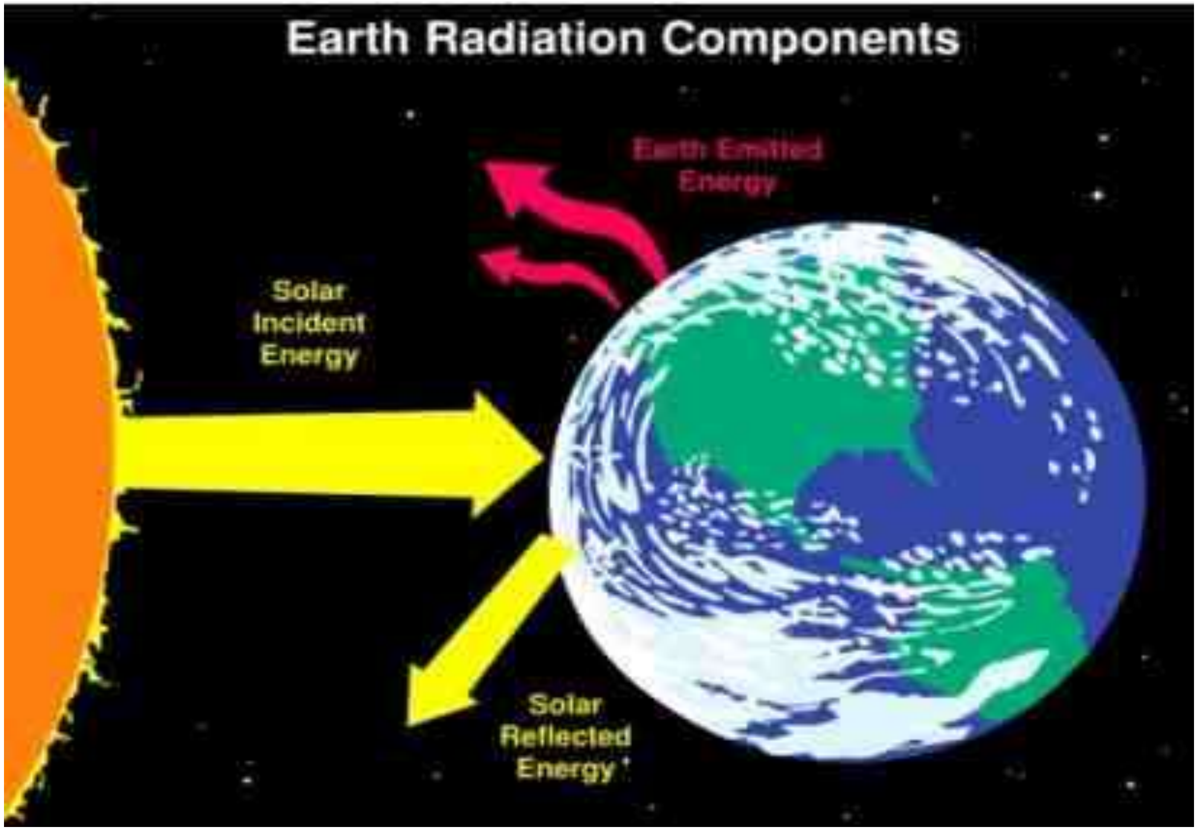
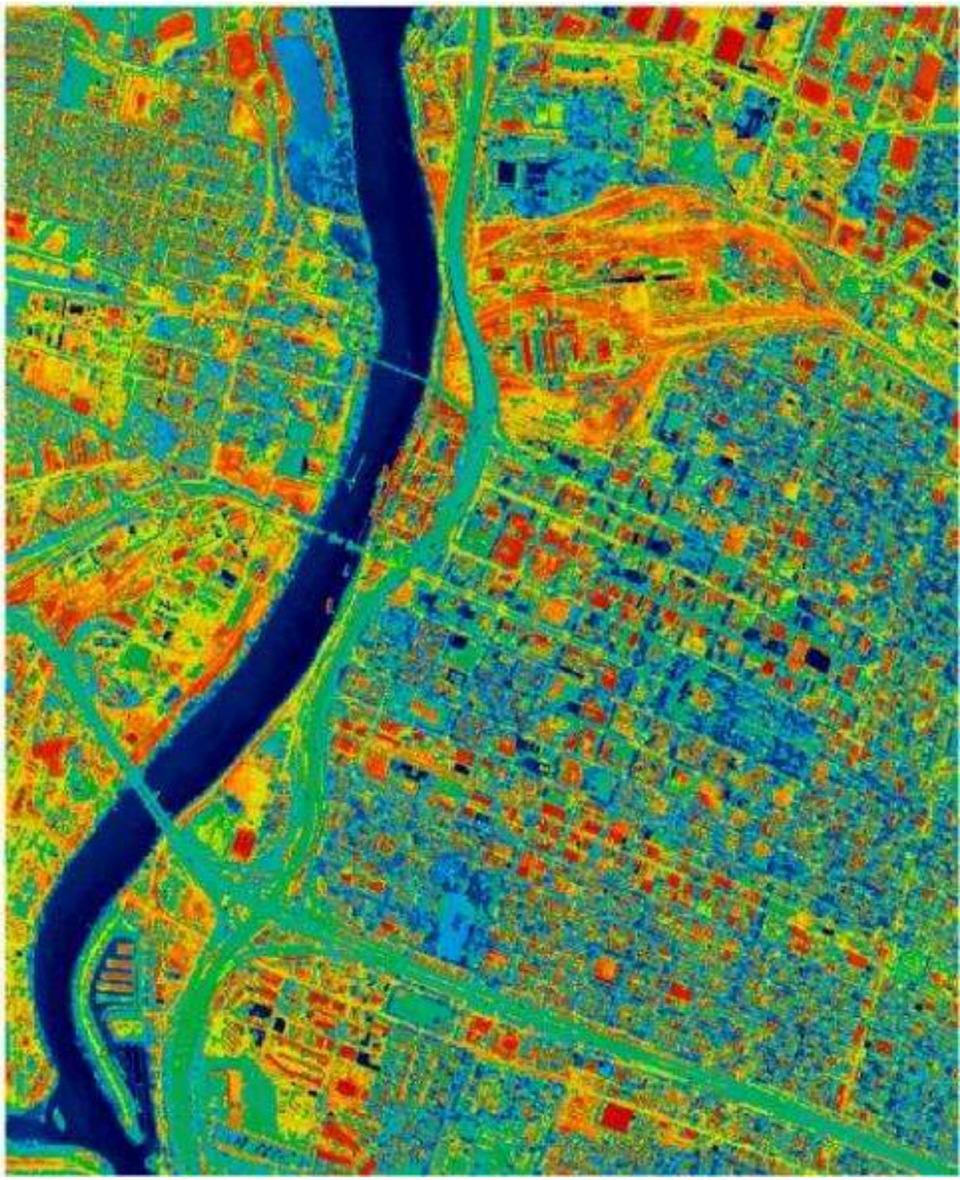
Thermal Infrared Remote sensing (3-14 microns)

Features of thermal RS:



- records longer wavelengths and a measure of temperature as it involves emitted <u>NOT</u> reflected IR
- Works day / night (temperatures above 0 K = -273 Celsius)
- Usually lower pixel resolution as there is less energy to capture

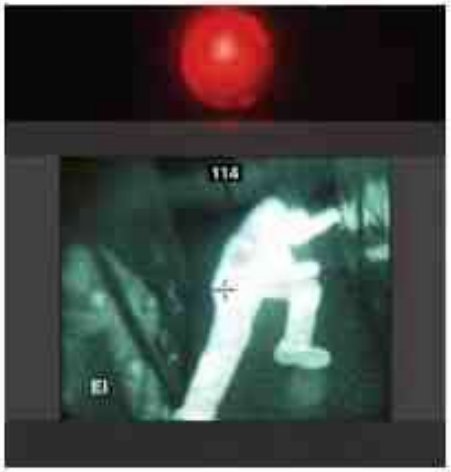
Normal colour and thermal images of Sacramento, CA



Colour composite in RGB

Thermal band in pseudocolour

Thermal Infrared (3-14 microns)



