Hot or Cold?

Measuring Infrared Radiation
Emitted from Various Sources

In this activity, your group will explore:

- **The Electromagnetic Spectrum**
- **Infrared Radiation**
- **The Effect of Material Composition on Temperature**

NSF DUE-1205110; 0903270

Beth Stein
Geospatial Instructor
Virginia Geospatial
Extension Program
bstein2@vt.edu

John McGee
Coordinator
The Virginia Geospatial
Extension Program &
VirginiaView
jmcg@vt.edu

Jim Campbell
Professor, VT
jayhawk@vt.edu

Acknowledgements: This curriculum was initially developed by HawaiiView and was modified by VirginiaView in partnership with GeoTEd.

Hot or Cold?

Exercise: Measuring Infrared Radiation Emitted from Various Sources

Beth Stein bstein2@vt.edu **John McGee** jmcg@vt.edu

Summary of skills covered:	• **The Electromagnetic Spectrum** • **Infrared Radiation** • **The Effect of Material Composition on Temperature** • **Collecting data** • **Graphing results**
Data needed:	**Students will collect and graph their own data using an Infrared Thermometer.**
Equipment and Software needed:	**Hardware: Infrared Thermometer (A kit is available from VirginiaView / the Virginia Geospatial Extension Program). Contact John McGee (jmcg@vt.edu) or Jim Campbell (Jayhawk@vt.edu) for details.** **Software: None**
Related book exercise (if applicable):	**No text necessary.**
Data Source:	**Not applicable**

Objective

During this activity you will collect infrared data from various surface materials using the Extech InfraRed Thermometer (IRT) in order to better understand what land cover types help or hinder global warming. In this activity, you will determine the effects of material composition and water content on the absorption and emission of infrared radiation in solar energy. You will also gain an understanding of the electromagnetic spectrum and reflectance of light.

You may like to review this Youtube video: http://www.youtube.com/watch?v=Rz7EXNAMsyg&feature=youtu.be

The Electromagnetic Spectrum

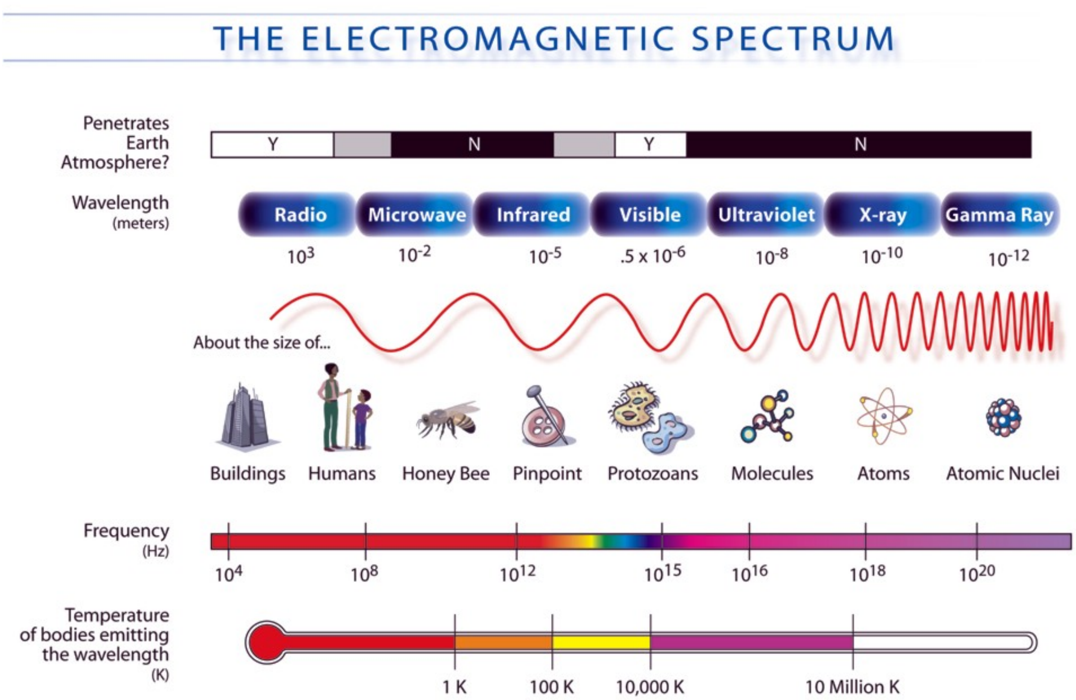

Figure 1: The electromagnetic spectrum
Courtesy: NASA, http://mynasadata.larc.nasa.gov/

