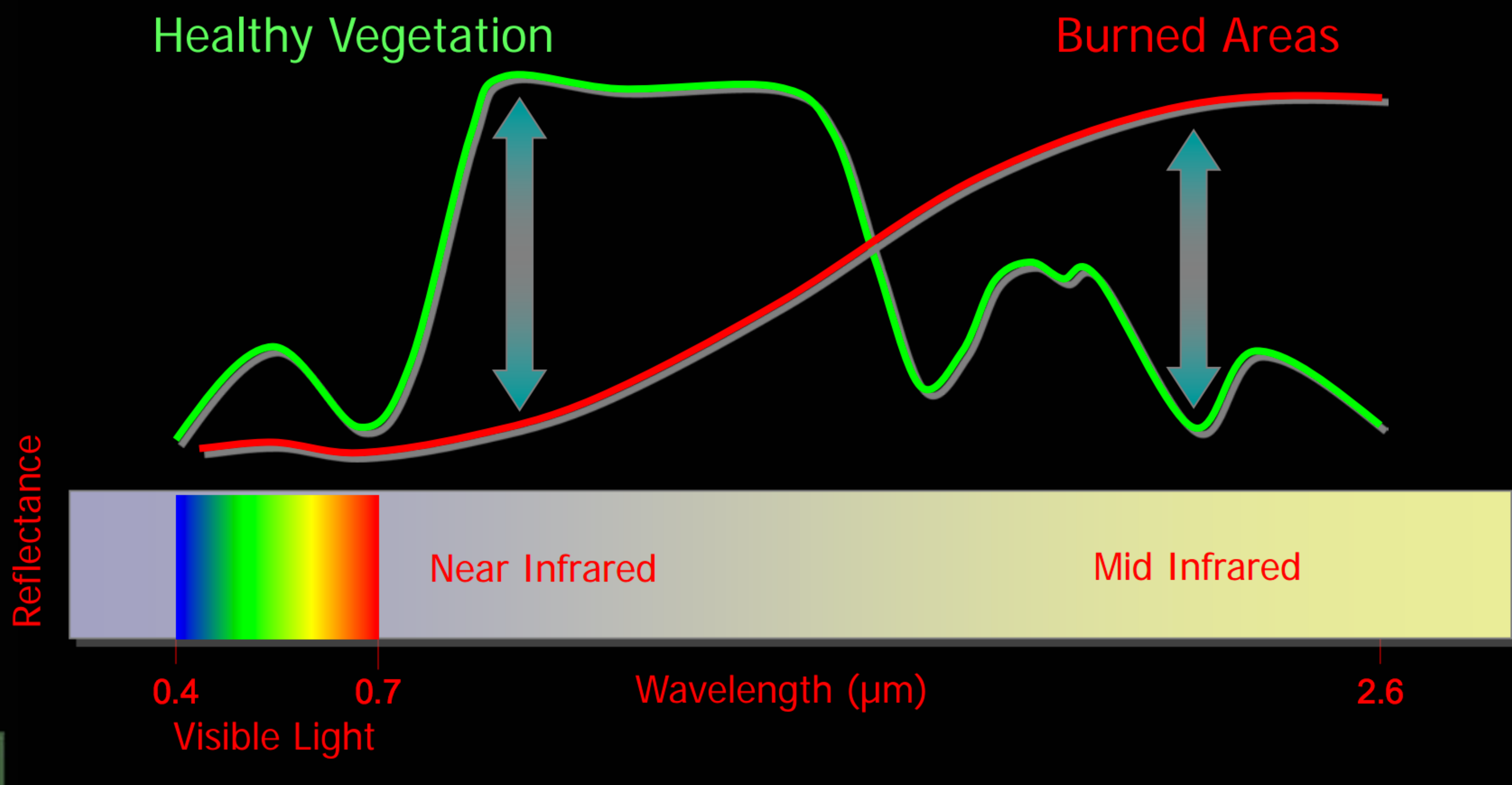
Burn scar vs. Active Fire



False color image:
Landsat 8, OLI
7-5-3

Find an index, like NDVI, that identifies the burn areas

Reflectance Spectroscopy



The Normalized Burn Ratio (NBR)
=(NIR-SWIR)/(NIR+SWIR)