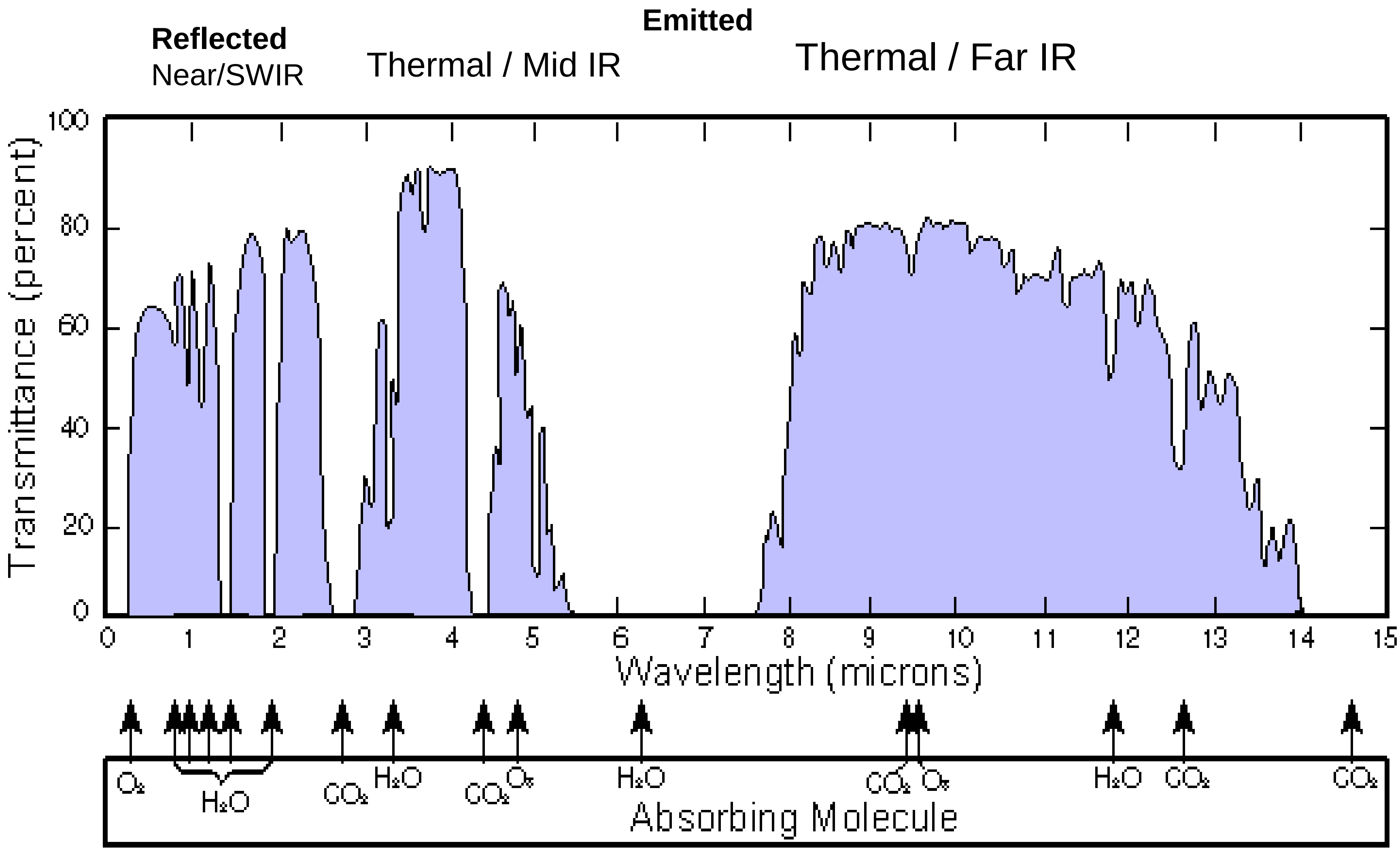
Thermal IR can 'see' through

haze and smoke - but not clouds

A comparison of a thermal image and an ordinary photograph. The plastic bag is mostly transparent to long-wavelength infrared, but the man's glasses are opaque.

1. Thermal Wavelengths (3-14 µm) windows:3-5,8-14

In 5 - 8 micrometres, energy is **absorbed by water vapour** in the atmosphere.

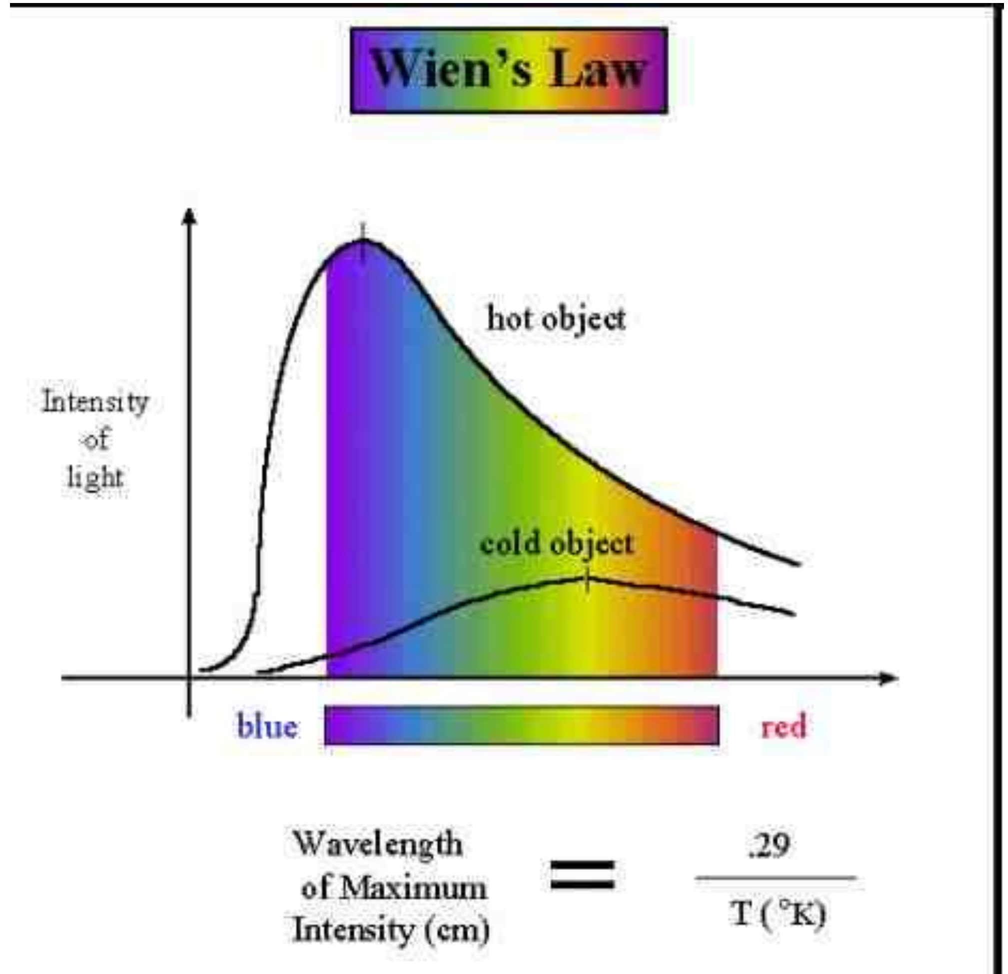


2. Wavelength & Temperature

…. All objects emit energy if their temperature is > 0 Kelvin (= -273C)

Wien's Law: "the maximum emission of energy from a body occurs at a wavelength **inversely** proportional to its temperature"

Named for Wilhelm Wien



Wavelength = 2898 /temp K (microns)

-> so (cooler) earth radiates energy at longer wavelengths than the sun

Wien's Equation: max energy wavelength (micrometres)

= **2898 / Temperature (K)**

Earth (temp = 27°C = 300K) = 2898 / 300 = 9.5

(thermal IR/long)

Forest fire (temp = 600K) = 2898 / 600 = 4.8

(thermal IR / mid)

SUN (temp= 6000K) = 2898 / 6000 = 0.5

(green)

Energy in VNIR/SWIR is <u>reflected</u> solar energy
Energy in Mid/Far IR is <u>emitted</u> terrestrial energy
There is no solar energy beyond ~ 4.5 microns

3. Brightness Temperature (DN) & Emissivity

Emissivity = the relative power of a surface to emit heat by radiation.

It is the ratio of energy radiated by a particular material to the energy radiated by a (perfect) 'black body' at the same temperature.