Introduction

Radio waves, microwaves, **thermal radiation**, visible light, x-rays and gamma radiation all travel through space at the speed of light, but the waves have different lengths. In order to maintain the same speed (speed of light is constant so ALL wavelengths travel at the same rate, no matter the size of the wave) the frequency of the waves must vary. This means that very long waves have a low frequency and very tiny wave lengths have a very high frequency (see Figure 1). Imagine a very tall person with long legs walking next to a small child and they are walking at the same speed. For every one step the very tall person takes, the small child takes multiple steps. Therefore, for the tall person, the stride length ("wavelength") is larger and the number of steps (frequency) is lower compared with the child's stride.

Different kinds of electromagnetic radiation differ in wavelength and this results in a spectrum. The portion of the spectrum that humans can 'see' is called the visible spectrum. The visible spectrum is only a small portion of the larger electromagnetic spectrum. The electromagnetic spectrum is divided into major types of radiation and are listed below. This lesson will focus on Infrared waves, which are slightly longer than visible wavelengths.

- Radio waves (including microwaves)
- **Infrared**
- Visible light
- Ultraviolet
- X-Rays
- Gamma and Cosmic rays

The only part of the electromagnetic spectrum that humans can see is the visible light spectrum. The exception was the artist, Monet. Monet developed a cataract and had it removed in 1923. Once the lens was removed, it is possible that Monet could see the ultraviolet (UV) rays, which appear as a whitish-blue color to humans. In his paintings after 1923, he depicts water lilies in a pale blue color, instead of the white they appear to us. However, we don't have to remove the lenses in our eyes to "see" UV rays; instead, we can use special equipment to surpass the limits of our vision.

Today you will use a device that will allow you to measure a wavelength that people cannot 'see,' infrared (IR) wavelengths (think heat or thermal). Our eyes measure the amount of radiation reflected from objects around us, with our brains translating these measurements into an image of our surroundings. However, our eyes are only sensitive to the areas between the red and purple ends of the visible spectrum, a very small section of the entire range of electromagnetic spectrum (locate the visible portion of the EM spectrum in Figure 1). As a result of this, other wavelengths of light, including the infrared and ultraviolet portions of the spectrum, are invisible to the human eye. However, the Sun radiates radiation across the entire spectrum, and as a result, although we cannot see it, all of the objects around us interact with this invisible radiation (see Figure 2). By designing equipment that is sensitive to these wavelengths of light we can use artificial "eyes" to study these interactions.

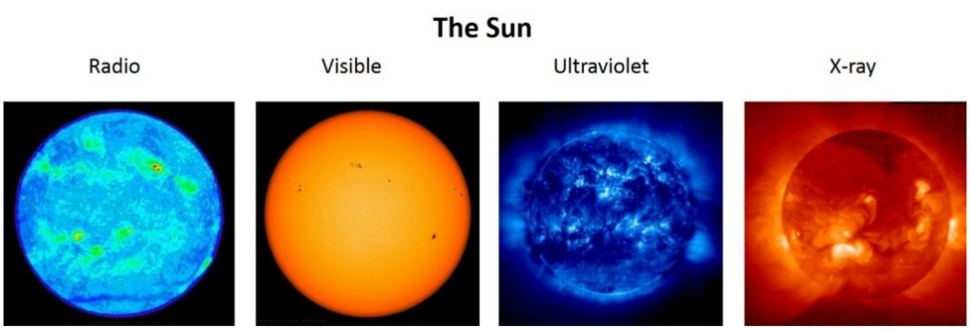

Figure 2: Images of the Sun at various wavelengths.
Courtesy: NASA, http://www.nasa.gov

Each type of electromagnetic radiation has its own unique wavelength and moves through space as a wave. The wavelength of electromagnetic radiation is the distance from one crest of a wave to the next crest (or one trough to the next trough). These types of waves can also be described by their frequency. The frequency of a wave is the number of whole waves or cycles that pass by a given point in a certain amount of time (See Figure 1).

