Thermal Infrared (TIR) Remote Sensing: Challenges in Hot Spot Detection

ASF Seminar Series

Anupma Prakash

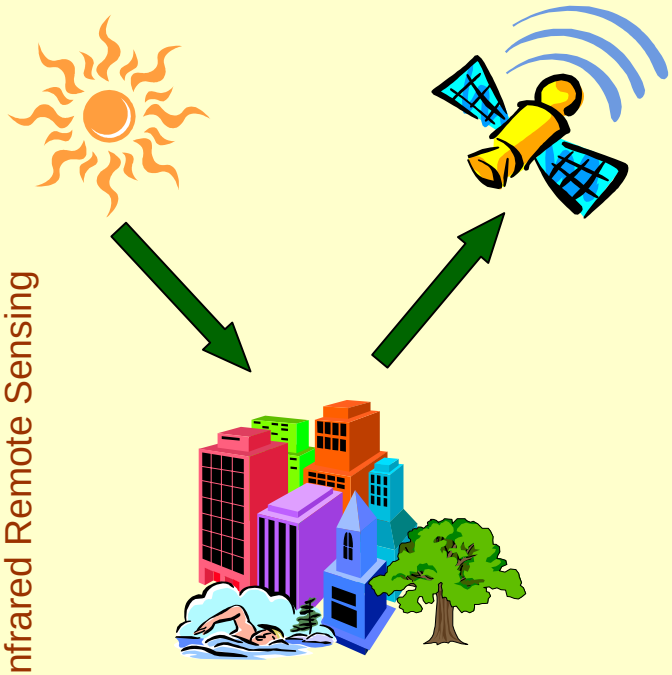
Day	: Tuesday
Date	: March 9, 2004
Time	: 2.00 pm to 2.30 pm
Place	: GI Auditorium

Geophysical Institute, University of Alaska Fairbanks

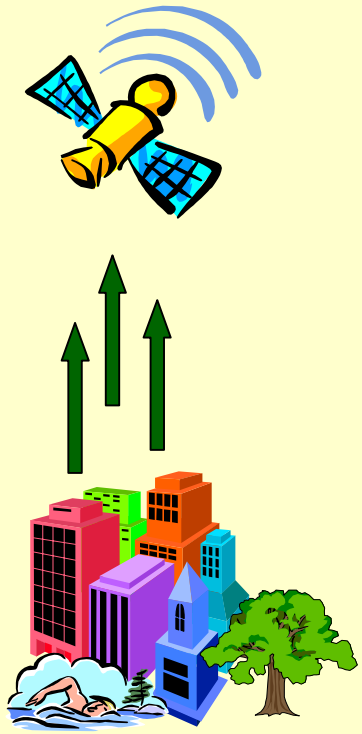
Contents

- Concepts and principles
- Operational challenges in TIR remote sensing
- Hot spot detection techniques and limitations

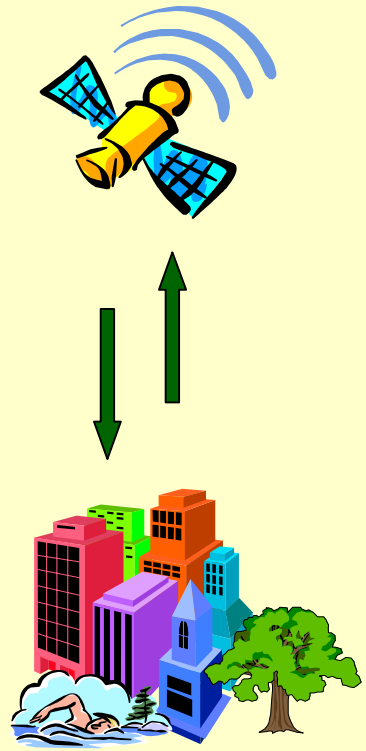
TIR Remote Sensing



Passive
(reflected)