Brightness Temperature (DN) = emissivity x temperature ^{4}

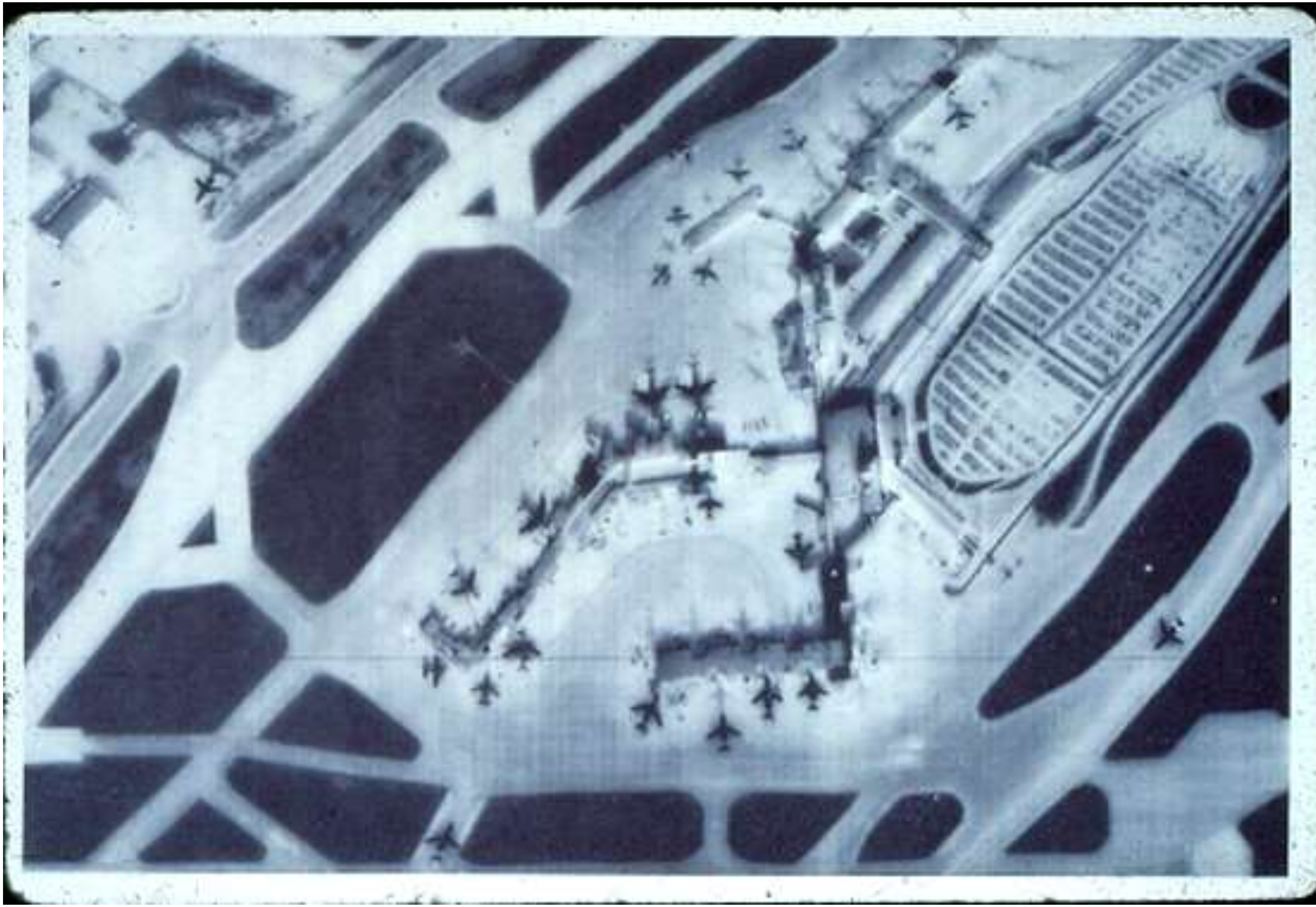
i.e. Actual temperature = $\sqrt[4]{}$ DN /emissivity

Sample emissivity values:

Water	0.99
Wet soil	0.95
Dry soil	0.92
Snow	0.85
Sand	0.76

Result: features with similar DNs may have different temperatures
we use an infrared thermal radiometer to 'ground truth' e.g. sea buoys

Dusseldorf airport thermal image



Daytime image - – note the ‘ghost’ plane shadows

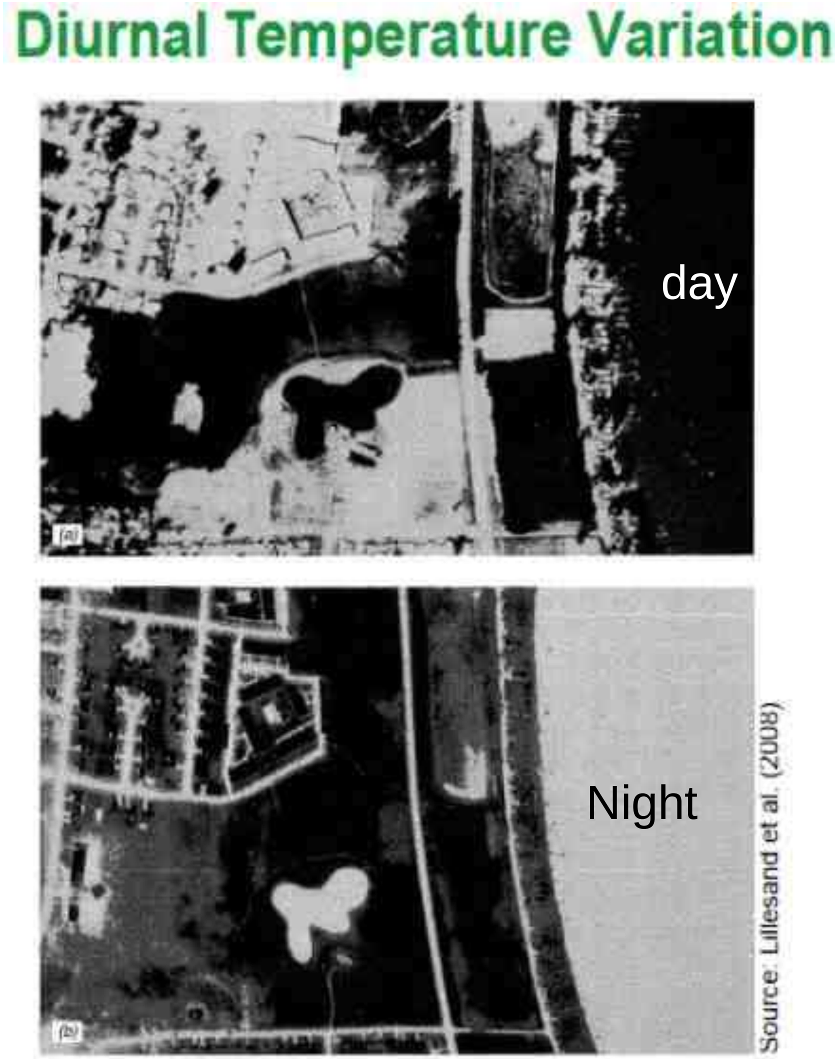
4. Thermal Capacity of Surfaces: the role of water in moderating temperature

Thermal capacity determines how well a material stores heat.
Water has a very high capacity

Water heats up and cools down slowly, as it absorbs Visible / IR during the day and releases energy at night as thermal IR

