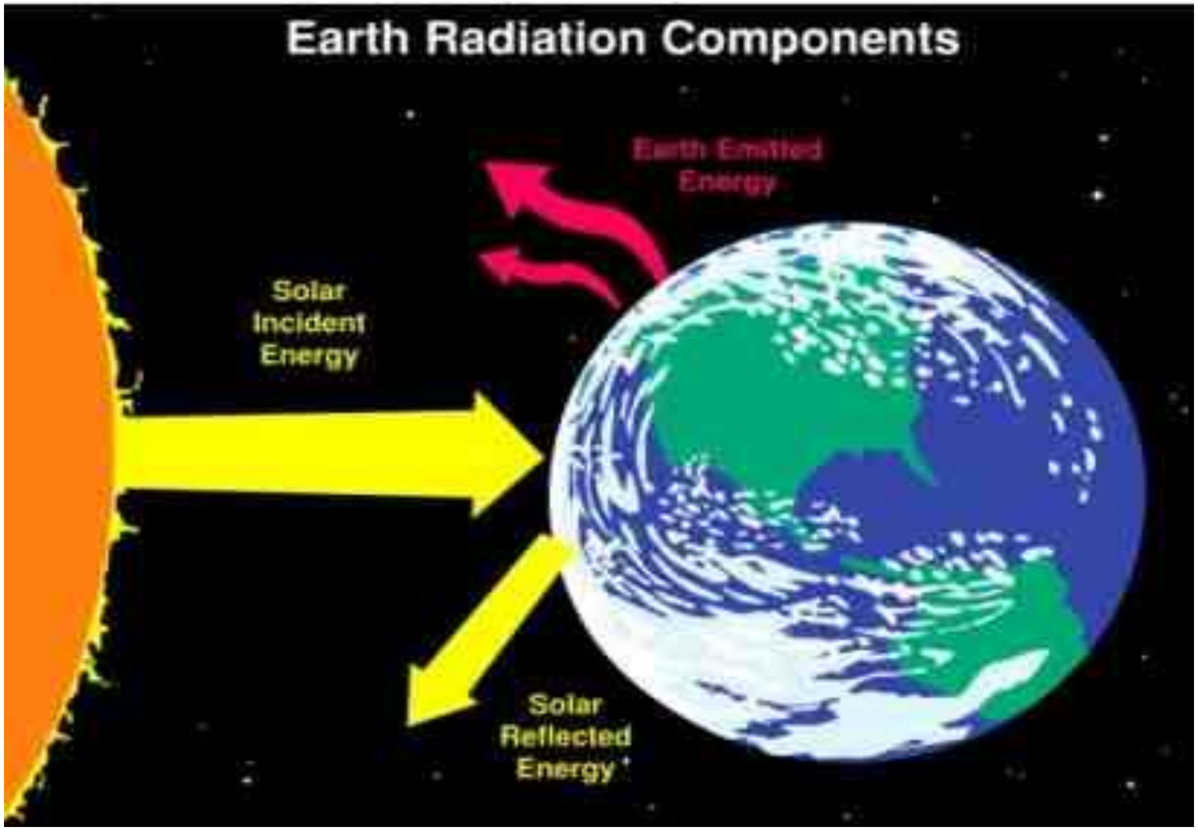
Thermal Infrared (3-14 microns)

Features of thermal RS:

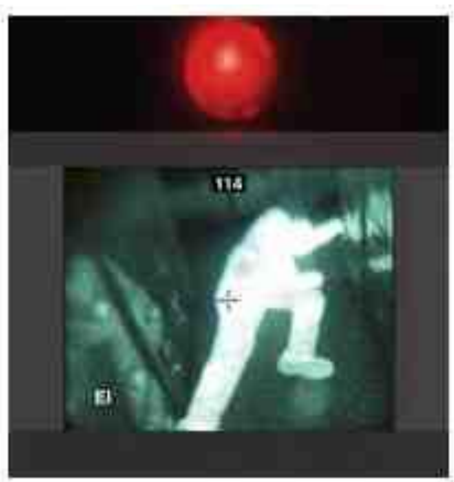


records longer wavelengths and a measure of temperature as it is emitted NOT reflected IR

- Works day / night (temperatures above 0 K = -273 Celsius)

Usually lower pixel resolution as there is less energy to capture

Thermal Infrared (3-14 microns)