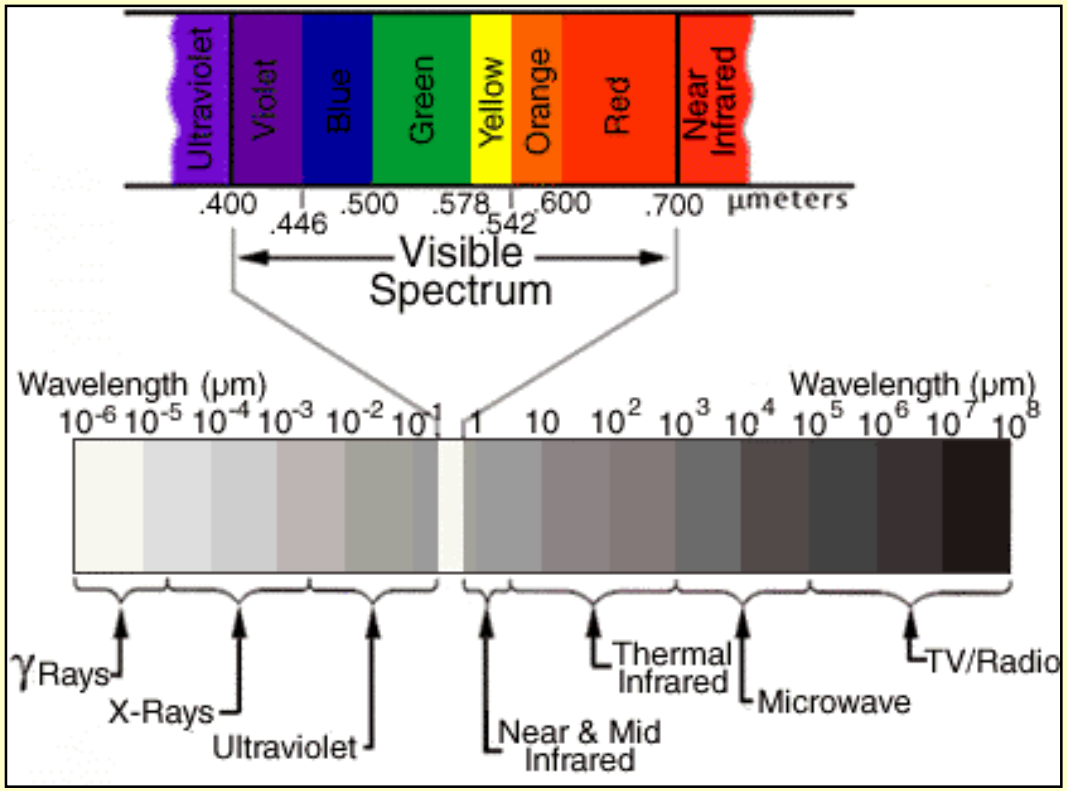
Passive
(emitted)



