Damietta University
Faculty of Science
Geology Department

Geothermal Course

For

First Year Geophysics Program

Code: 103 Geoph

Lecture 8:Remote Sensing For Geothermal Exploration Part 3

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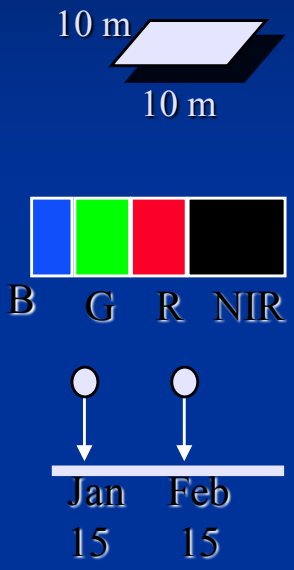
Remote Sensing Method

Part 3

Resolutions

- The characteristics of remote sensing systems can be described by the following types of resolutions:
  - Spatial resolution,
  - Radiometric resolution,
  - Spectral resolution, and
  - Temporal resolution.
- These resolutions control our ability to interpret remote sensing data.

Resolution

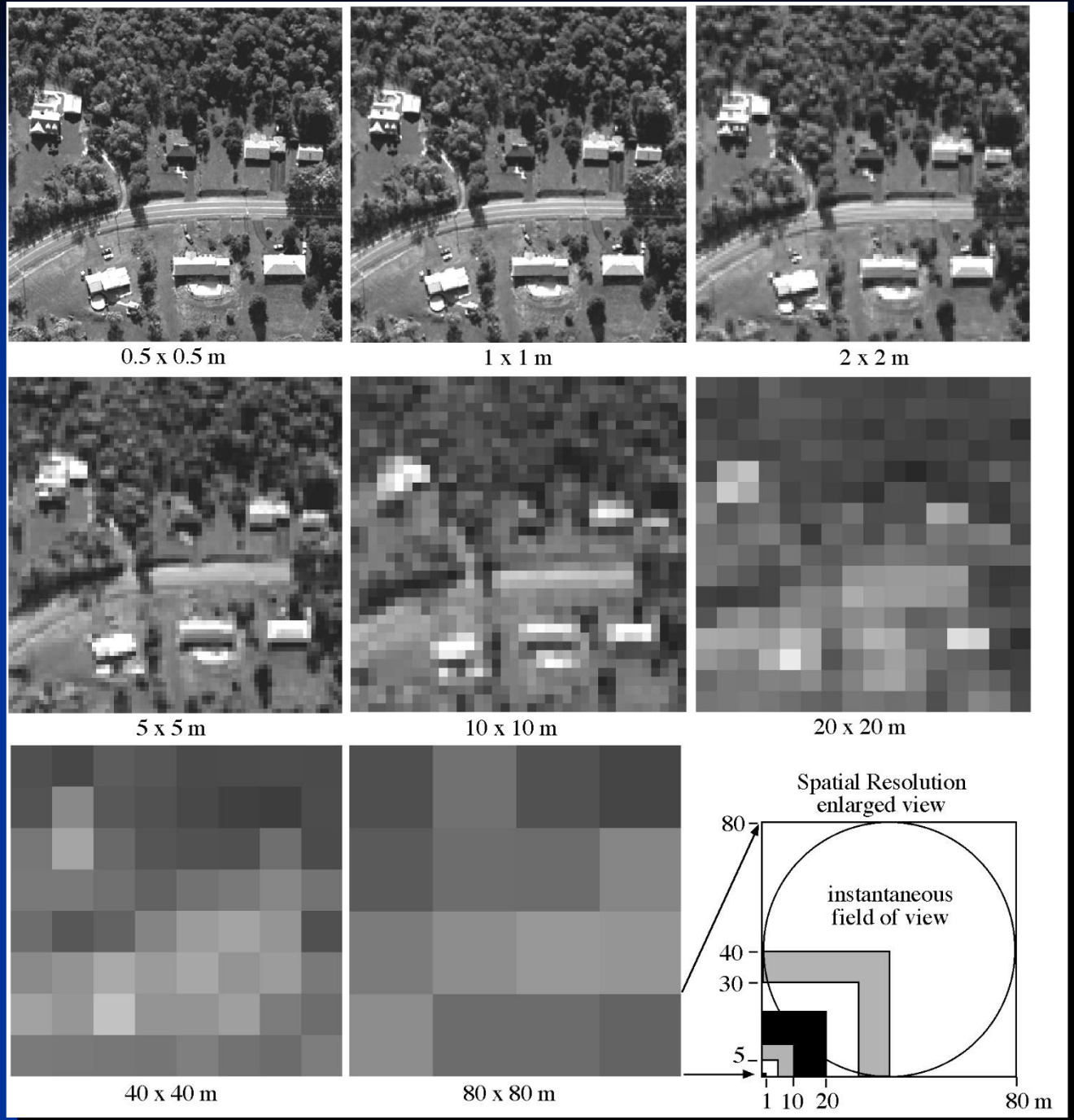


- Spatial - the size of the field-of-view, e.g. 10 x 10 m.
- Spectral - the number and size of spectral regions the sensor records data in, e.g. blue, green, red, near-infrared, thermal infrared, microwave (radar).
- Temporal - how often the sensor acquires data, e.g. every 30 days.
- Radiometric - the sensitivity of detectors to small differences in electromagnetic energy.

Spatial Resolution

- The fineness of detail visible in an image.
  - (course) Low resolution – smallest features not discernable
  - (fine) High resolution – small objects are discernable
- Factors affecting spatial resolution
  - Atmosphere, haze, smoke, low light, particles or blurred sensor systems

Spatial Resolution

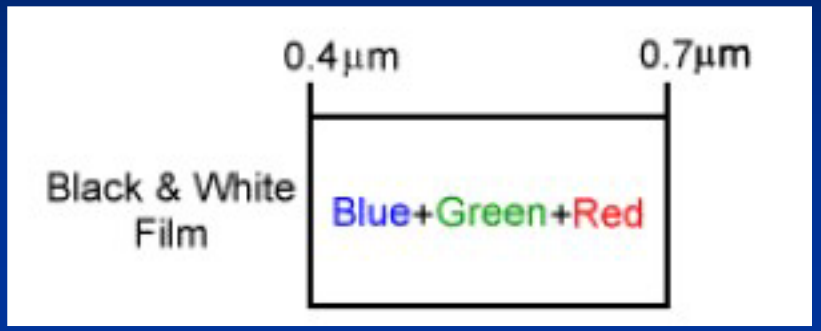


Imagery of residential housing in Mechanicsville, New York, obtained on June 1, 1998, at a nominal spatial resolution of 0.3 x 0.3 m (approximately 1 x 1 ft.) using a digital camera.

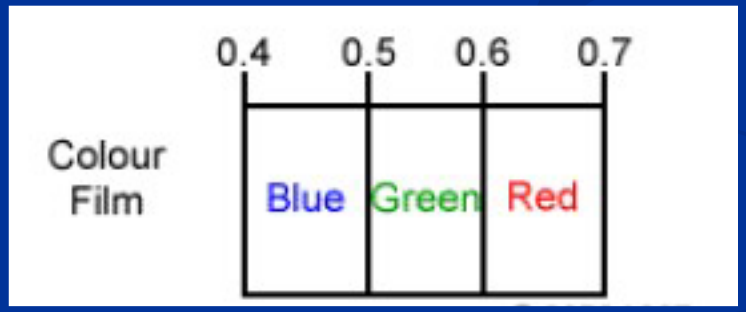
Spectral Resolution

- Spectral resolution describes the ability of a sensor to define fine wavelength intervals.
- The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.
  - Black and white film records wavelengths extending over much, or all of the visible portion of the electromagnetic spectrum.
  - Color film is individually sensitive to the reflected energy at the blue, green, and red wavelengths of the spectrum.
  - Color film has higher spectral resolution when compared to black and white film.