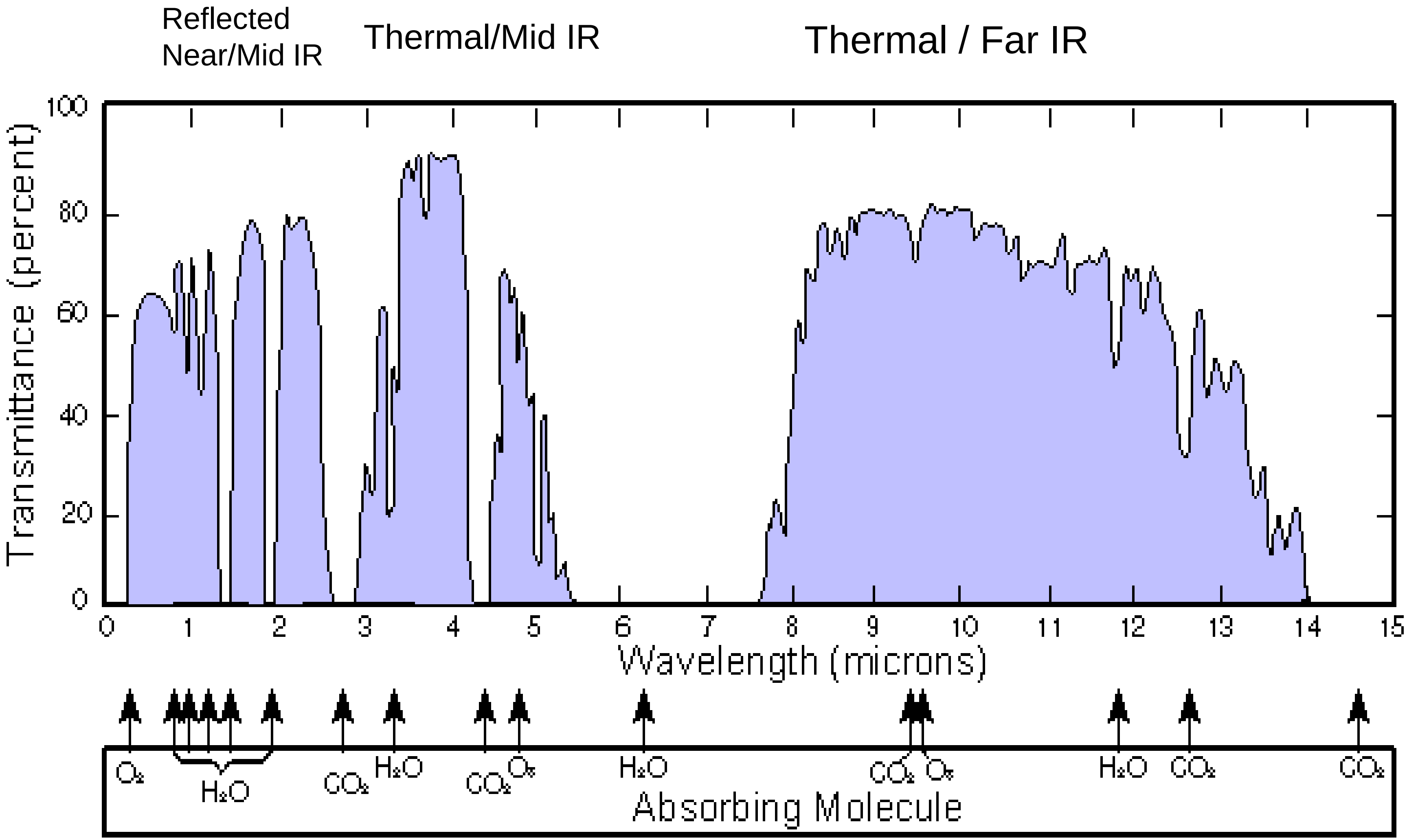
Thermal IR can 'see' through

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.

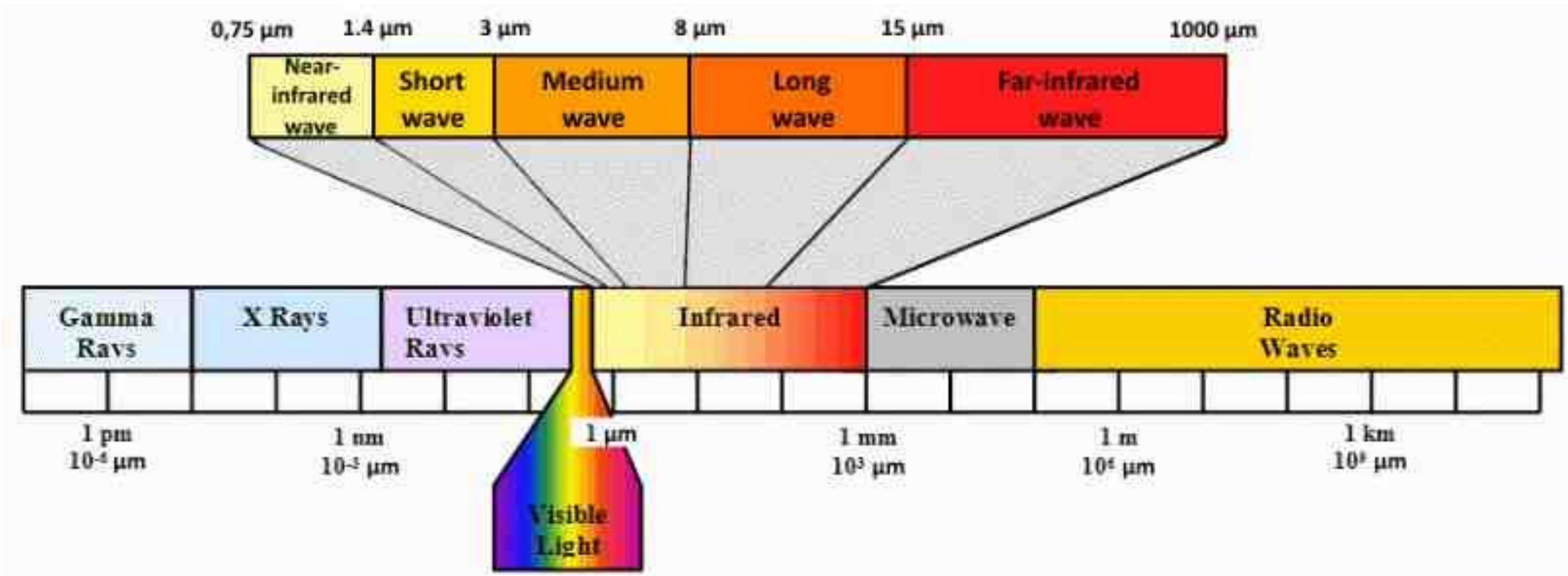
1. Thermal Wavelengths (3-14 µm) windows:3-5,8-14