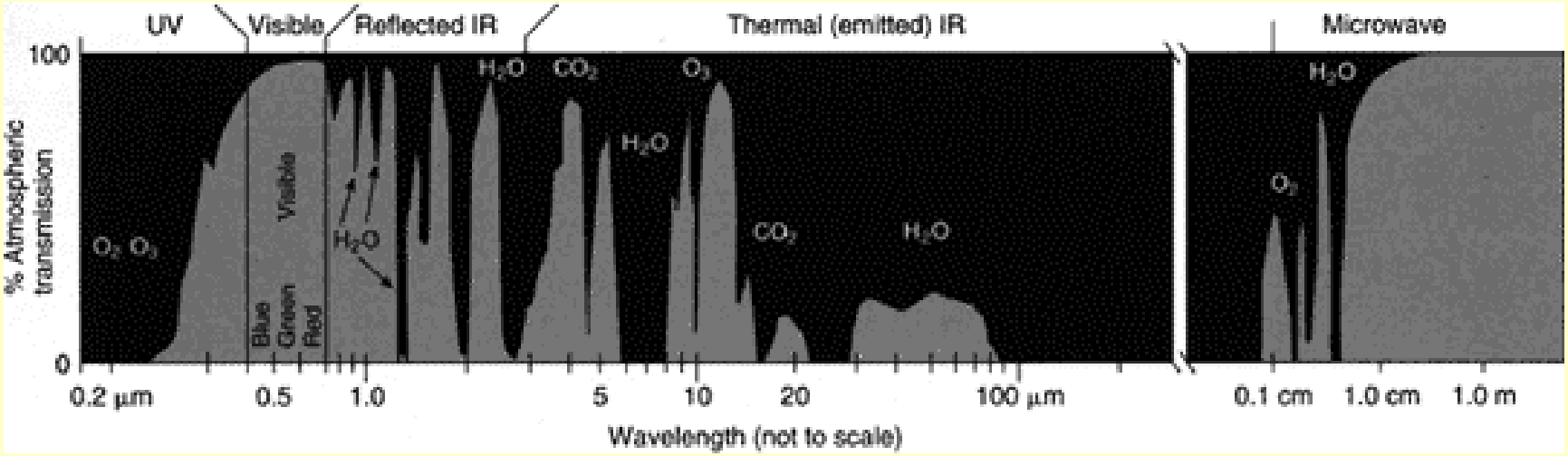
Active

Wavelength range

- For terrestrial remote sensing the 3-35μm region is referred to as TIR



Problems with the TIR region



- Only 3 atmospheric windows in TIR
  - 3-5 µm
  - 8-14 µm
  - 17-25 µm

Concepts

- Everything above absolute zero (0K or -273.1°C or -459°F) emits radiation in the infrared range of the electromagnetic spectrum

- How much energy is radiated, and at which wavelengths, depends on the emissivity of the surface and on its kinetic temperature

Concepts

- Emissivity: Emissivity is the emitting ability of a real material compared to that of a black body. It depends on nature of the object's surface. Emissivity denoted by epsilon (ε) is a ratio and varies between 0 and 1.

- Temperature: Temperature (kinetic) is a measure of the amount of heat energy contained in a body. It is measured in different units, such as in Kelvin (K); degrees Centigrade (°C); degrees Fahrenheit (°F).

Plank's Law

Planck's law determines the emission pattern/spectra of EMR of a blackbody as a function of it's wavelength and temperature

$$W_\lambda = \frac{C_1}{\lambda^5[\exp(C_2/\lambda T) - 1]}$$

where

W_λ = total spectral exitance = $L_\lambda * \pi$

T = Blackbody Temperature in Kelvin

λ= wavelength in consideration

C_1 and C_2 are constants

Inverse Planck's equation

- Inverting Planck's equation one can calculate the temperature of a blackbody from spectral radiance (L_λ)