Spectral Resolution



Spectral sensitivity of black and white films



Spectral sensitivity of color film

Spectral Resolution

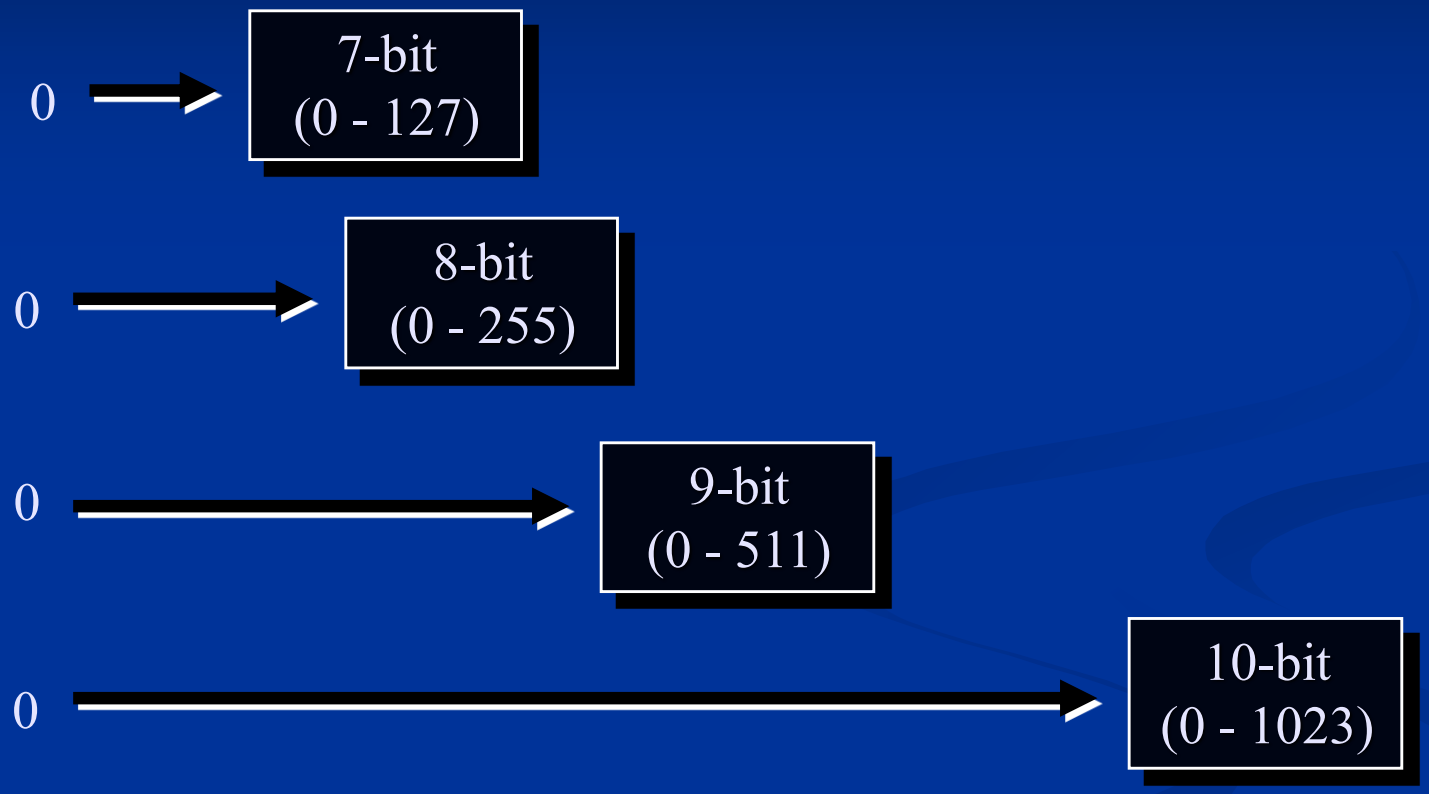
Radiometric Resolution

- Radiometric resolution of an imaging system describes its ability to discriminate very slight differences in the recorded energy.
- The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.
- For digital imagery, the radiometric resolution is defined by the number of bits used for coding the recorded grey values.
  - By **comparing a 2-bit image with an 8-bit image**, one can see that there is a large difference in the level of discernible details

Radiometric Resolution

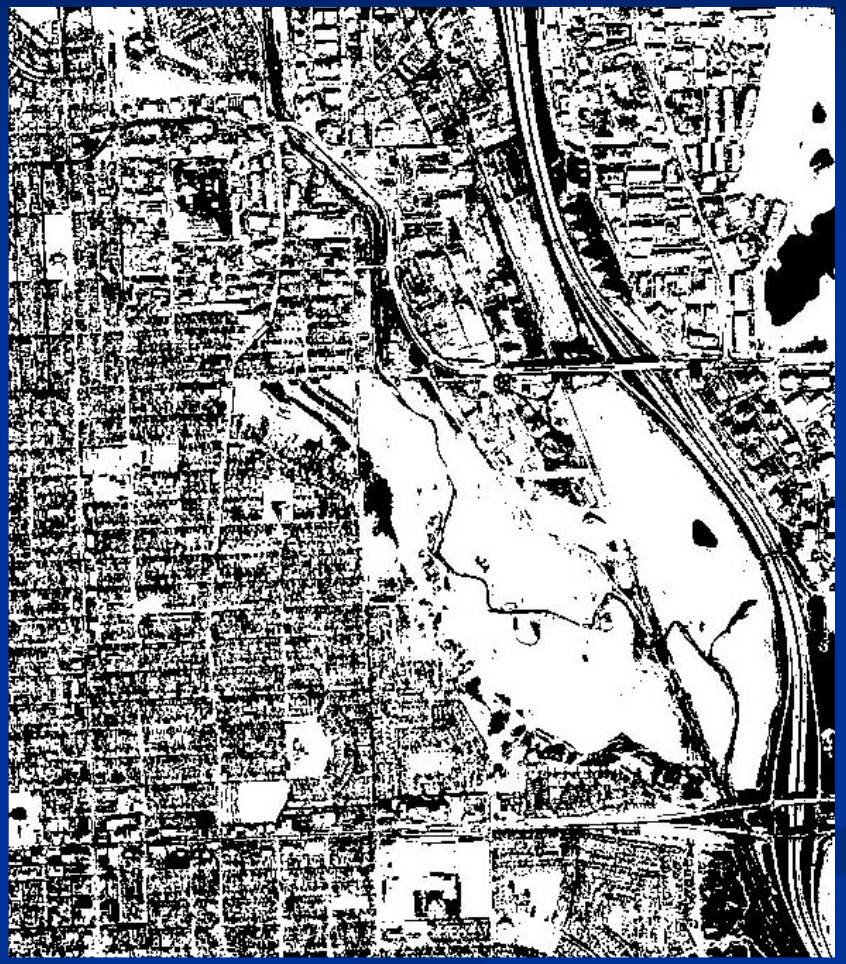
- **Radiometric resolution**, or radiometric sensitivity refers to the number of digital levels used to express the data collected by the sensor. In general, the greater the number of levels, the greater the detail of information.