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



There is some confusing naming of IR sections of the spectrum

Bands NIR SWIR / MIR TIR



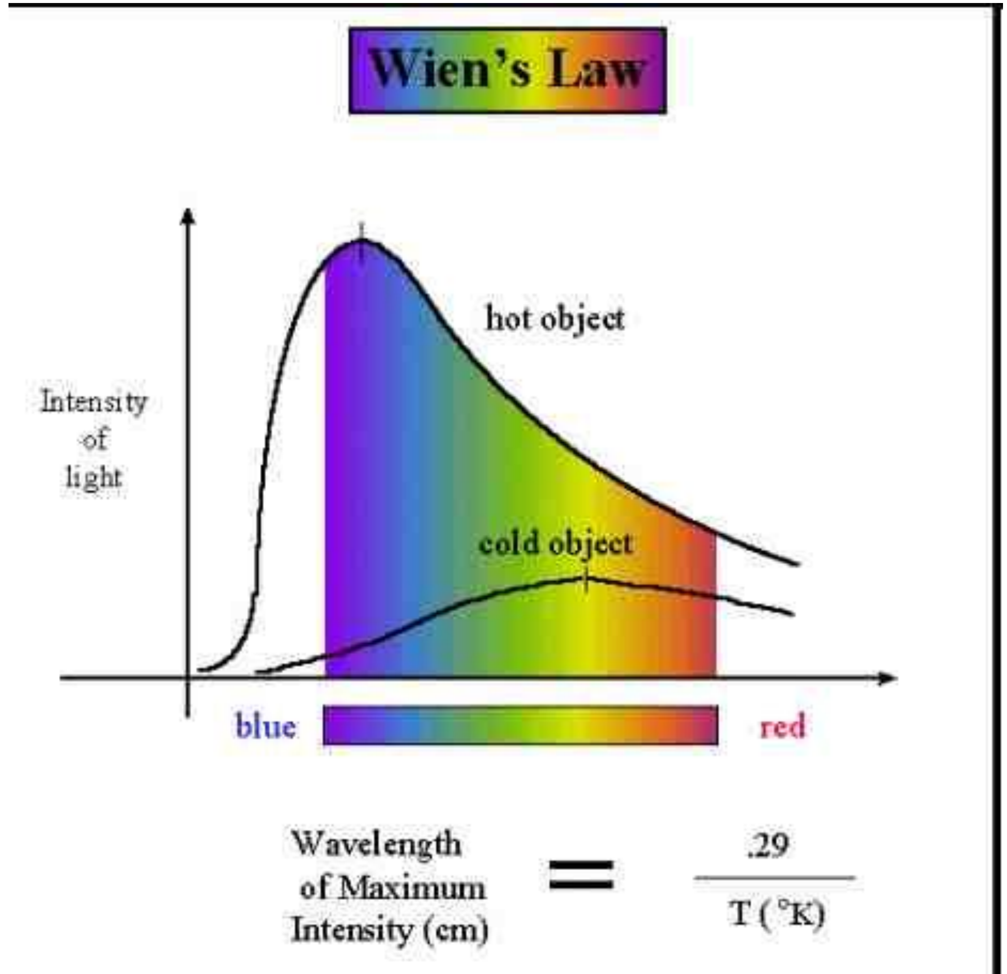
Different scientific areas use different terms

2. Wavelength & Temperature

Thermal IR is emitted terrestrial energy, received from the sun and absorbed.

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

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



Wavelength = 2898 /temp K (microns)

-> so 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)

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 black body at the same temperature.

Brightness Temperature = emissivity x temperature ^{4}

(DN converted back to radiance)

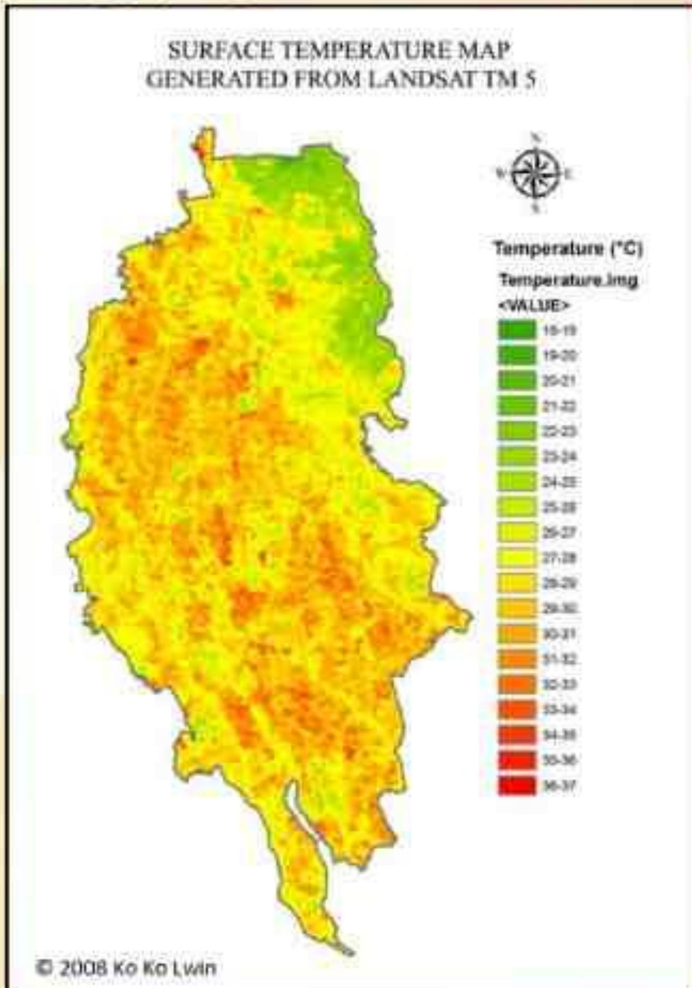
$$\text{i.e. Actual temperature} = \sqrt[4]{\text{DN}/\text{emissivity}}$$

Sample emissivity values:

Water	0.99
Wet soil	0.95
Dry soil	0.92
Snow	0.85

Converting thermal DN values to radiance → temperatures

3.3 Apply Algorithms *(continued)*



<u>Step1. Conversion of the Digital Number (DN) to Spectral Radiance (L)</u>

L = LMIN + (LMAX - LMIN) * DN / 255

Where

L = Spectral radiance

LMIN = 1.238 (Spectral radiance of DN value 1)

LMAX = 15.600 (Spectral radiance of DN value 255)

DN = Digital Number

<u>Step2. Conversion of Spectral Radiance to Temperature in Kelvin</u>

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L} + 1\right)}$$

Where

K_1 = Calibration Constant 1 (607.76)

K_2 = Calibration Constant 2 (1260.56)

T_B = Surface Temperature

<u>Step3. Conversion of Kelvin to Celsius</u>

$T_B = T_B - 273$

Tsukuba City surface temperature map generated from Landsat TM5 satellite acquired by 1987-05-21, 11:00AM Local Time (JST)