$$T = \frac{C_2}{\lambda \ln[(C_1 \lambda^{-5}/\pi L_\lambda) + 1]}$$

The rest is simple…

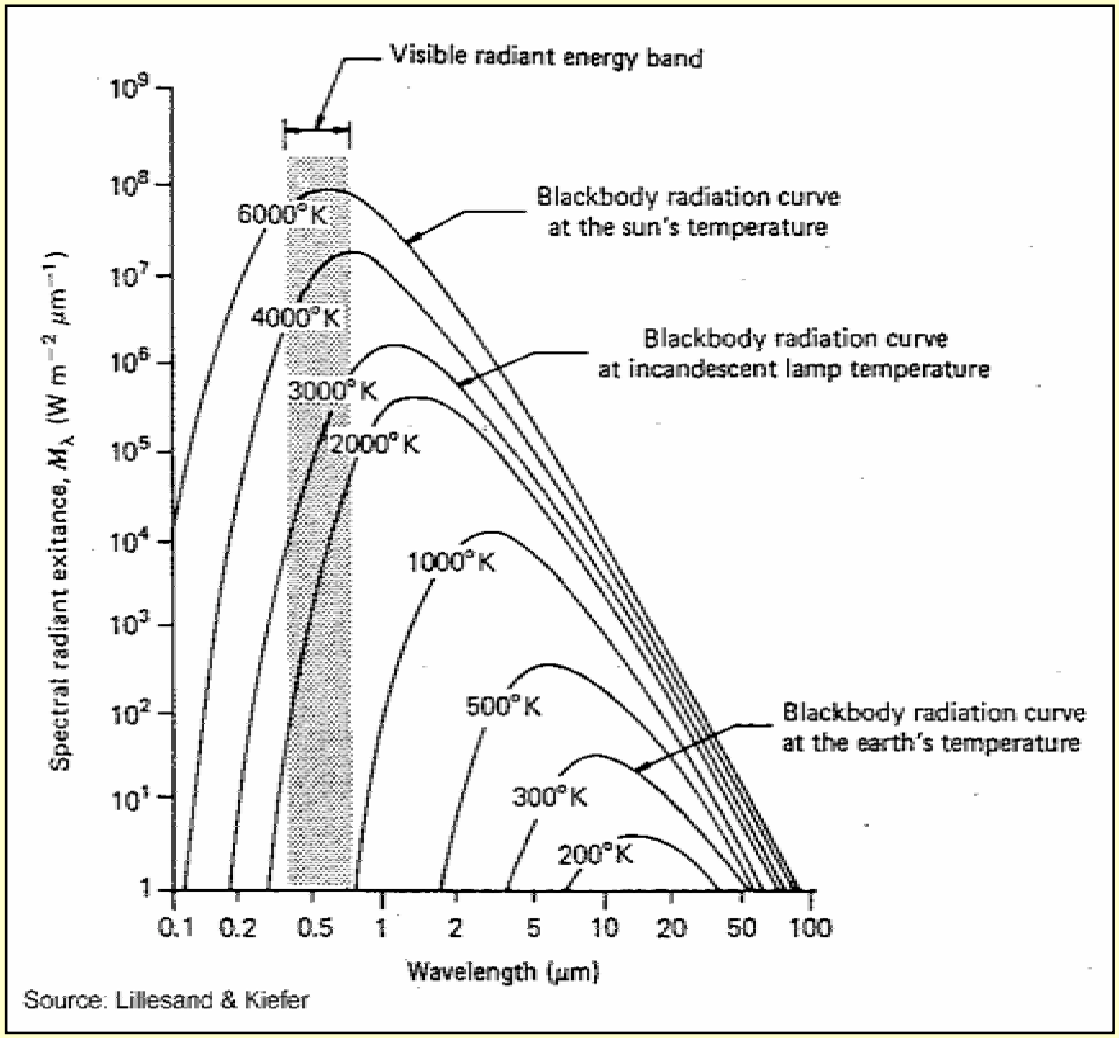
- Procedures to convert digital values on a TIR to spectral radiance are established

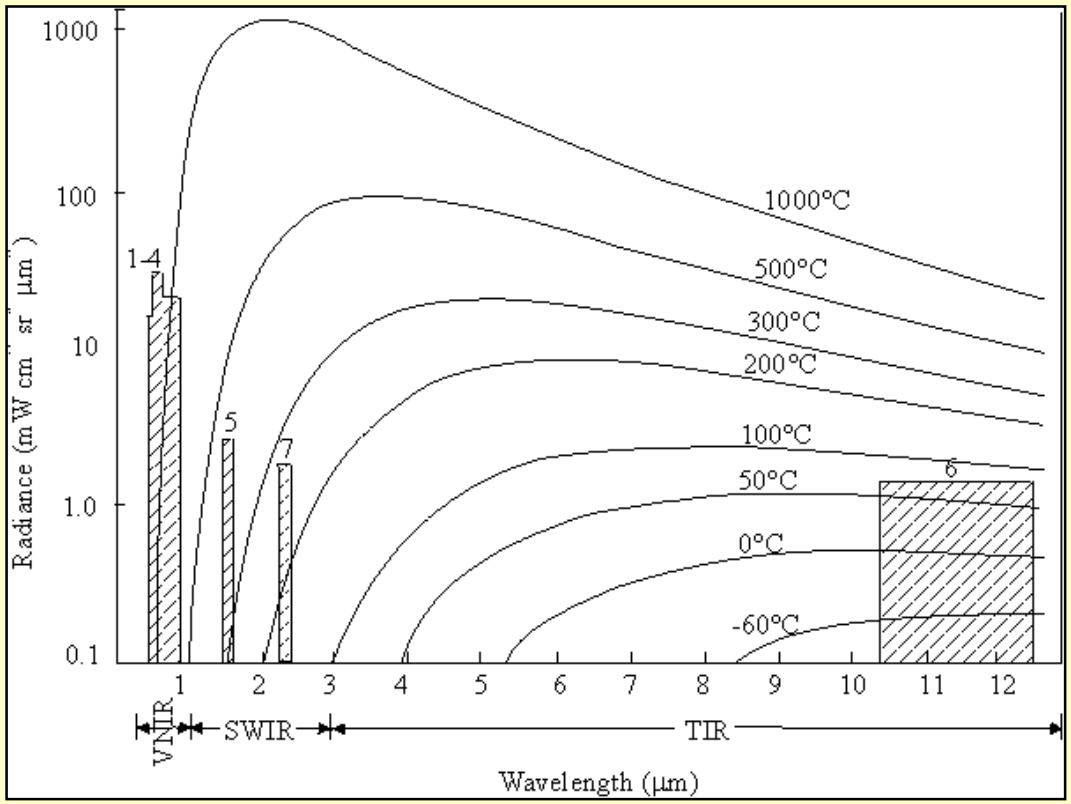
$$L_\lambda = L_{min(\lambda)} + \frac{L_{max(\lambda)} - L_{min(\lambda)}}{Q_{cal\,max}} Q_{cal}$$