Radiometric Resolution



Radiometric Resolution

8 bits per pixel

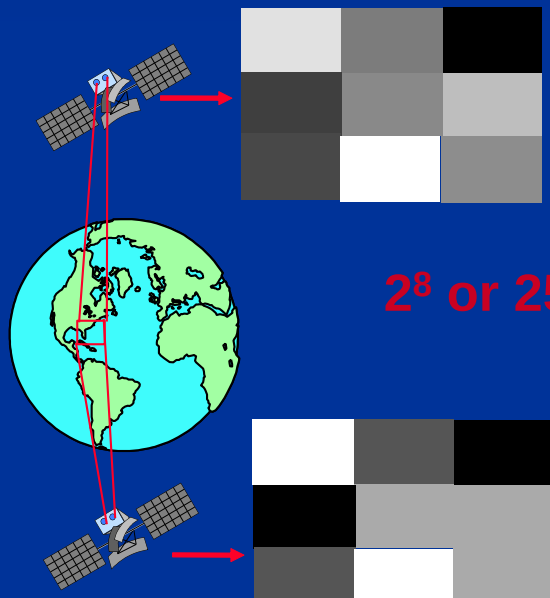


2 bits per pixel

Radiometric Resolution

The ability of a sensor to perceive differences in brightness value levels

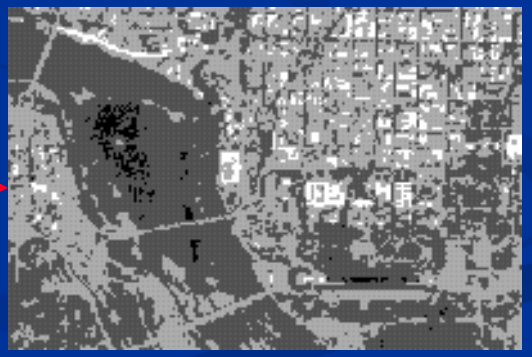
Sensor “A”



225	124	0
63	137	190
72	255	141

2^8 or 256 intensity levels

3	1	0
0	2	2
1	3	2



Sensor “B”

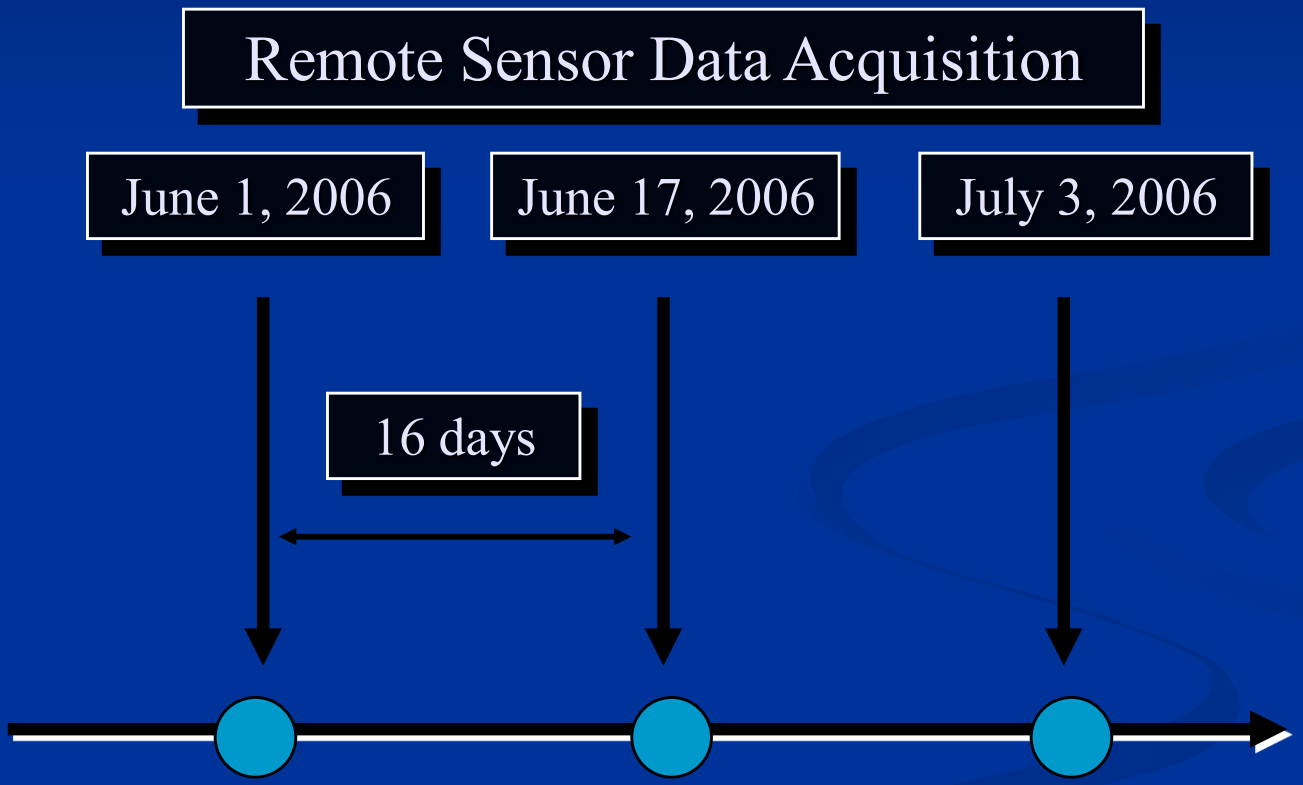
2^2 or 4 intensity levels

Temporal Resolution

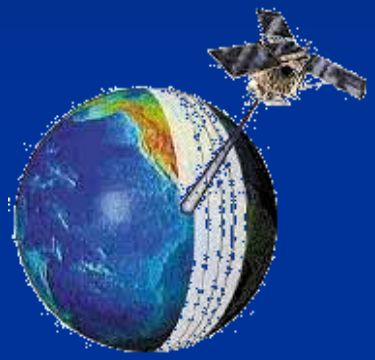
- Temporal resolution of a remote sensing system refers to the frequency with which it images the same area.
- Frequent imaging is important for:
  - – Disaster & environmental management.

    For example, floods, oil slicks, spread of forest disease from one year to the next.
- – Change detection applications.

Temporal Resolution

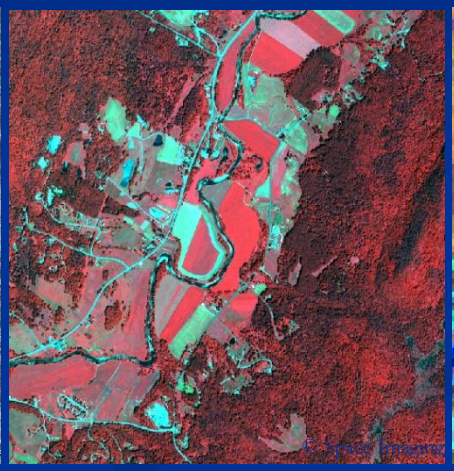


Comparison

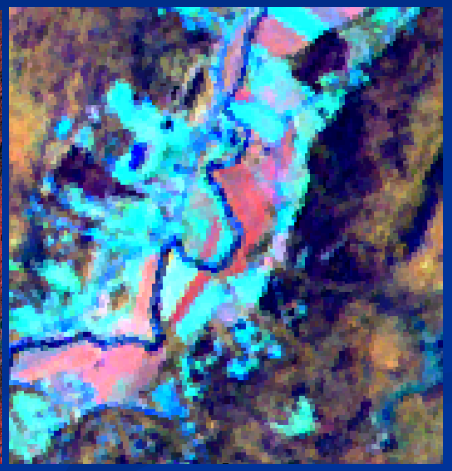


Aerial Photo

IKONOS



Landsat



Spatial Resolution	½ m	4m	30m
Spectral Resolution	1	4	7
Radiometric Resolution	8 bit	11 bit	8 bit
Temporal Resolution	On demand	3-4 days	16 days