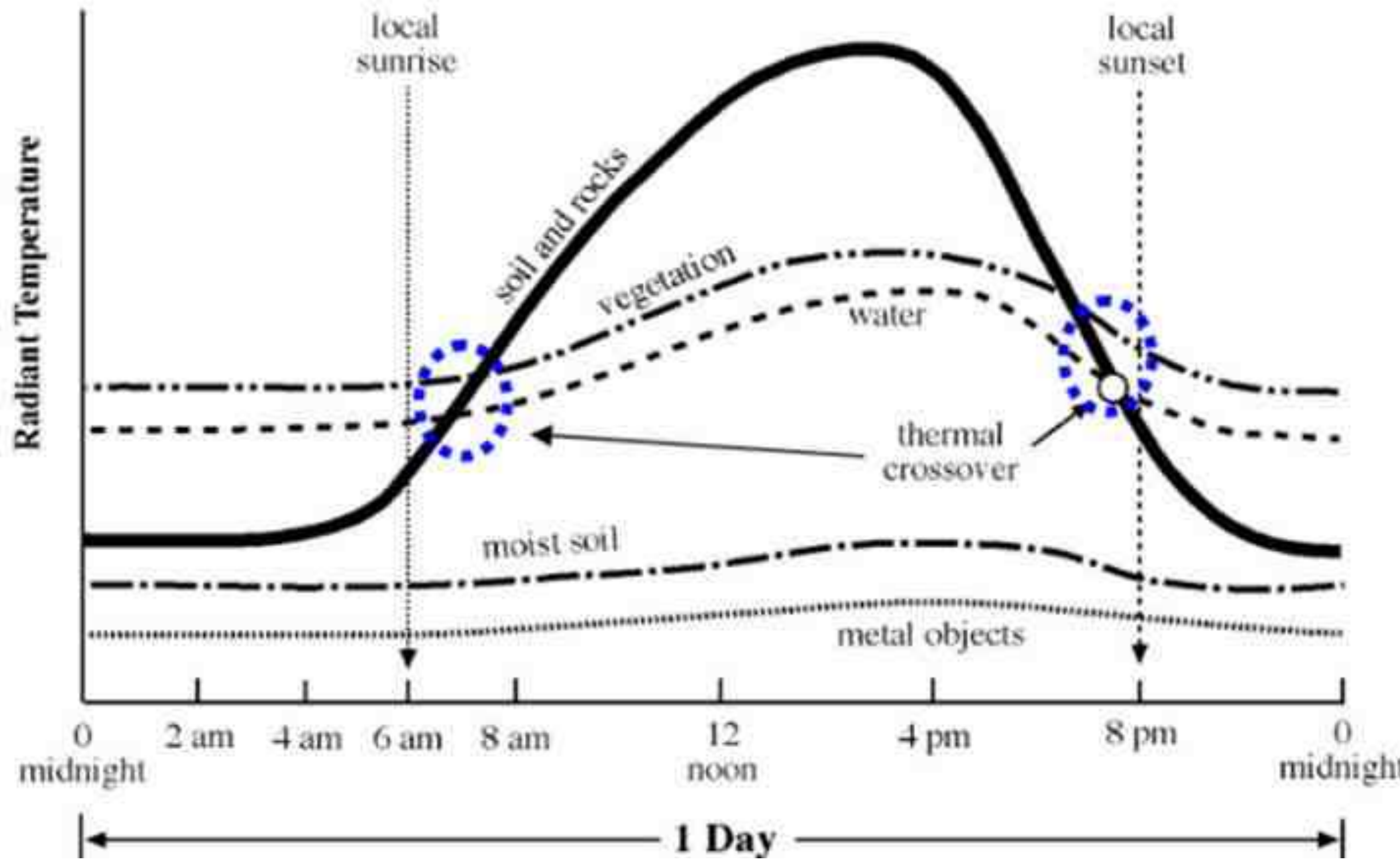
In temperate climates, water is warmer in winter than land surfaces and cooler in summer; and may be warmer at night than land and cooler during the day.

Overall night-time is better to avoid shadows



Diurnal variation – and thermal crossovers

The diurnal or seasonal times when land and water are equal in temperature and scanned images show least contrast. Such '**crossover** periods ' should be avoided in thermal sensing.



Landsat thermal bands

Landsat thermal bands are affected by:

- low radiance = reduced DN range (60-120m pixels)
- shadows (10.30am)
- recent moisture
- it is mostly daytime - not most ideal time for thermal remote sensing

– except for ‘ascending orbit’ on the 'dark side of the earth'

Sensors, wavelength, resolution:

Landsat 4/5 TM: 10.45-12.4 120m

Landsat 7 ETM+: 10.31-12.46 60m

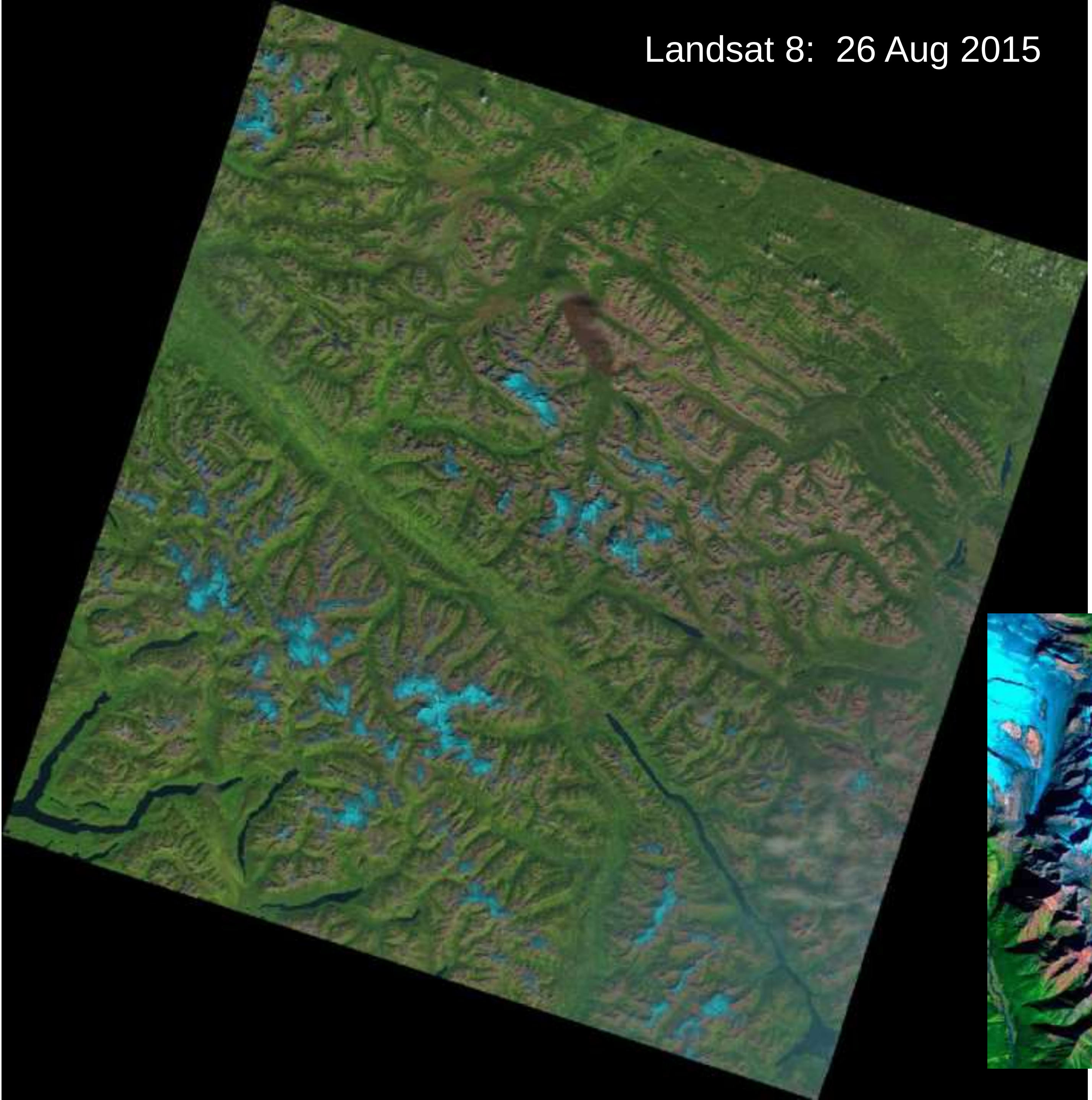
Landsat 8 (2013): 10.3-11.3; 11.5-12.5 100m