- Once the radiant temperature is known, kinetic temperatures are estimated

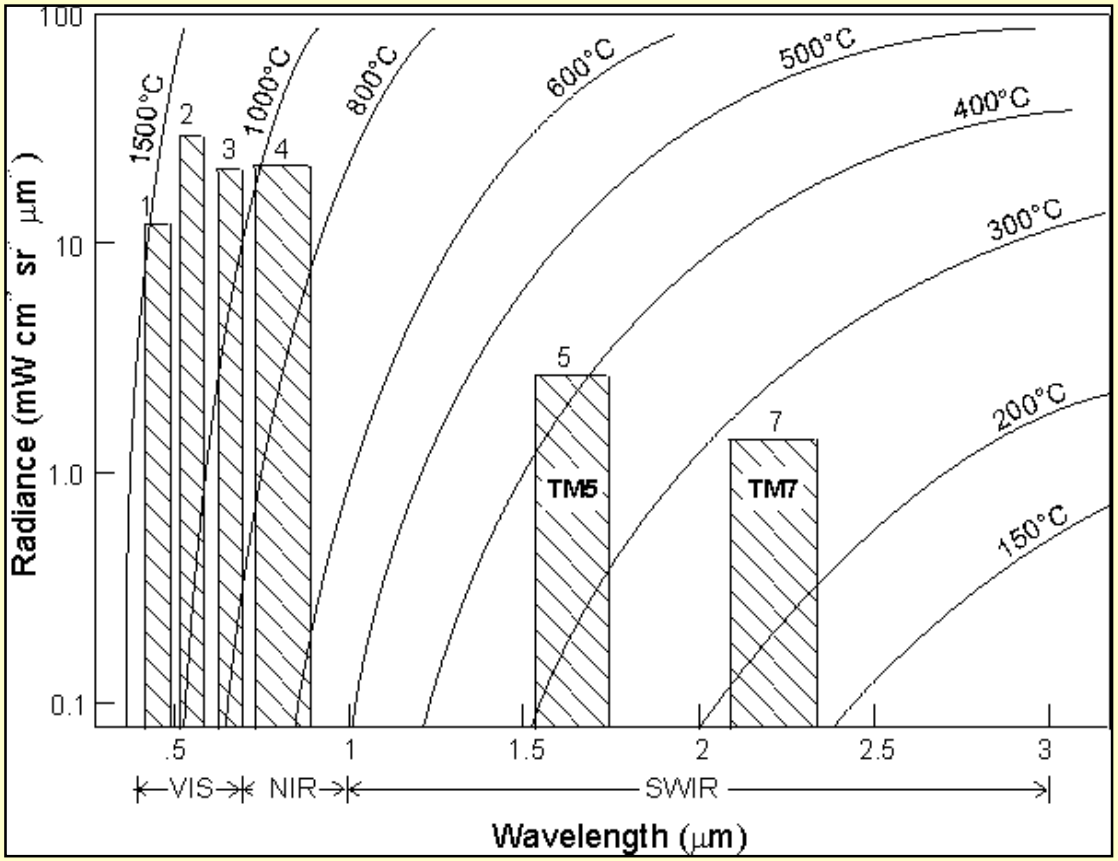
$$T_R = \varepsilon_\lambda^{1/4} T_K$$

Spectral distribution of energy radiated from blackbodies of various temperatures