Thermal infrared of EM spectrum

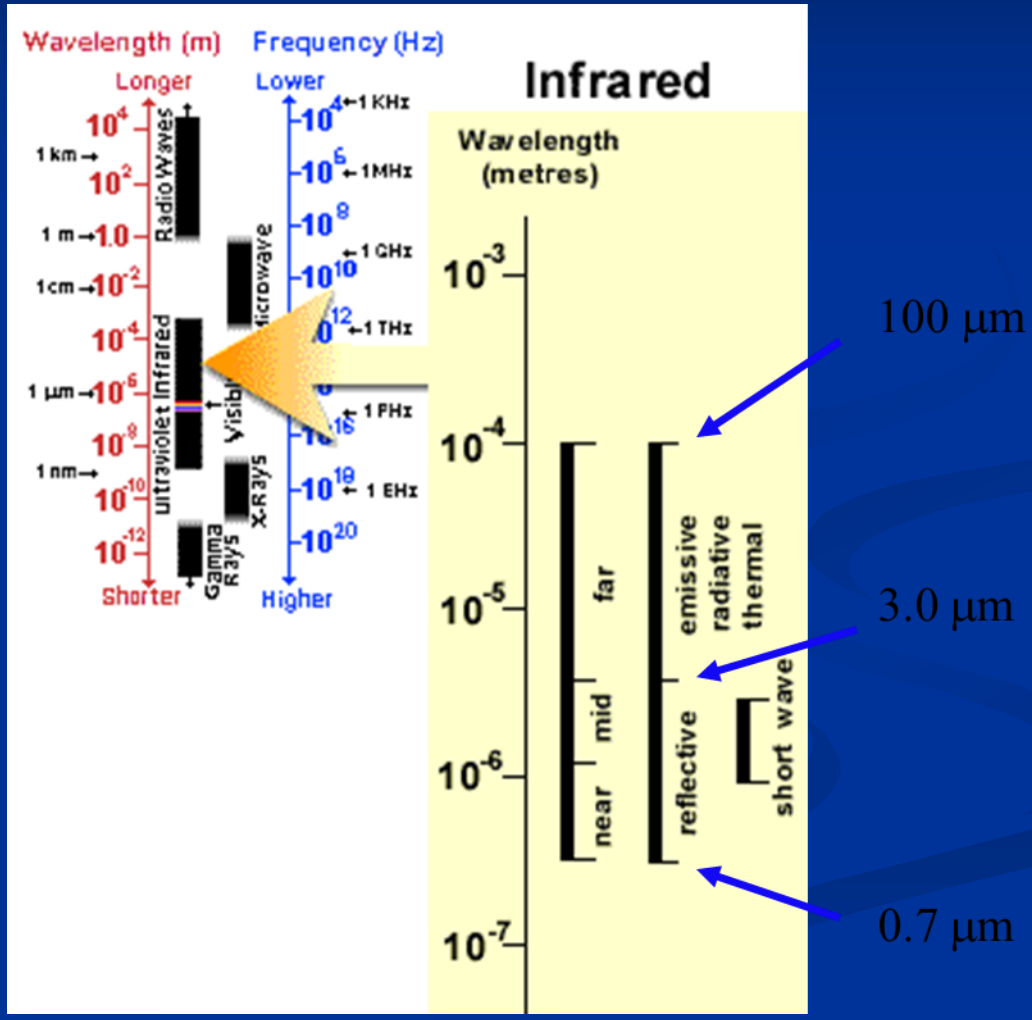
Infrared (IR) waves:

Near IR:0.7 to 1.3 µm•

Mid IR: 1.3 to 3 µm•

Far IR: 3-100 µm•

Thermal IR: 3 to 14 µm•



Emitted Energy

Optical remote sensing

- Examine abilities of objects to reflect solar radiation

Emissive remote sensing

- Examine abilities of objects to absorb shortwave visible and near-IR radiation and then to emit this energy at longer wavelengths

Main Advantages of Thermal RS

Thermal IR can 'see' through night, haze and smoke.

Thermal infrared remote sensing measures

- Land and ocean surface temperature,
- Atmospheric
  - Temperature and humility
  - Trace gas concentrations
- Emissivity

Kinetic heat, radiant flux and temperature

- The energy of particles of matter in random motion is called kinetic heat (also referred to as internal, real, or true heat).
- We can measure the true kinetic temperature (T_{kin}) or concentration of this heat using a thermometer.
- We perform this in situ (in place) temperature measurement when we are ill.
- We can also measure the true kinetic internal temperature of soil or water by physically touching them with a thermometer.

Kinetic heat, radiant flux and temperature

- When these particles (have kinetic heat) collide they change their energy state and emit electromagnetic radiation called radiant flux (watts).
- The concentration of the amount of radiant flux exiting (emitted from) an object is its radiant temperature (T_{rad}).

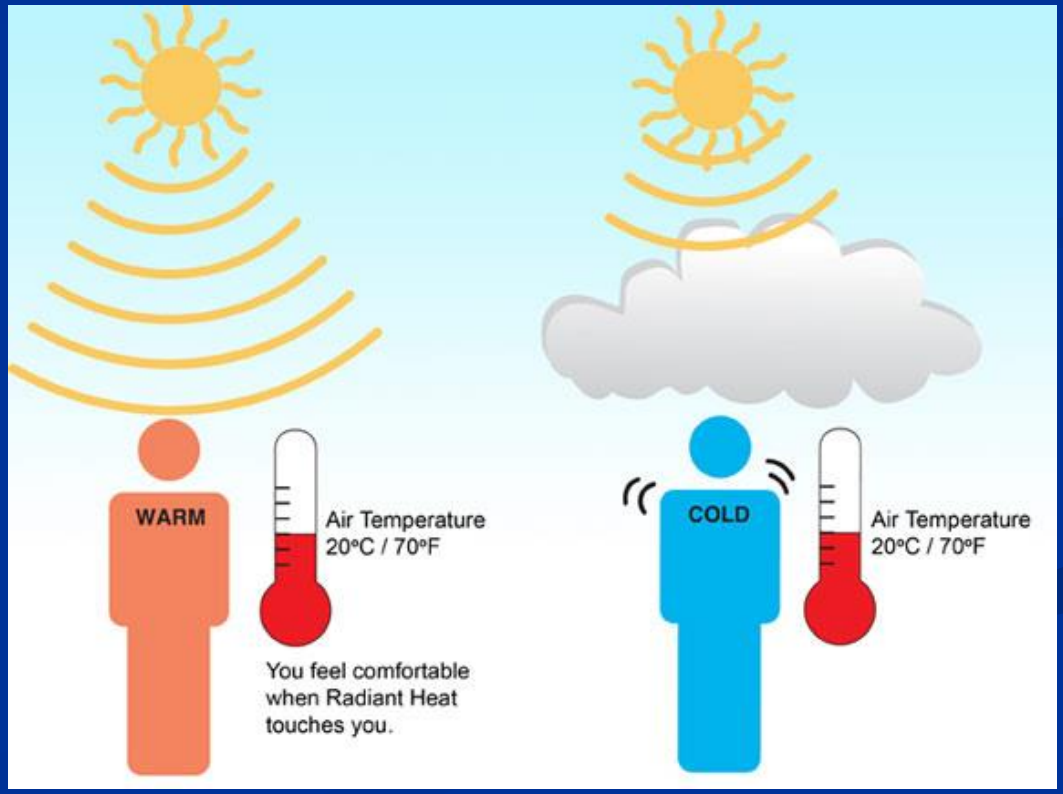
Kinetic temperature

- Kinetic temperature (F^o C^o K^o)
  - thermal energy of molecules within a substance

Radiant temperature

- Radiant temperature
  - the emitted energy

This figure Clarifying the Difference Between Radiant Temperature and Air Temperature.