This could be a topic for advanced RS

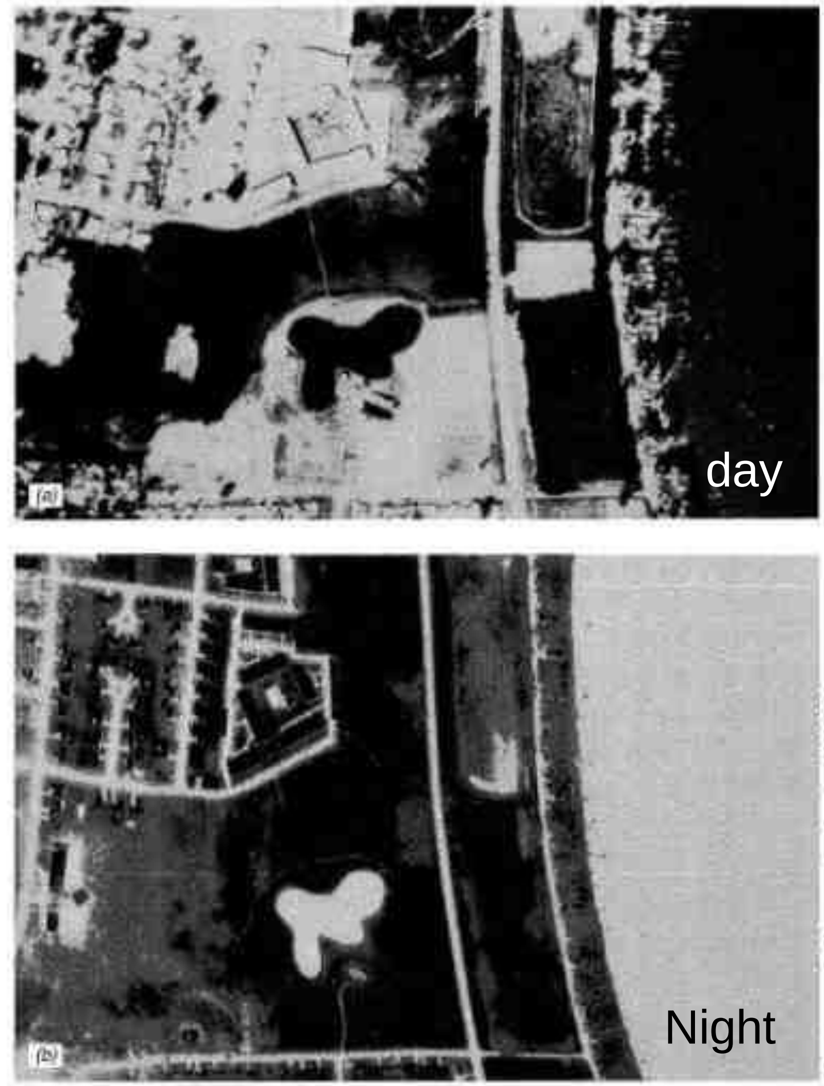
4. Thermal Capacity of Surfaces: the role of water

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

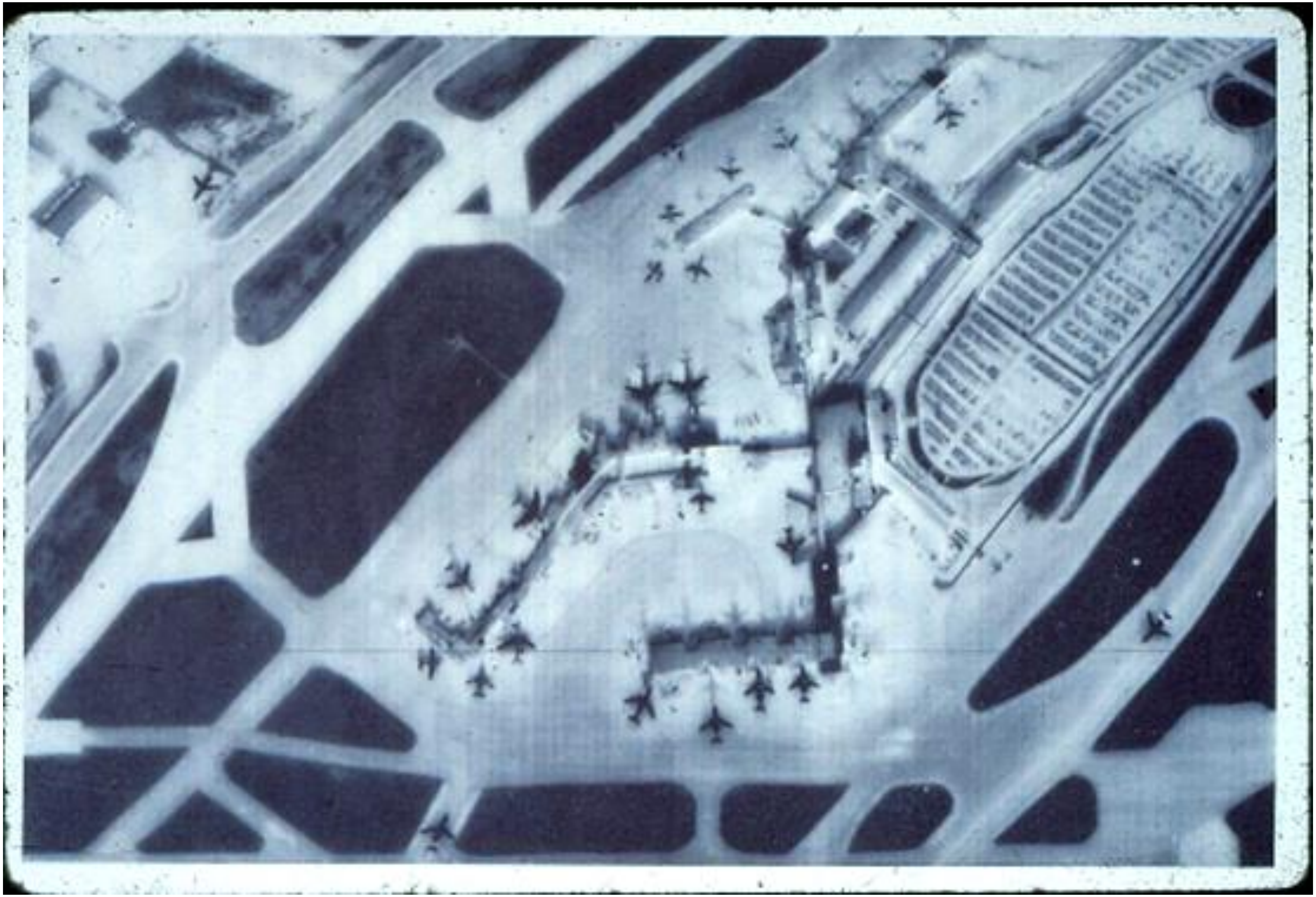
In temperate climates, water is warmer in winter than land surfaces and cooler in summer; and may be warmer at night than land and cooler during the day.