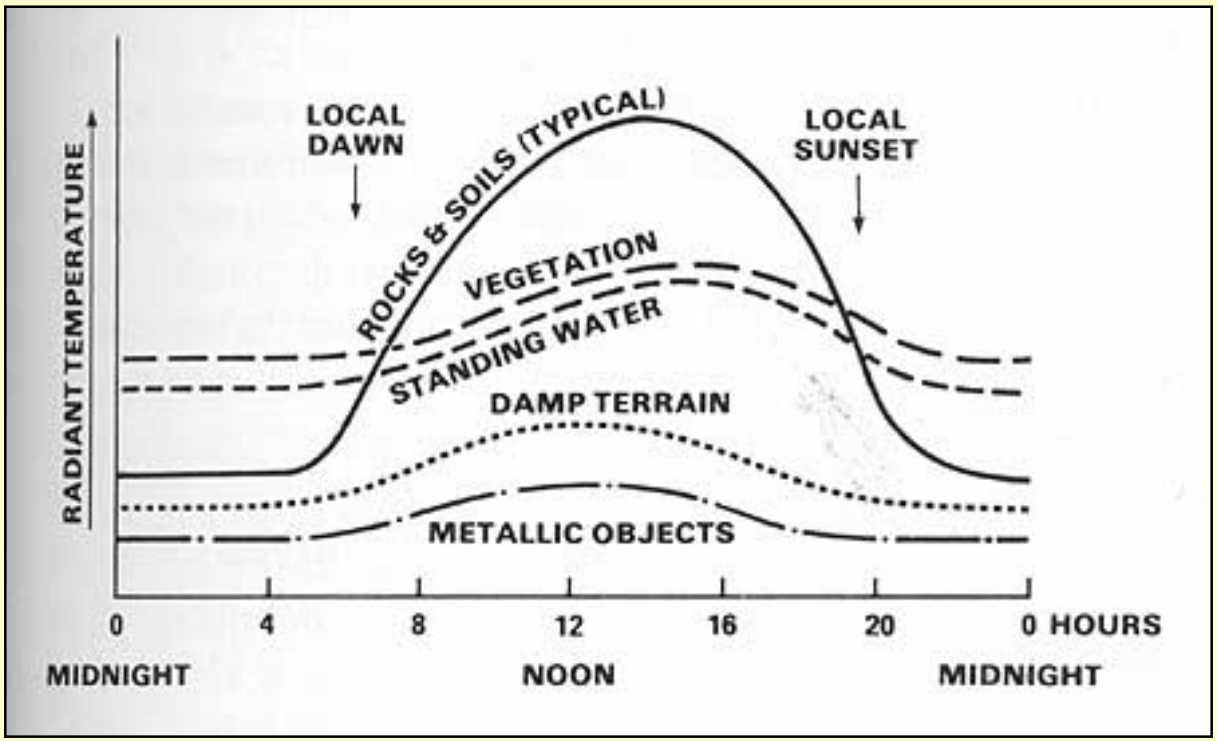
- Landsat Thematic Mapper: This graph shows the wavelength dependence of the thermal radiance at various temperatures as related to the sensitivity of the TM sensors (after Rothery et al., 1988)



- TM bands 7 and 5 can be together used to measure pixel-integrated temperatures from 160°C to 420°C

Diurnal temperature variation

- Temperatures usually drop at night primarily by radiative cooling (maximum radiative cooling occurs under cloudless conditions), accompanied by some conduction and convection.