Kinetic heat, radiant flux and temperature

There is usually a high positive correlation between the true kinetic temperature of an object (T_{kin}) and the amount of radiant flux radiated from the object (T_{rad}).

Kinetic heat, radiant flux and temperature

Therefore, we can utilize radiometers placed some distance from the object to measure its radiant temperature which hopefully correlates well with the object's true kinetic temperature. This is the basis of thermal infrared remote sensing.

Kinetic heat, radiant flux and temperature

Unfortunately, the relationship is not perfect, with the remote measurement of the radiant temperature always being slightly less than the true kinetic temperature of the object.

This is due to a thermal property called emissivity.

Emissivity

- Emissivity: e = M/Mb
  - e-emissivity
  - M-emittance of a given object
  - Mb-emittance of blackbody
  - e = 1 (blackbody)
  - e = 0 (whitebody, perfect reflector)

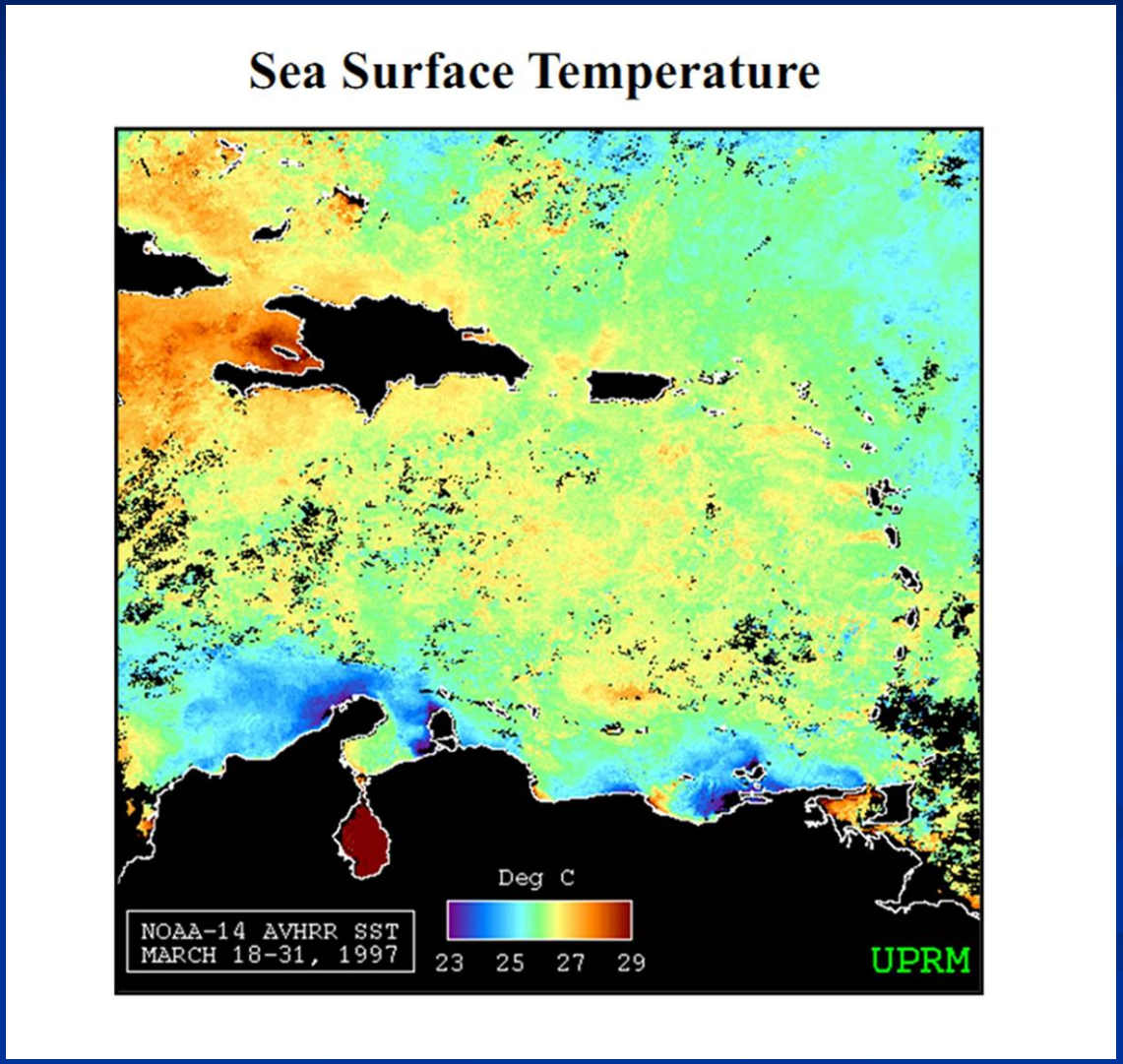
Practical considerations in thermal remote sensing

- Lower thermal wavelengths can get mixed with reflected solar energy (3-5 mu).
- 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 (radiance) resolution can be as fine as 0.1 C.
- Pixel size is usually larger (courser resolution), than for reflected bands