Diurnal Temperature Variation



Source: Lillesand et al. (2008)

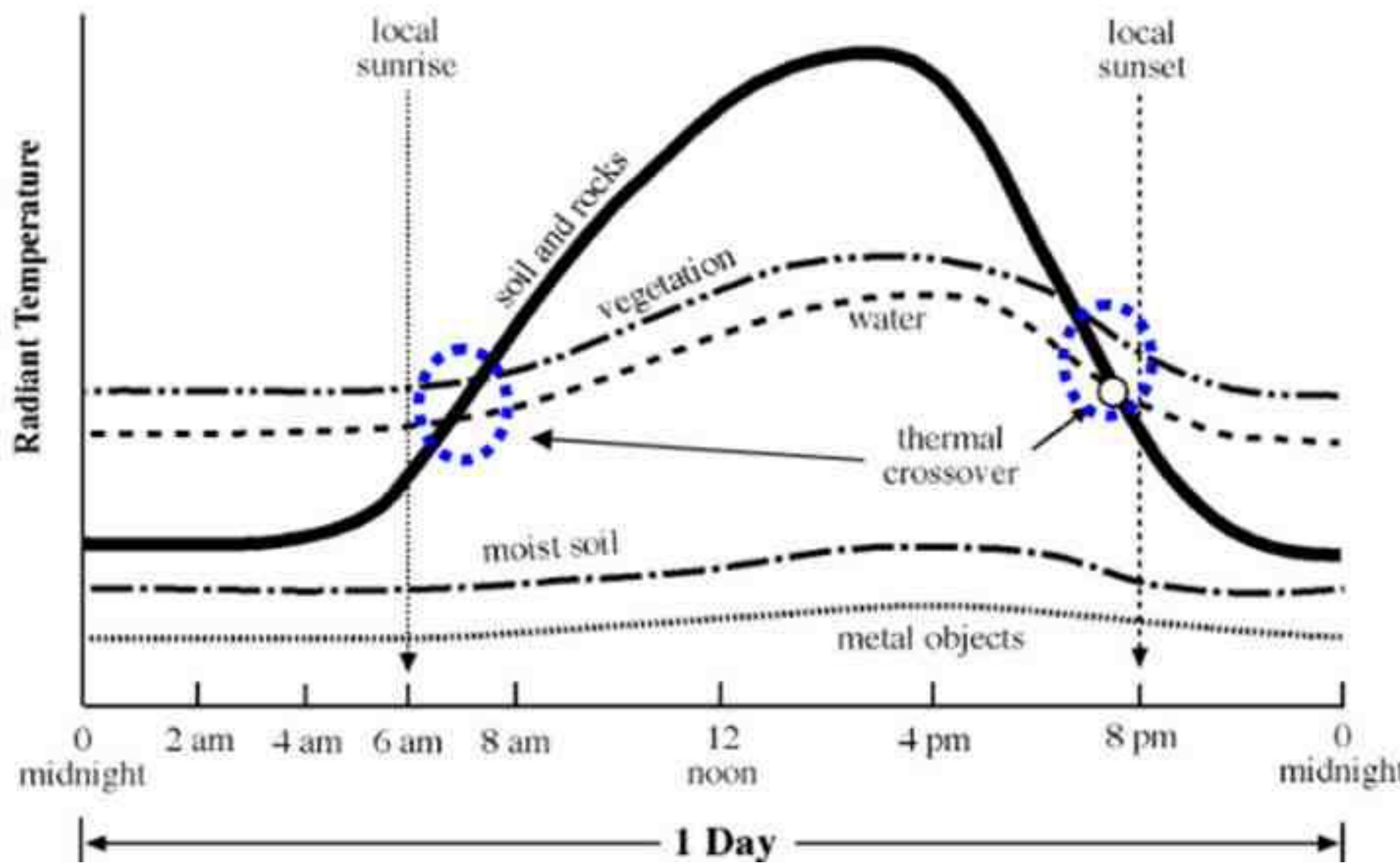
Dusseldorf airport thermal image



Daytime image - – note the ‘ghost’ plane 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.



Practical considerations in thermal remote sensing

- Lower thermal wavelengths can get mixed with reflected solar energy (3-5 microns).

- Night time is preferred to avoid shadowing (topographic / clouds) and solar heating.

- The larger the pixel area, the finer temperature differences can be detected. …. Temperature resolution can be as fine as 0.1° C.

- pixel size is larger (courser resolution), than for reflected bands …. as there is less energy to capture

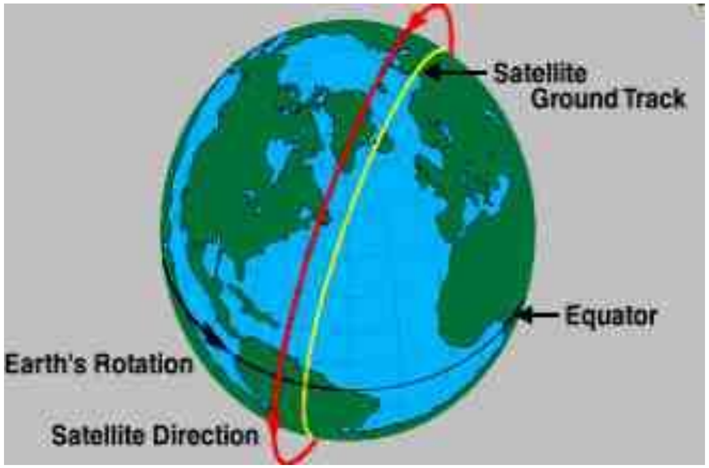
Landsat thermal bands

Landsat thermal bands are affected by:

- low radiance = reduced DN range (60-120m pixels)
- shadows (10.30am)
- recent moisture
- it is mostly daytime so not ideal for thermal remote sensing – except for 'ascending orbit' '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



Sun-synchronous orbit

Prince George Landsat 5   Band 6 - thermal-IR

'Brightness temperature' – related to surface thermal qualities

(Landsat) thermal applications (short list)

- Urban heat island effects
- Volcanic hazard assessment
- Mapping lake thermal plumes from power plants
- Burnt area mapping and active fires
- Glaciers ????