Source: Sabins

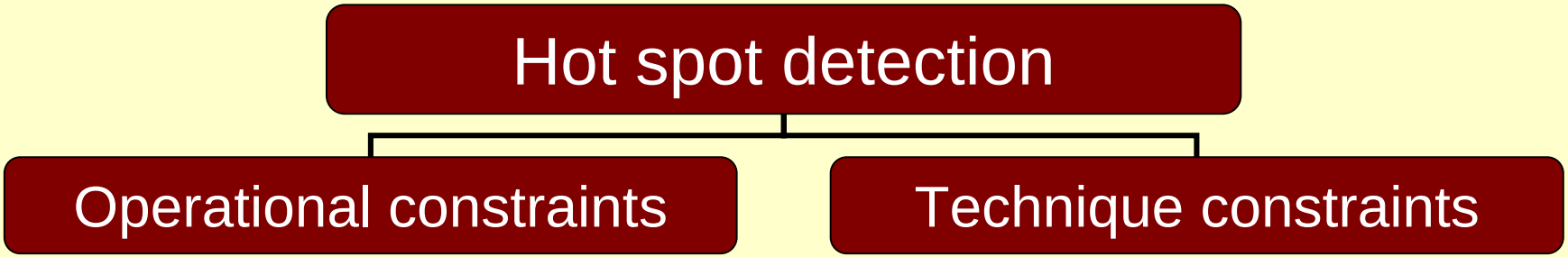
Atlanta TIR images

Daytime TIR

Predawn TIR

Source: NASA Remote Sensing Tutorial

Challenges in hotspot detection



- Most operational satellite sensors that acquire data in TIR region (Thematic Mapper, Aster, Modis, AVHRR etc.) pass over targets around 10.00 – 11.00 am or same time at night. These times are not ideal for remote sensing in the TIR region

Challenges in hotspot detection

- Relatively little radiation is emitted from the earth in the TIR region of the EM spectrum. However, many of the satellites which detect TIR radiation have relatively high velocities. Therefore, the spatial resolution which must be used in order to gather enough radiation to produce an image must be fairly large
- This coarse spatial resolution is a limitation for several potential application

Challenges in hotspot detection

- The detector technology poses some other challenges. For example, the detector must be kept extremely cold during use. Thermal infrared imaging systems need to be regularly and carefully calibrated

Challenges in hotspot detection

- We require more optimally spaced spectral bands in the MIR region to detect high temperature phenomena

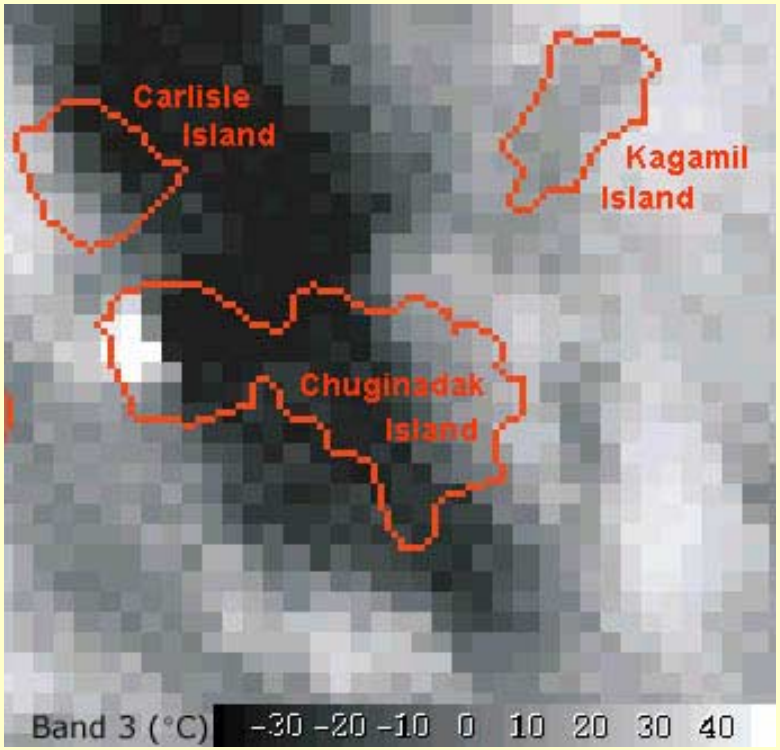
Surface coalmine fire in China:
Photo by A. Prakash, GI, UAF