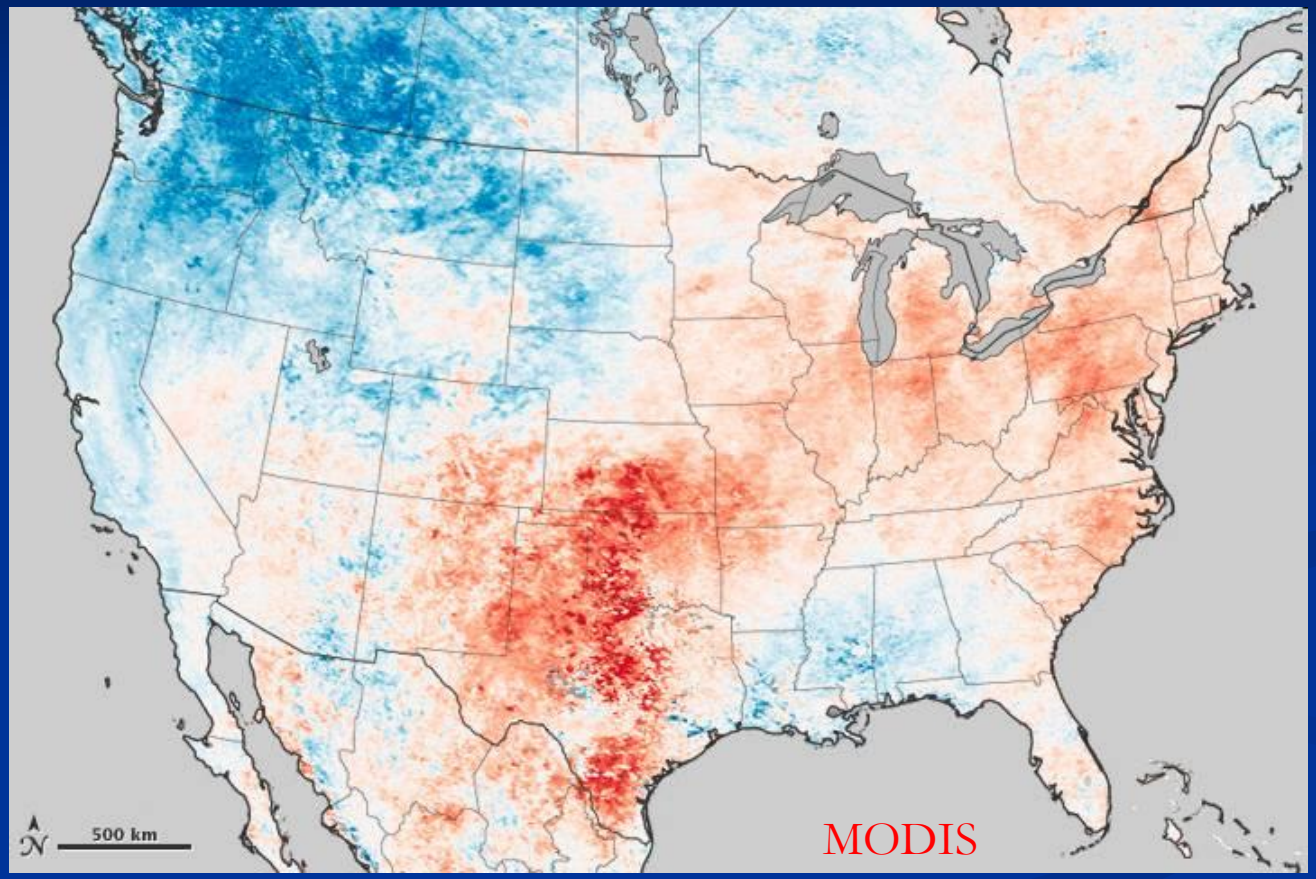
Thermal applications

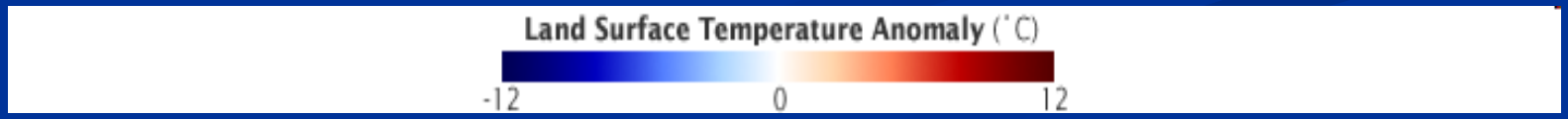
- Surface Temperature
- Geothermal Exploration
- Volcanic hazard assessment and modelling
- Urban heat island effects
- Burnt area mapping

Surface Temperature

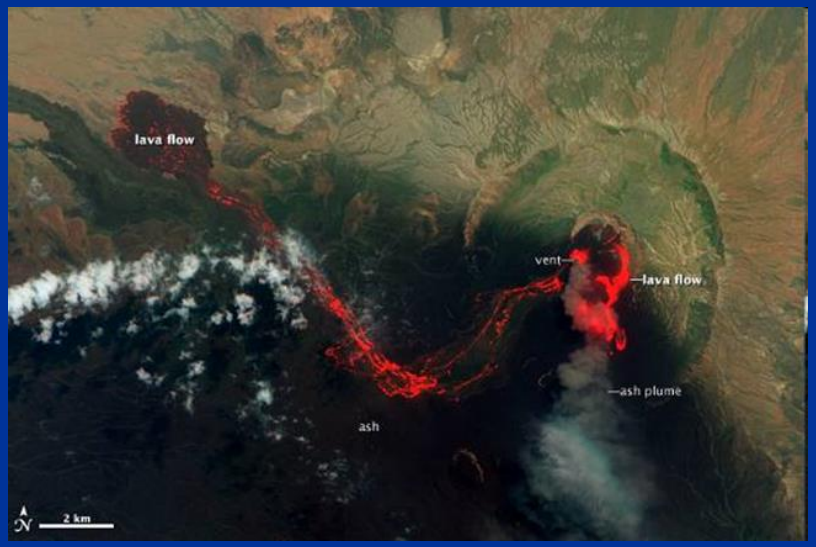


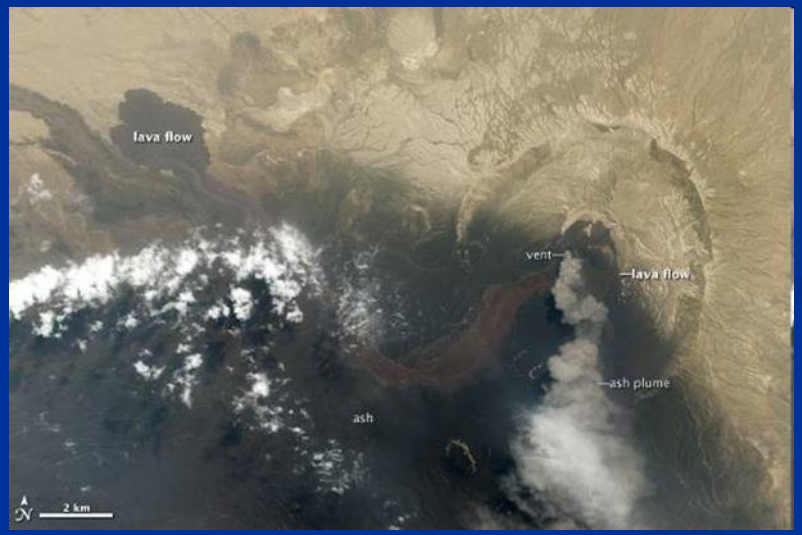
Temperature anomalies August 2011





Volcanic hazard monitoring





http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=50988

Fires burned along the coast of Queensland, Australia on October 17, 2009. The MODIS on NASA's Aqua satellite captured this true-color image the same day.