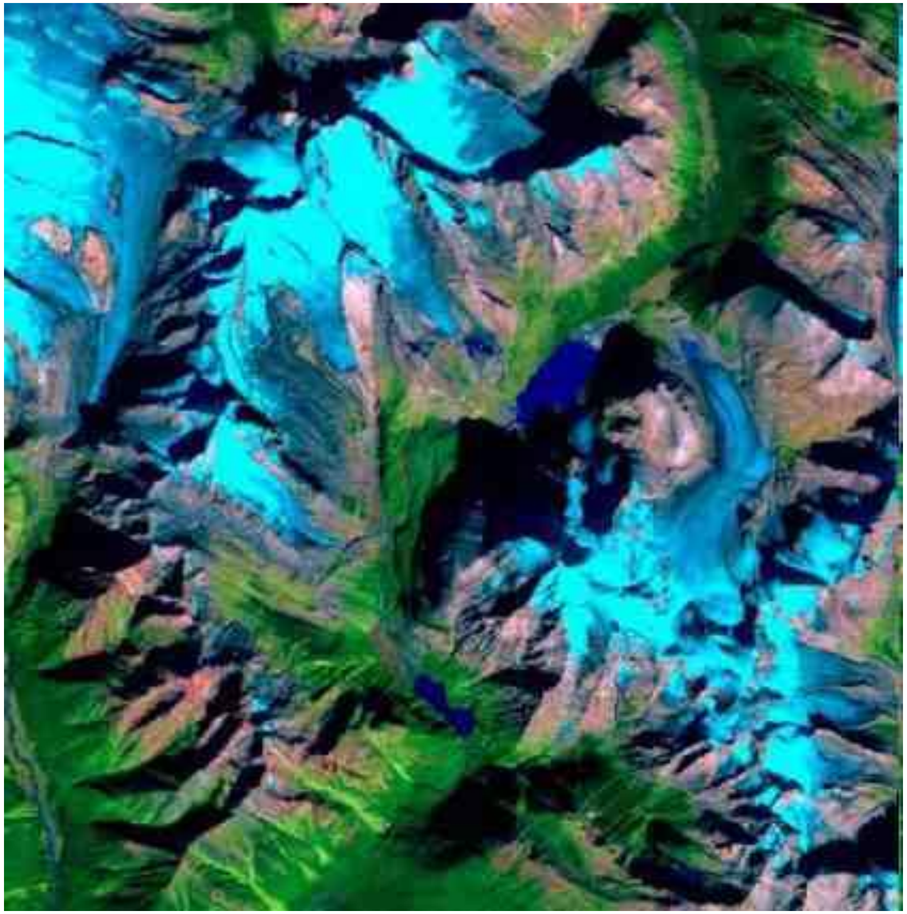
Thermal characteristics Mt. Robson, TM 543 composite/ thermal band 6

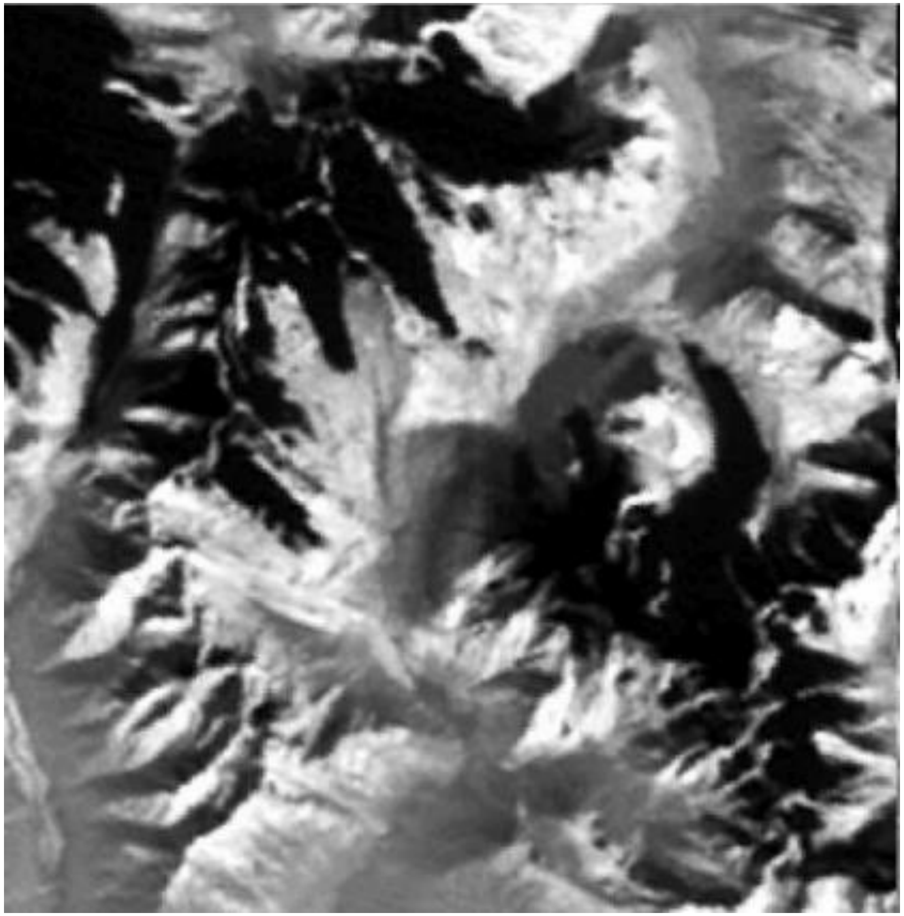
Water is cooler (darker) during day, but reversed at night .. due to heat transfer;

Vegetation is cooler than surroundings in day, warmer at night (leaves have moisture).