Kilauea Volcano, Hawaii:
Photo by Peter Mouginis-Mark, University of Hawaii

- Detecting subtle thermal anomalies using the broad 8-14μm window

Hot spot detection

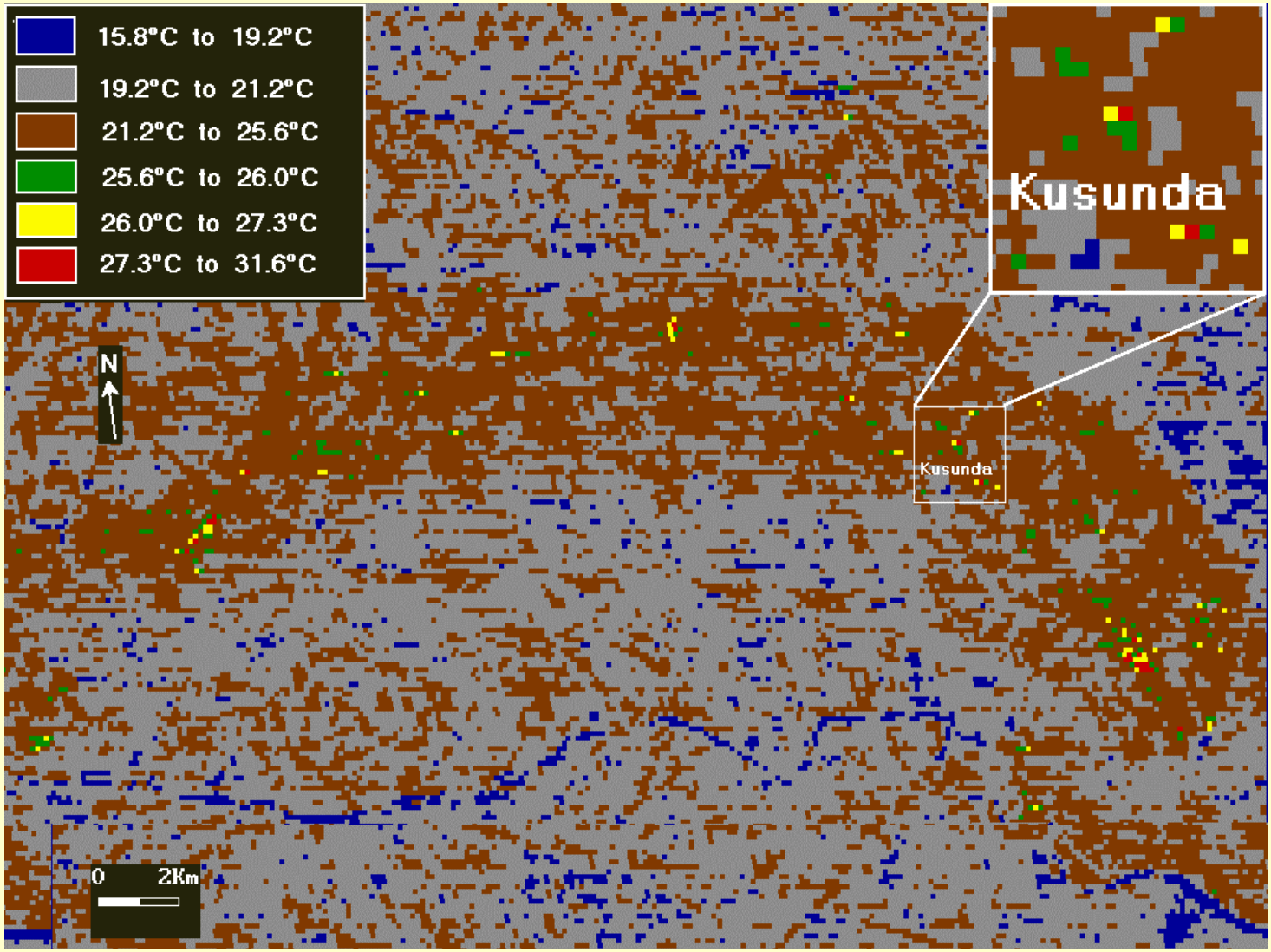
- Display thermal image in gray scale (or color coded) with a temperature scale and leave it for visual interpretation



Source: Alaska Volcano Observatory

Thresholding

- Trial-and-error



Global Thresholding

- Statistical parameters