Fires - MODIS

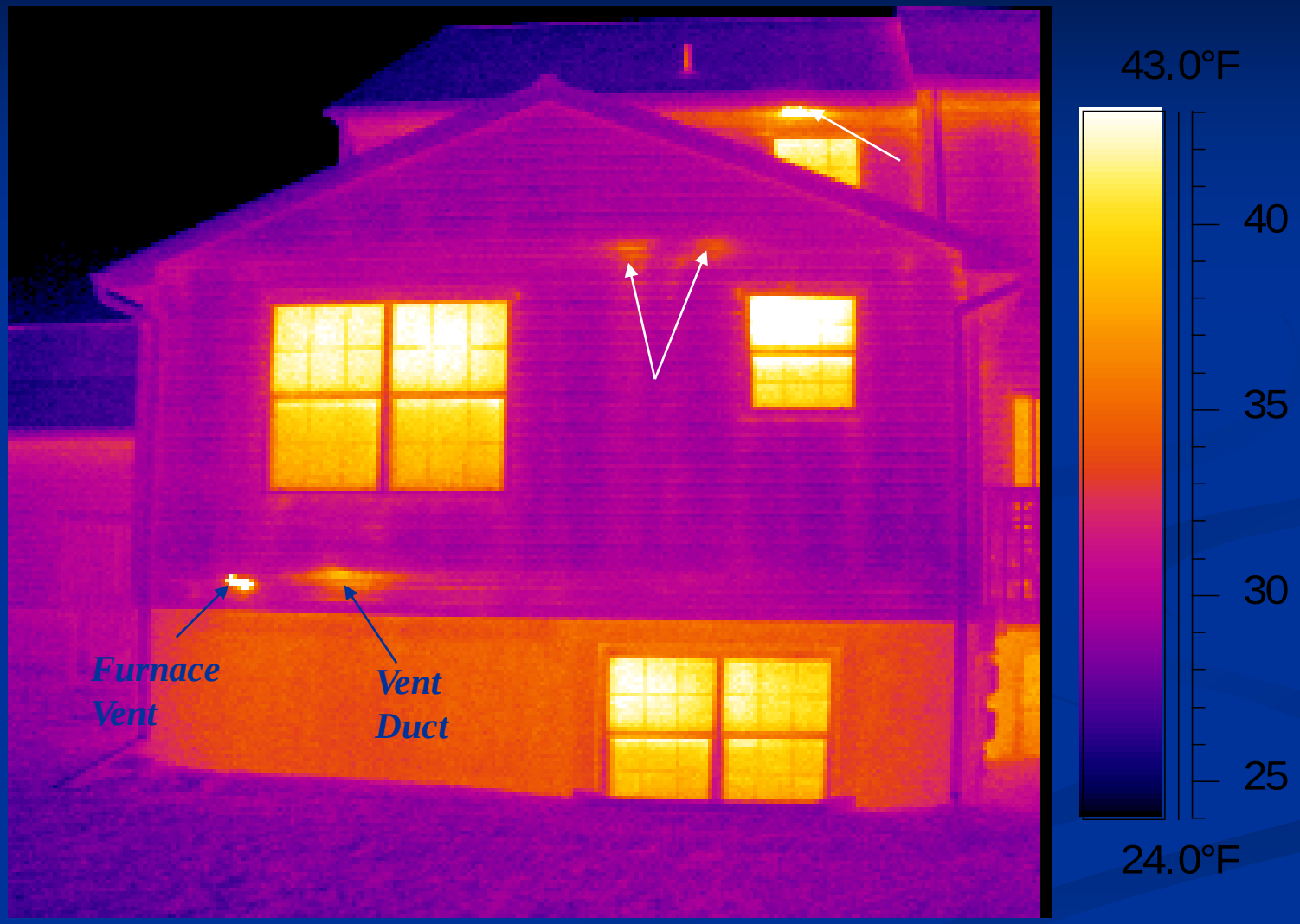
Fires in the Bahamas, Florida and Cuba (03 April 2004, 18:30 UTC) identified using MODIS Aqua and outlined in red on the MODIS 1km corrected product

active fire map – and burn scars (MODIS) http://activefiremaps.fs.fed.us/

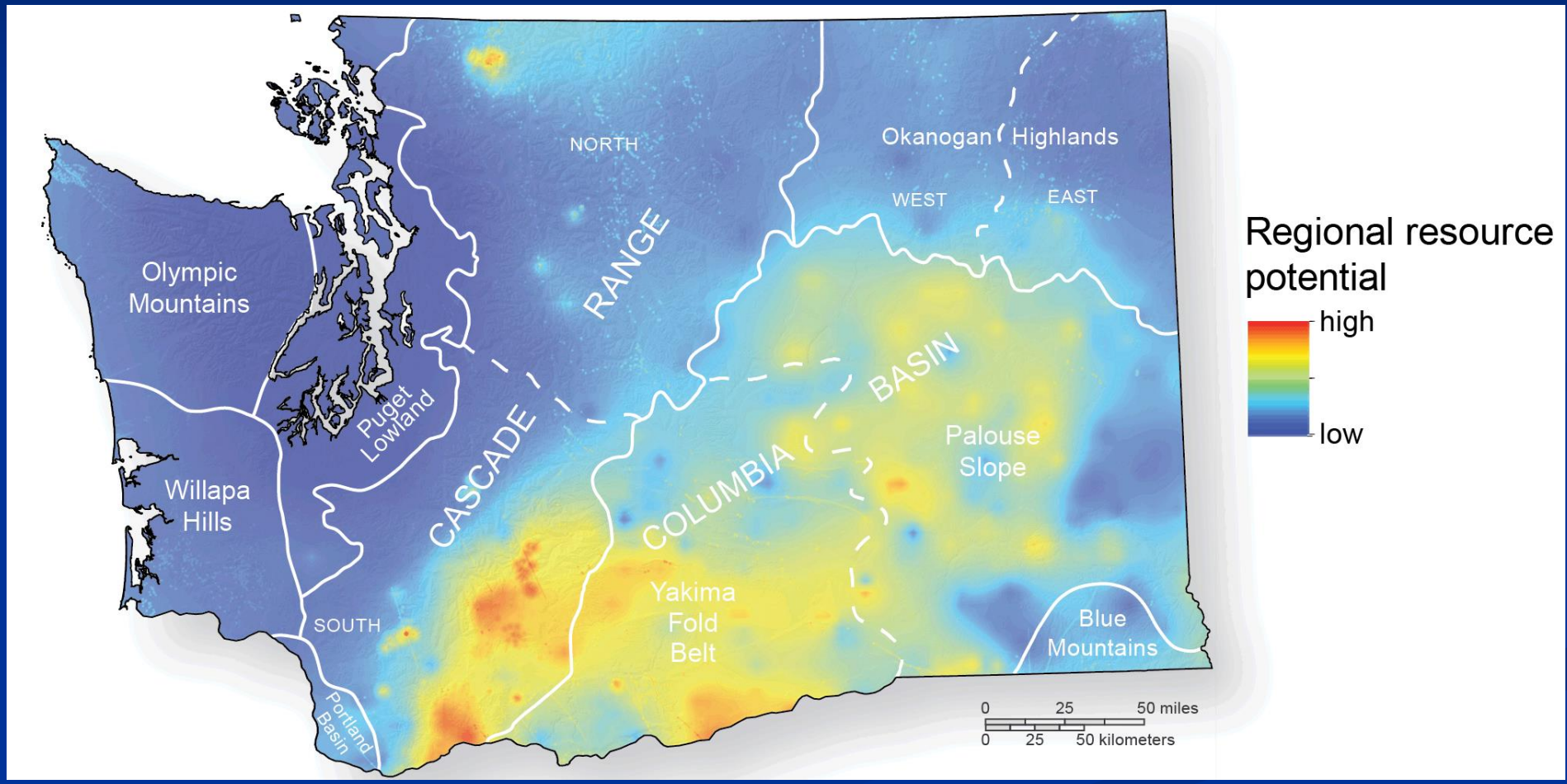
Typical IR imagery of Heat Loss in Residential Structures

One application: detection of loss of heat from buildings due to faulty insulation