Grass is warmer during day than forest, cooler-darker at night

Damp ground: Effect of absorbed water: cooler in day, warmer at night

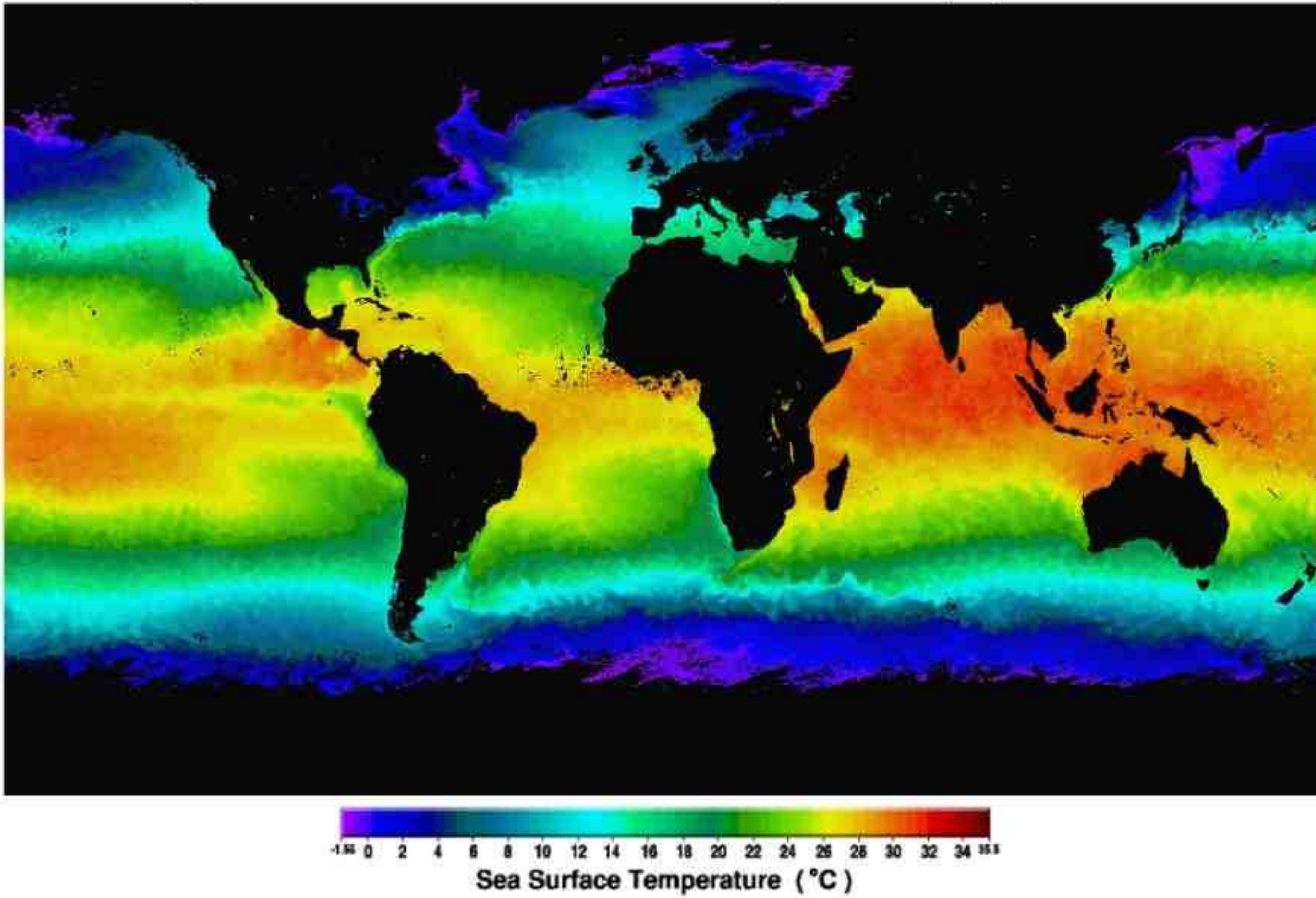




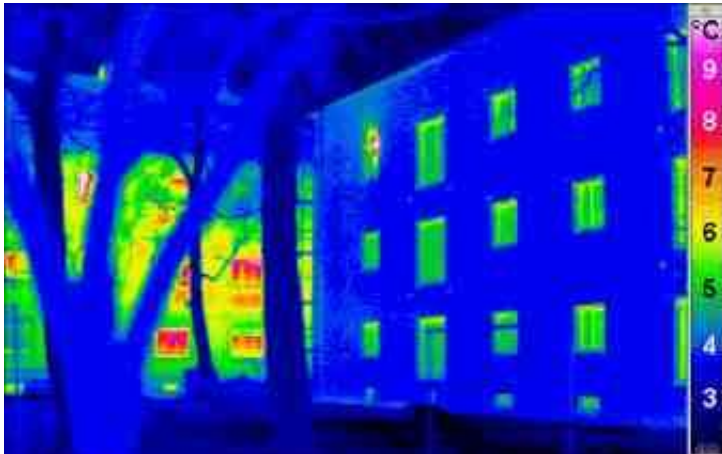
Fires – MODIS

Fires in the Bahamas, Florida and Cuba (03 April 2004, 18:30 UTC) identified using MODIS Aqua and outlined in red on the MODIS 1km active fire map (MODIS)
http://activefiremaps.fs.fed.us/