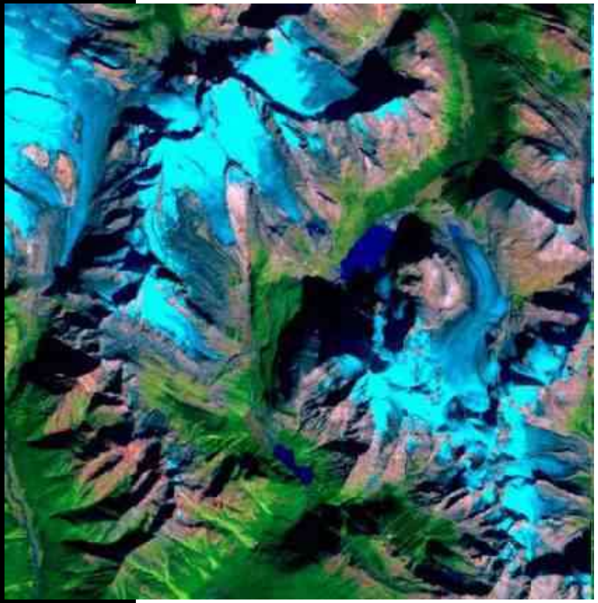
Landsat 9 (2021): 10.6-11.2; 11.5-12.5 100m

Prince George Landsat 5   Band 6 - thermal-IR

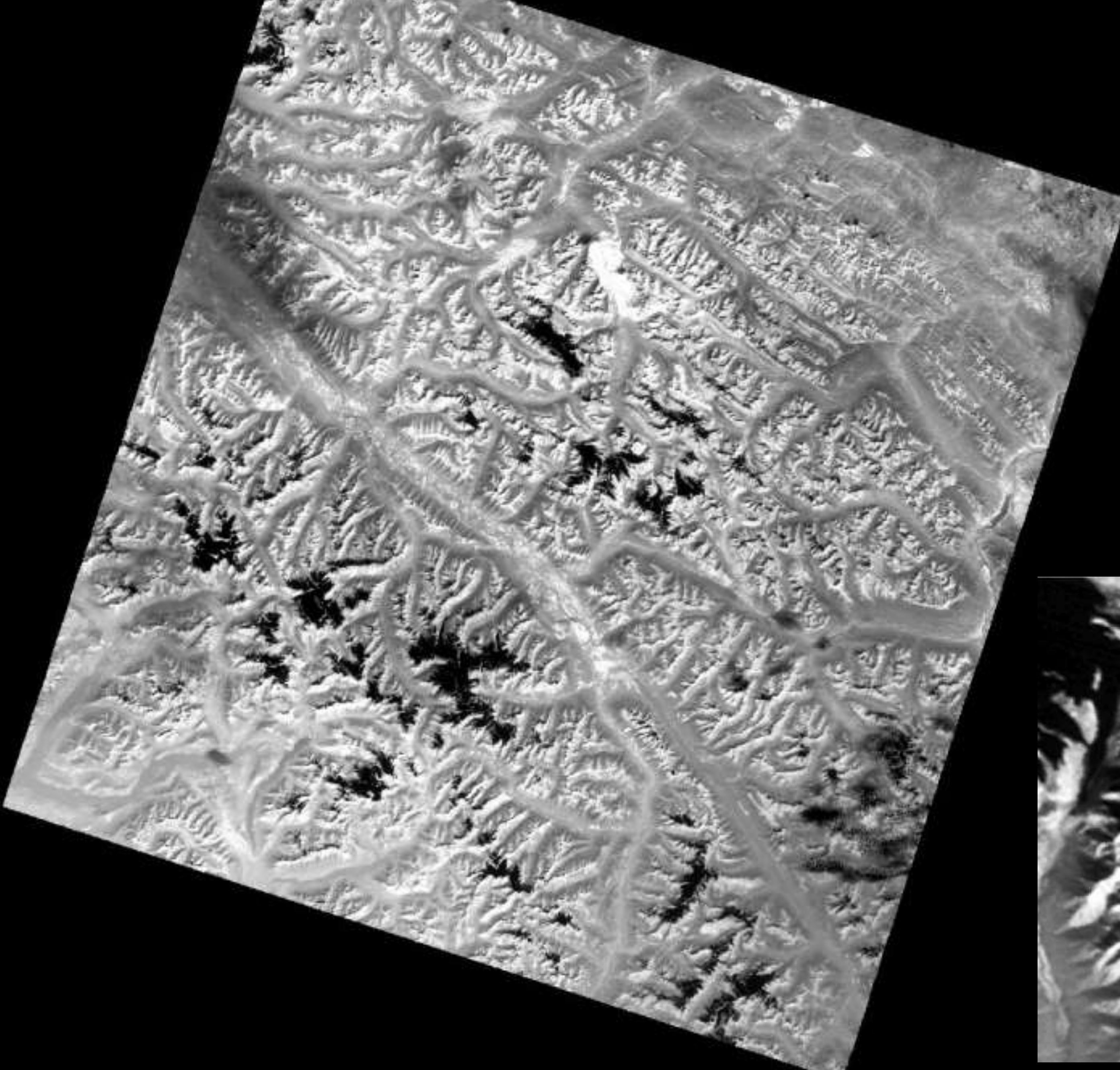
‘Brightness temperature’ – related to surface thermal qualities

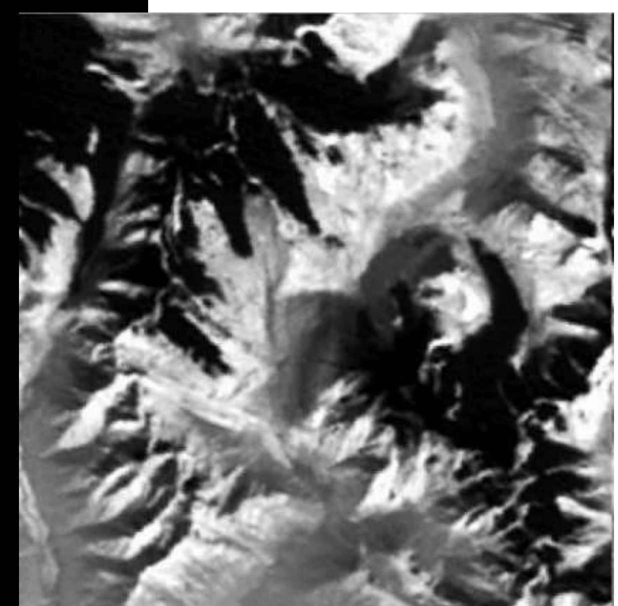
Landsat 8: 26 Aug 2015





Thermal band: 26 Aug 2015



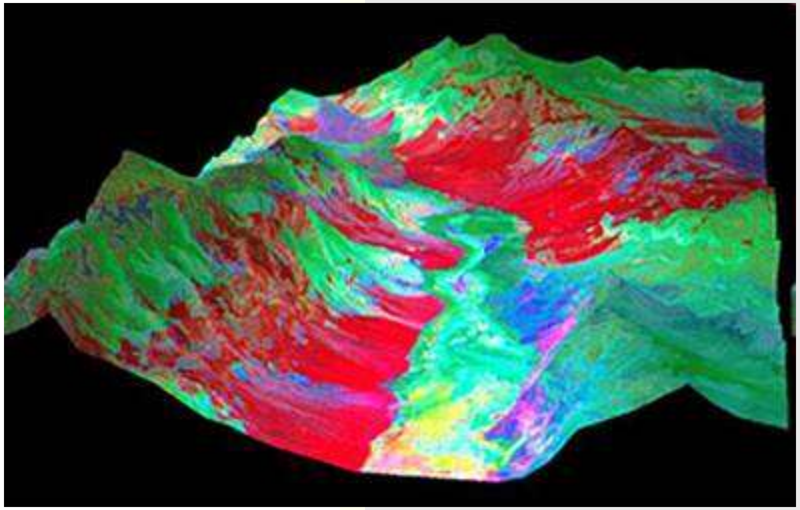


Landsat and other sensors :thermal applications (short list)

- Geological features (desert areas)
- Volcanic hazard assessment
- Mapping lakes, thermal plumes from power plants
- Surface sea temperatures
- Burnt area mapping and active fires
- Urban heat island effects
- Wildlife monitoring
- Thermography
- Glaciers ????