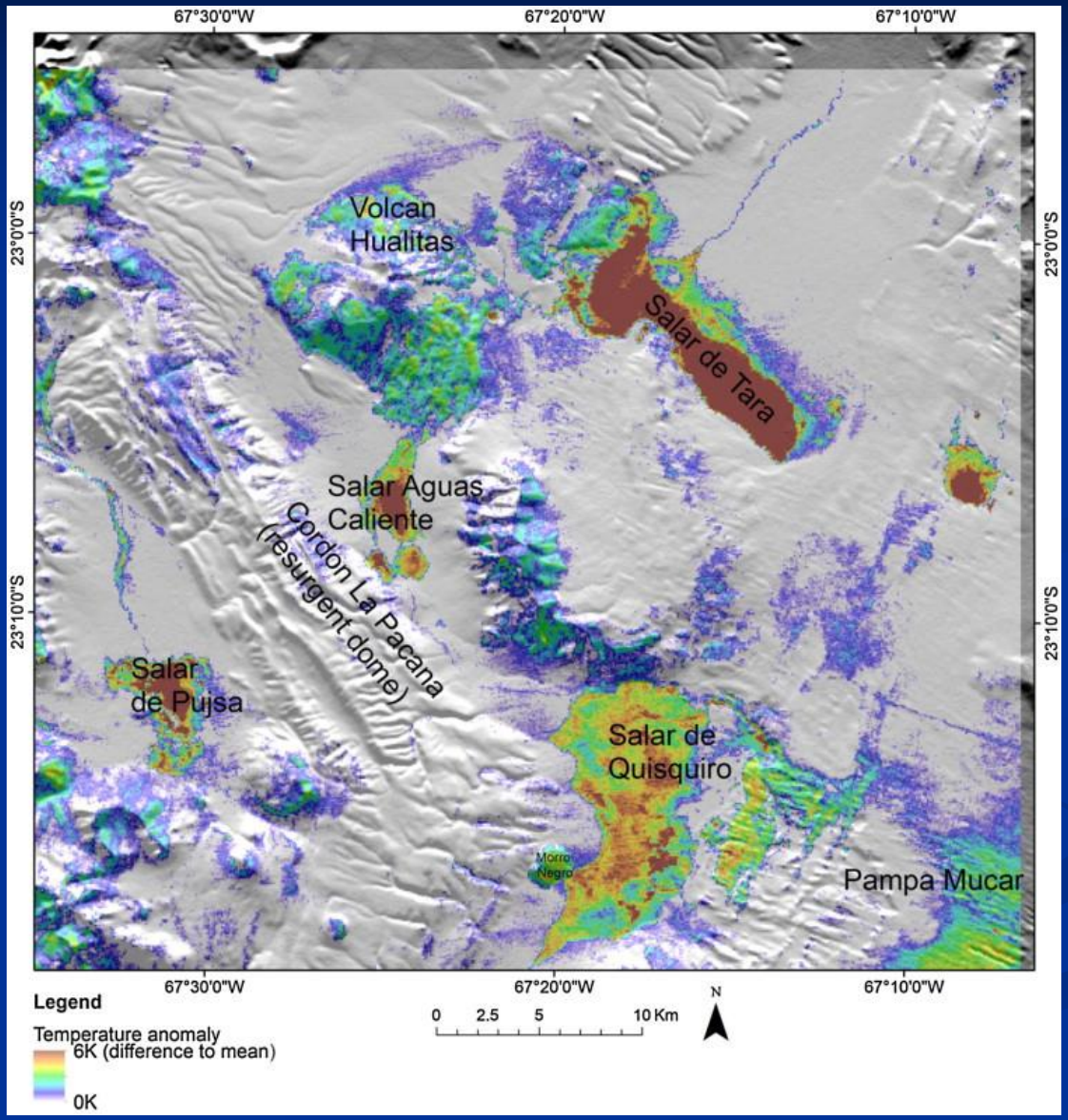
Typical IR imagery of Heat Loss in Residential Structures



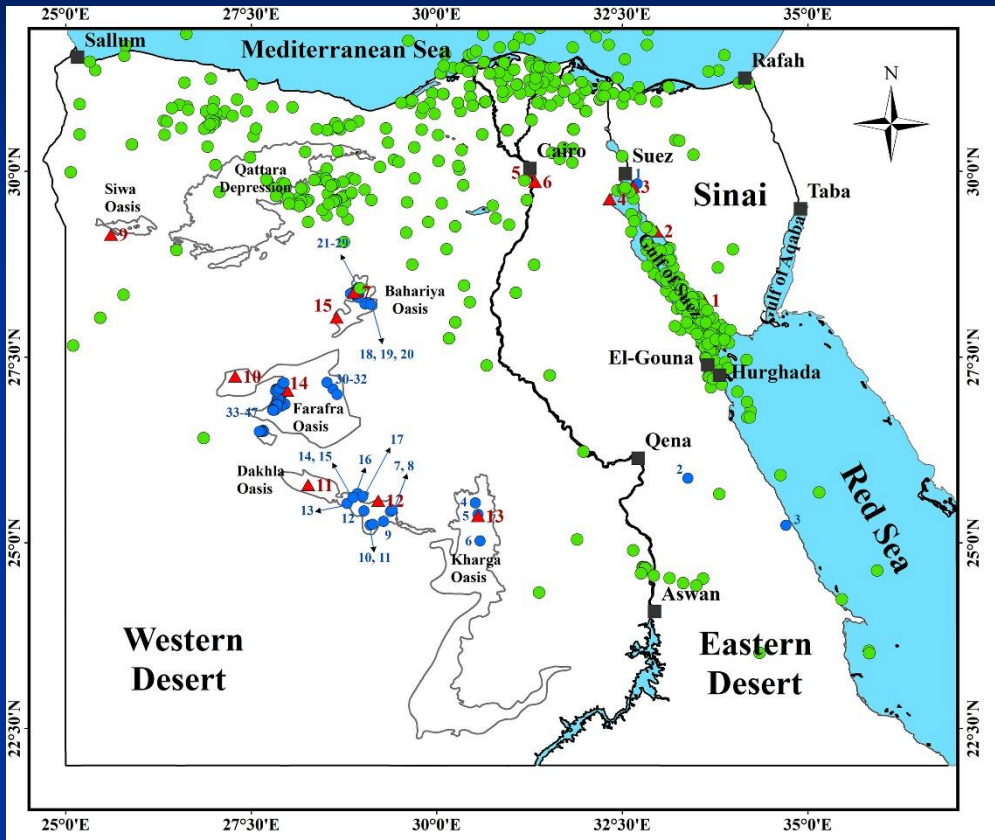
Geothermal Exploration



Geothermal Exploration



Geothermal Resources in Egypt



Legend

Hot springs

No.	T°C	Hot spring name
1	48	Hammam Musa
2	71	Hammam Faraun
3	37	Ayun Musa
4	33	Ain Sukhna
5	40	Ain El-Sira
6	36	Ain Helwan
7	31.6	Ain El-Bishmo
8	33.7	Ain Bowitti
9	27	Ain El-Arayes
10	35	Ain Dalla
11	40	Ain El-Gabal
12	39	Ain El-Kasr (Qasr)
13	31	Ain El-Bousa
14	28	Ain El-Balad
15	28.3	Ain El-Ris

Oil and gas wells

0 100 200 300 km

Thermal wells

No.	T°C	Well name	No.	T°C	Well name
1	48.3	Ayun Musa Well	25	50	Qasaa
2	35	El-Laqeita	26	45	Hamra
3	35.8	Umm Khariga	27	43.5	Sigam
4	37.5	Mahariq	28	42	Givara
5	38	Kharga	29	42	Agouz
6	35	Bulaq 5	30	37	QRHO
7	38.9	Bir Balat No. 10	31	47	QR1
8	37.2	Bir Balat No. 10A	32	41	QR2
9	41.1	Bir Masara No.3	33	47.7	Bir-5
10	35	Bir Mut 1	34	51.7	Bir-3
11	42.2	Bir Mut 3	35	44	Bir-15
12	37.8	Bir Ezab Qasr 1A	36	47.8	Bir-1B
13	42.8	Bir El-Mahub	37	41.9	Bir-11
14	42.8	Bir Ezab Qasr 3	38	42	N2
15	38.3	Bir El-Dinariya	39	43.3	Bir-38
16	39	Bir El-Omda	40	53.4	Bir-2
17	38.3	Bir El-Qasr Elbalad	41	44.2	N-4
18	41.1	Ain El-Wadi	42	44.5	Bir-9
19	41.1	Bir Sigam	43	44.3	Bir-61
20	42.2	Halfa	44	45.8	Bir-40
21	47	El-Gawak	45	46.3	Bir-18
22	45.5	Halfa	46	44.6	Bir-400
23	46	El-Nebiga	47	52	Bir-39
24	37.5	Matar			