Aqua MODIS Sea Surface Temperature, April 2004

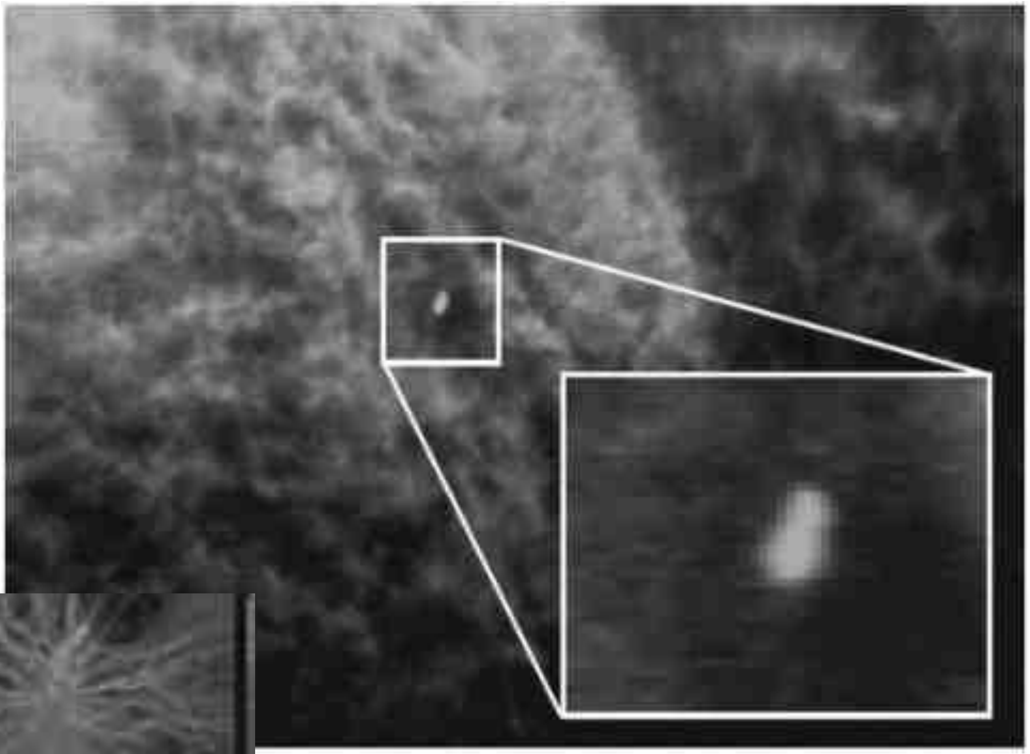


Thermography- Building heat loss



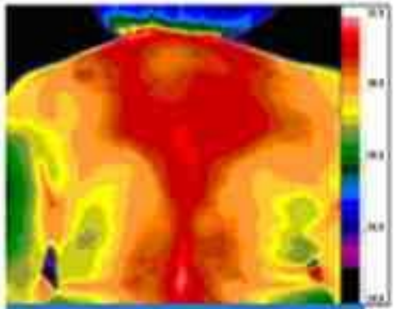
Wildlife:

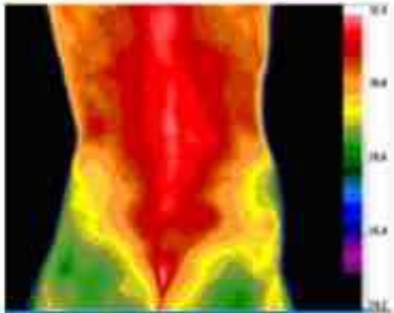
http://idahohelicopters.com/flir.htm **X**

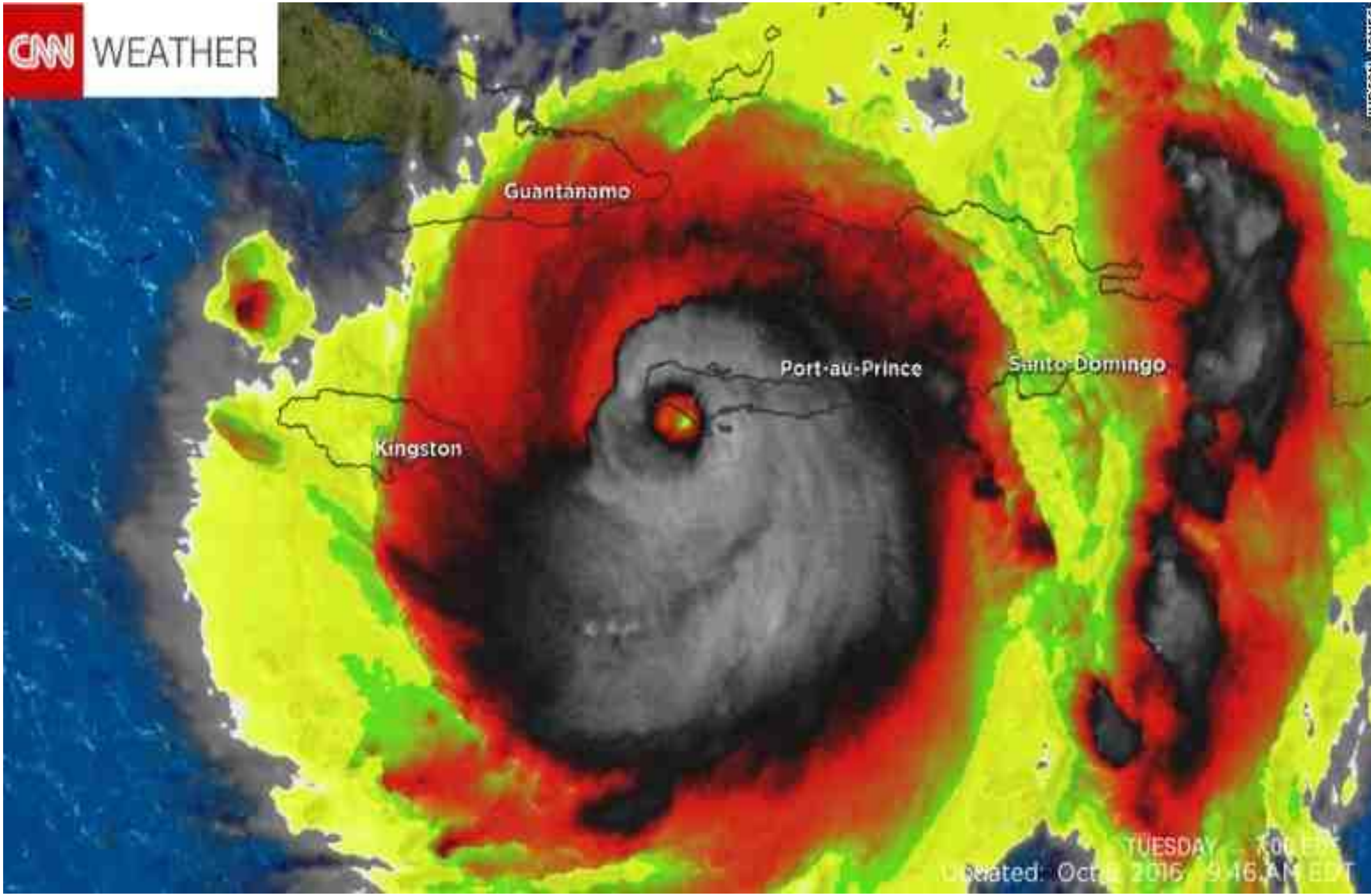


Thermography is a safe, non-invasive screening tool helpful in the diagnosis of the following:

- 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



Hurricane Matthew, October 2016