ASTER Instrument Characteristics

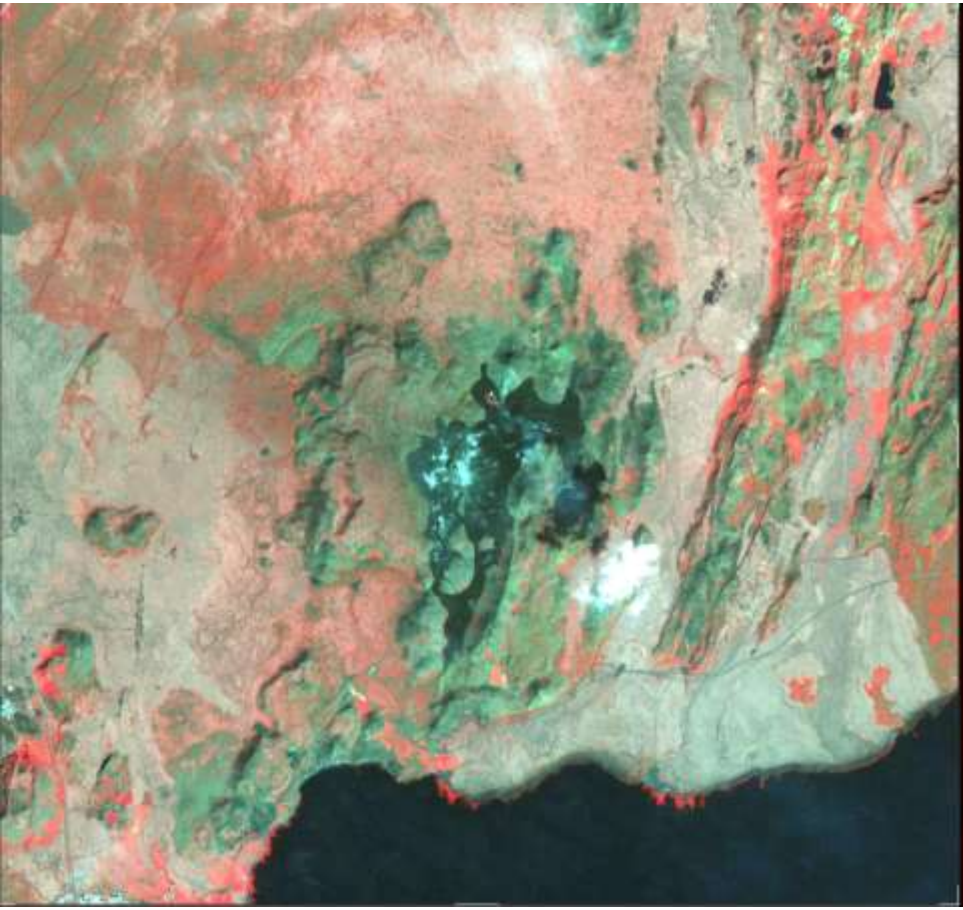
Characteristic	VNIR	SWIR	TIR
Spectral Range	Band 1: 0.52 - 0.60 µm Nadir looking	Band 4: 1.600 - 1.700 µm	Band 10: 8.125 - 8.475 µm
	Band 2: 0.63 - 0.69 µm Nadir looking	Band 5: 2.145 - 2.185 µm	Band 11: 8.475 - 8.825 µm
	Band 3: 0.76 - 0.86 µm Nadir looking	Band 6: 2.185 - 2.225 µm	Band 12: 8.925 - 9.275 µm
	Band 3: 0.76 - 0.86 µm Backward looking	Band 7: 2.235 - 2.285 µm	Band 13: 10.25 - 10.95 µm
		Band 8: 2.295 - 2.365 µm	Band 14: 10.95 - 11.65 µm
		Band 9: 2.360 - 2.430 µm	
Ground Resolution	15 m	30m	90m

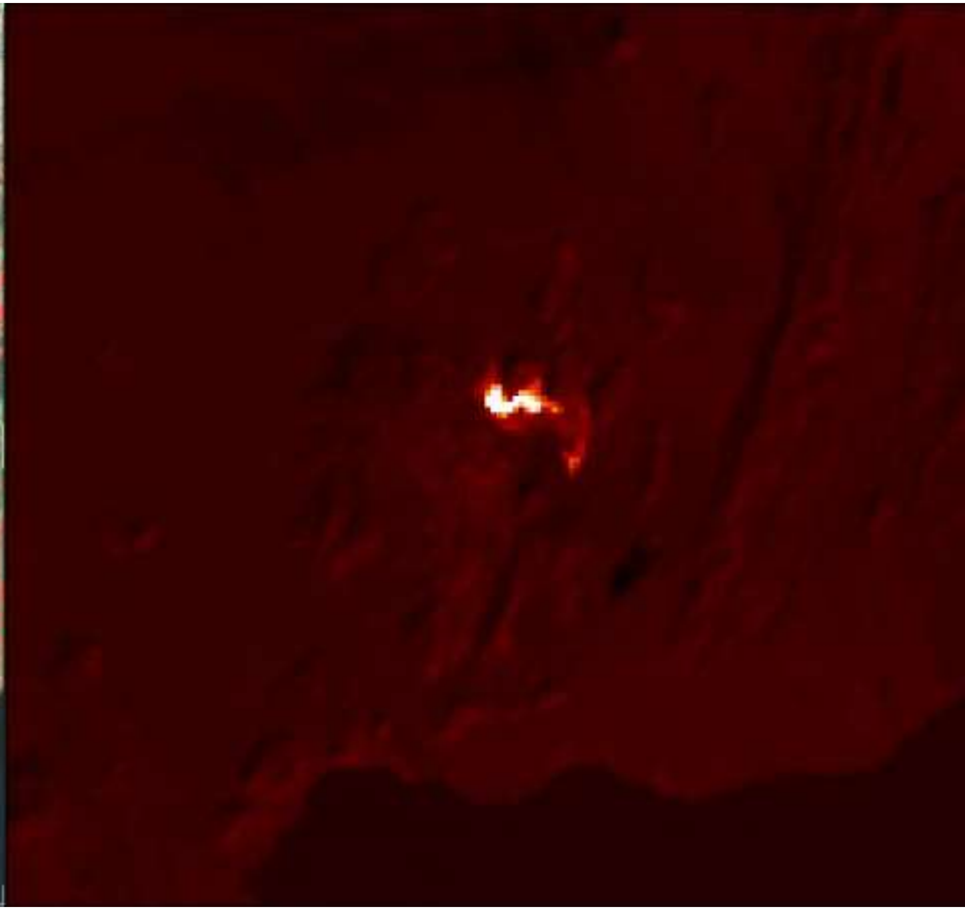


ASTER thermal bands: Death Valley
Blue = Band 10
Green = Band 12
Red = Band 13

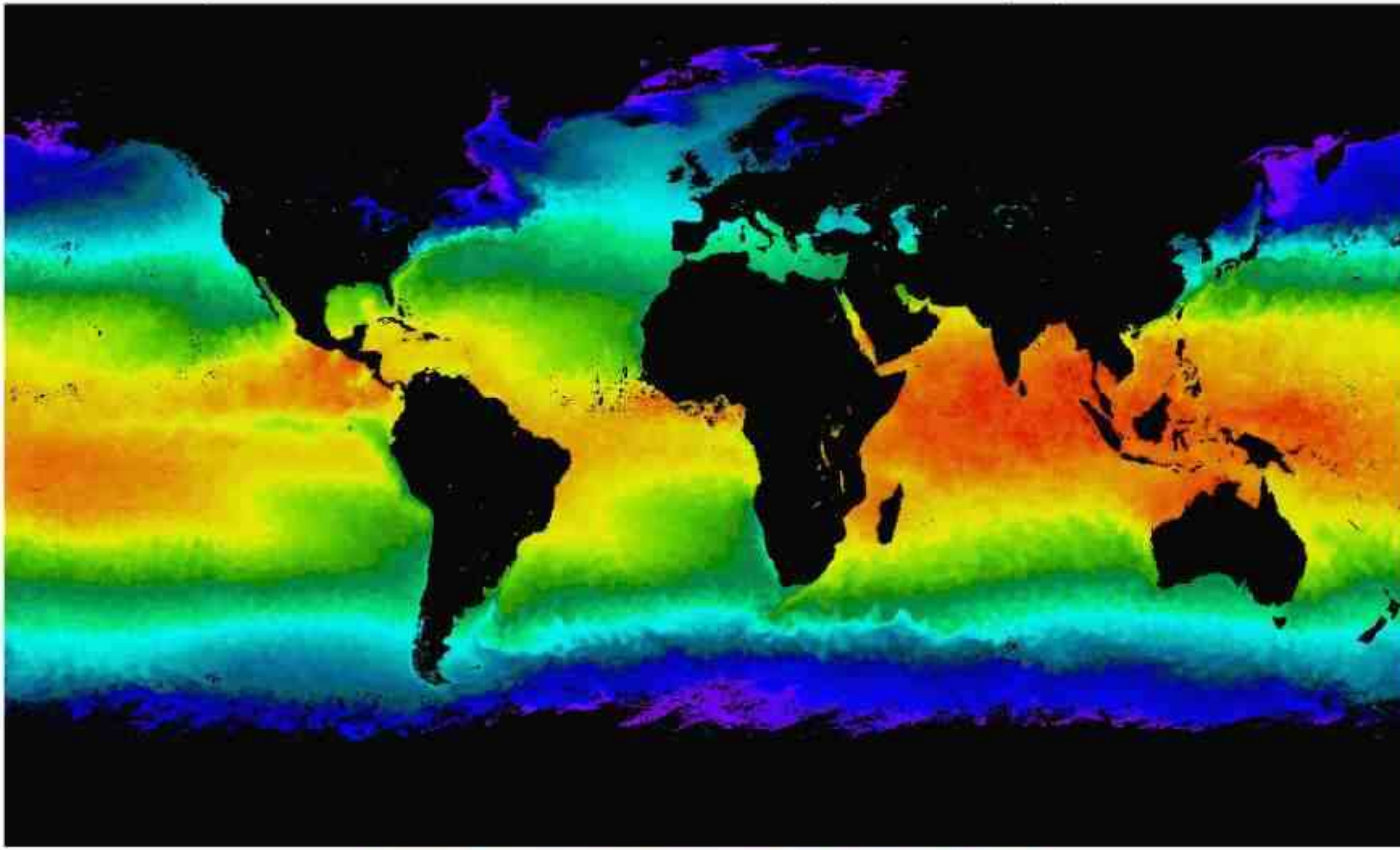
Fagradalsfjall Volcano, Iceland. August 15, 2022

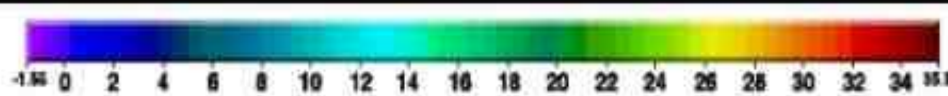
ASTER NIR-Red-Green Thermal





Aqua MODIS Sea Surface Temperature, April 2004

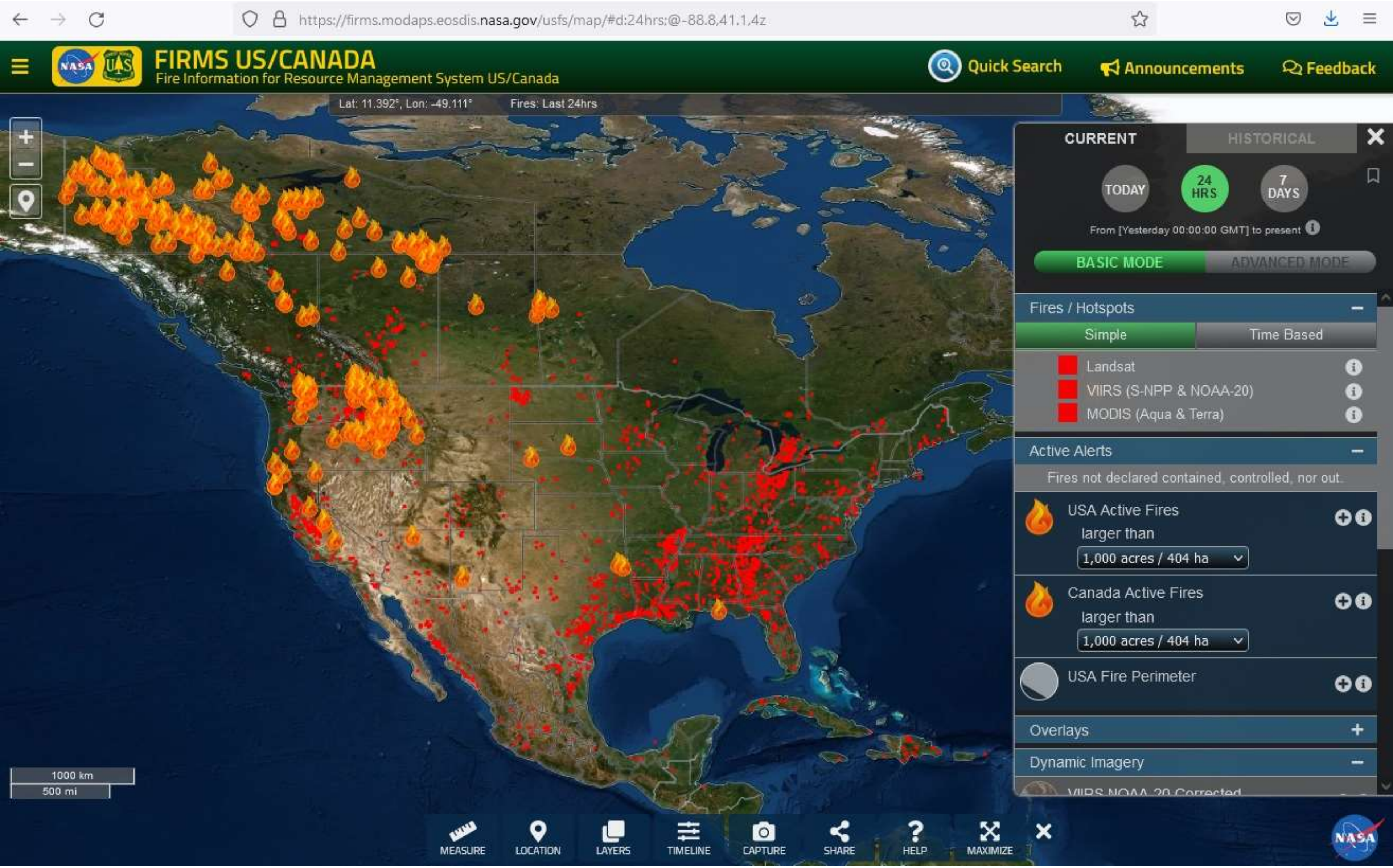




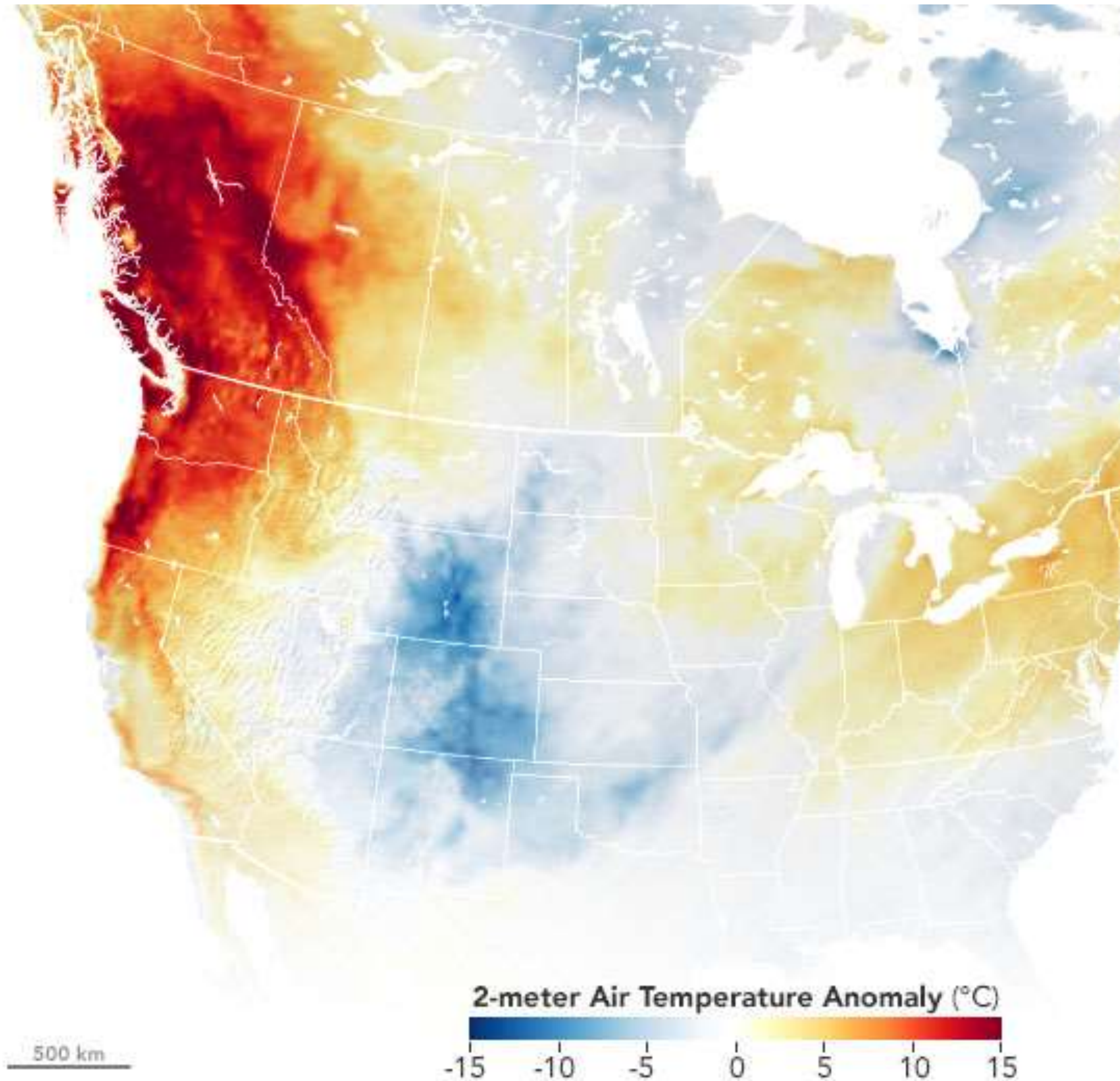
Verified by
sea buoys

All water = same
surface emissivity

Fires - MODIS



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

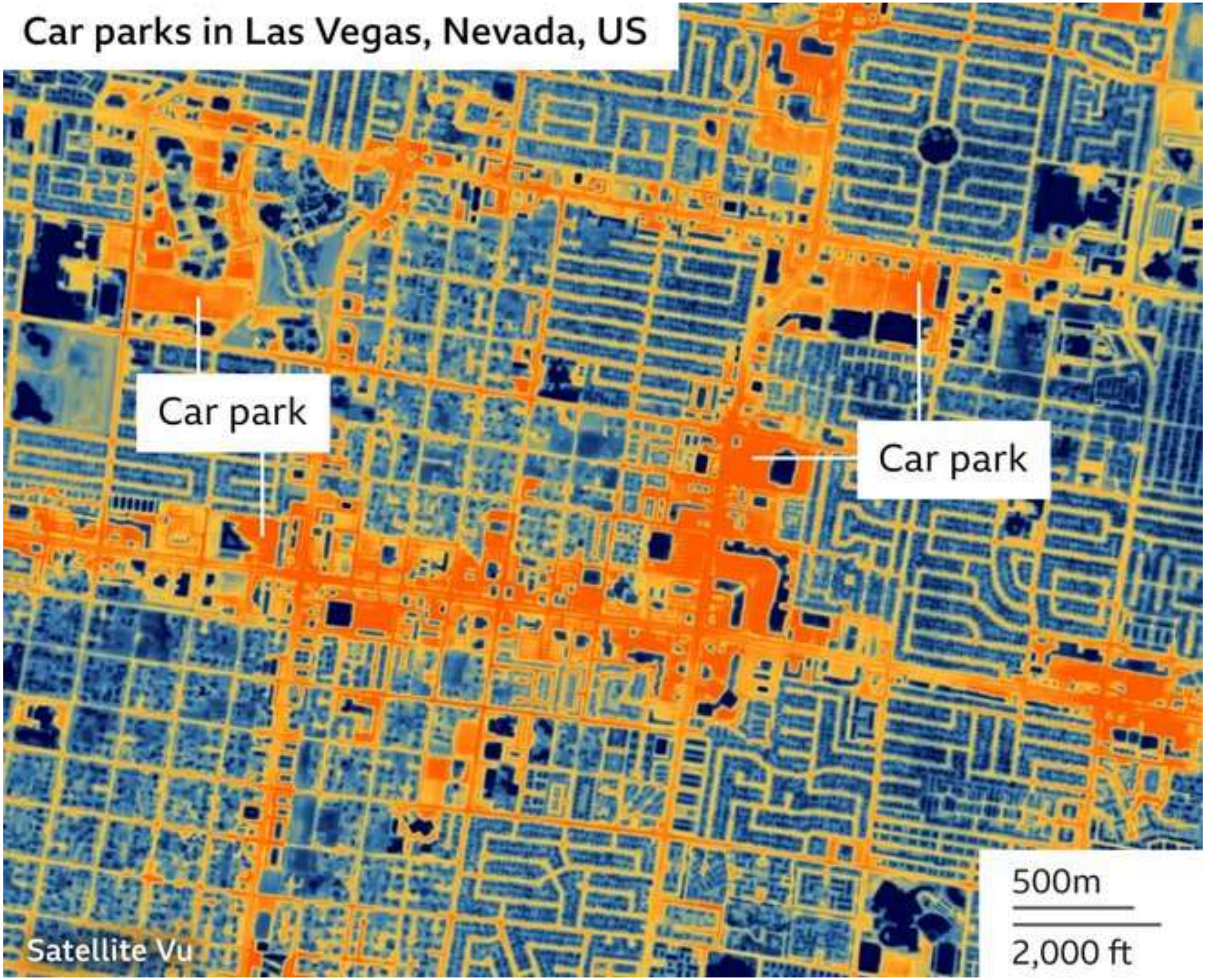


BC Heat dome

June 27, 2021
GOES imagery

Hotsat-1 resolution - 3.5m Mid-infrared - 3.4-5.0 µm, launched June 2023

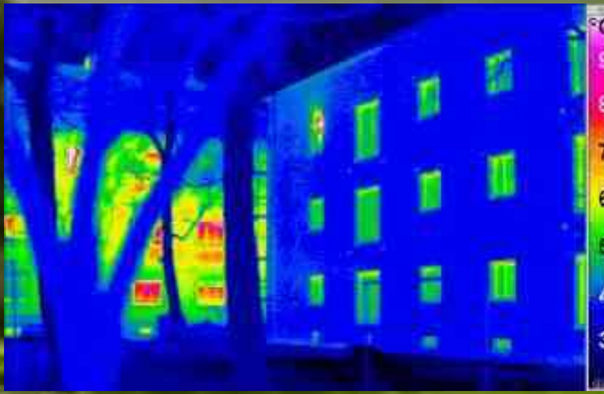
https://www.satellitevu.com



https://www.bbc.com/news/science-environment-67010377

Drones with thermal cameras used to locate Koalas in Australian bush fires

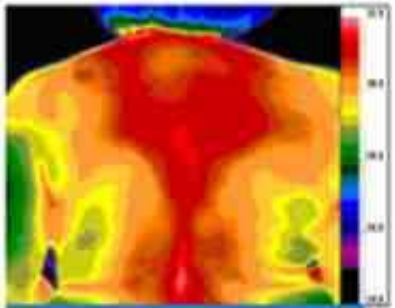
Welcome to Thermography Northern BC



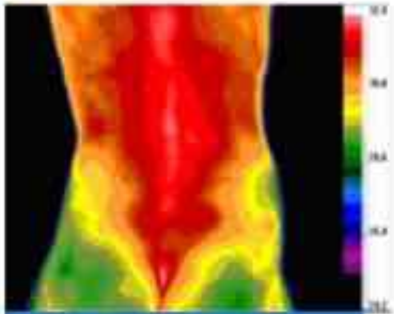
Home | Who is it for? | What is thermography | FAQ | Your appointment | Contact/Fees | Forms

Thermography is a safe, non-invasive screening tool helpful in the diagnosis of the following:

- Arthritis
- Breast Health Evaluation
- Carpel Tunnel Syndrome
- Chronic Low Back Pain
- Chronic Nerve Injury
- Complex Regional Pain Syndrome
- Fibromyalgia
- Headache / Sinus Pain
- Neck and Back Problems
- Pain Evaluation
- Referred pain
- Visualization of Pain
- Repetitive Strain Injuries
- Soft Tissue Injuries/ Sports Injuries
- Stroke Risk Assessment
- Musculo-Skeletal Syndromes
- Whiplash



Fibromyalgia or Chronic Fatigue



Chronic Back Ache