In this activity, you will obtain IR data for concrete, blacktop, and grass. The data will be measured in Celsius or Fahrenheit. After collecting all of the data you will plot it all on the same graph. This process of collecting data and graphing it is very similar what scientists do who use Earth observation satellites, such as Landsat, to study Earth's surface from space.

What is Infrared Light?

Infrared is light that has a wavelength longer than visible red light. The ranges of infrared include near infrared, mid infrared and far infrared, spanning wavelengths from about 710 nanometers (near infrared) to 100 micrometers (far infrared).

All objects emit light according to their temperature--this is called "black body radiation." The hotter the object, the shorter wavelength of light it emits. The Earth emits infrared light at a peak of about nine to 10 micrometers--and so do warm-blooded animals like humans. This light can be used to detect motion or warmth (think of night-vision goggles--these allow humans to "see" the IR).

LED IR Detectors

IR sensors detect infrared light. The IR light is transformed into an electric current, and this is detected by a voltage or amperage detector. A property of light-emitting diodes (LEDs) is that they produce a certain wavelength of light when an electric current is applied--but they also produce a current when they are subjected to the same wavelength light.

A pair of IR LEDs can be used as motion detectors. The first IR LED is wired to emit LED and the second LED is wired to transmit a signal when it receives an IR input. When an object comes within range of the emitted IR, it reflects the IR back to the receiving LED and produces a signal. This signal can be used to open sliding doors, turn on a light or set off an alarm.

See For Yourself

IR detectors (and emitters) can be found almost everywhere. If you have a computer mouse with a red LED or laser--it is using IR light. Try using this mouse on a damp mouse pad--water almost completely absorbs the IR and the mouse won't work as well.

TV and stereo remotes also use IR signals--the TV has an IR detector that interprets the signal from the remote. Most digital cameras are sensitive to IR light. Turn on your camera and point the TV remote at the camera. Press a button on the remote and you will see a pinkish or purplish light coming out of the remote on the LCD display of the camera. That is the IR signal from the remote.

Satellite sensors also detect thermal infrared radiation (see Figure 3). The latest Landsat satellite, Landsat 8, can measure thermal IR at two different wavelength regions. Although the previous Landsat satellite, Landsat 7, only measured thermal IR in one region of the spectrum, NASA enhanced the satellite's capabilities because of the importance of thermal IR detection. Agricultural and water resource scientists greatly rely on this information to learn about crop health and drought. Crops lacking water have a much higher temperature than those with sufficient moisture, so thermal IR reflectance can improve irrigation methods and water management.

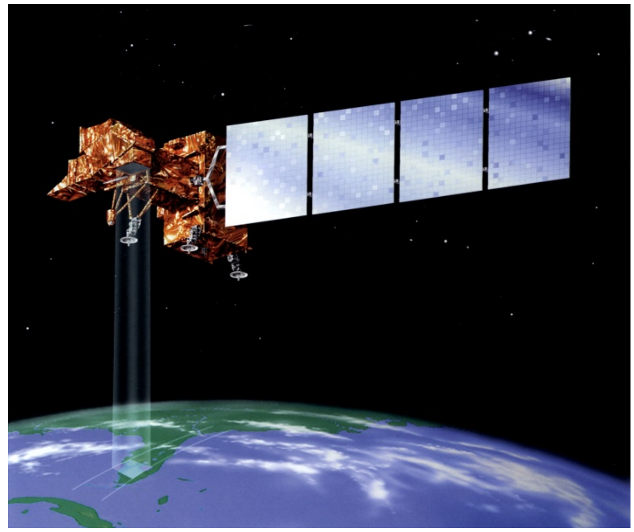

Figure 3: Landsat 7 Satellite
Courtesy: NASA, http://landsat.gsfc.nasa.gov/

How Laser Thermometers Measure Temperature

Laser thermometers are actually infrared thermometers. The laser is just there to make the thermometer easier to aim. Molecules are vibrating constantly; the hotter the molecule is, the faster it vibrates, creating infrared energy. Infrared thermometers measure the infrared energy given off by all objects. To display the temperature, the thermometer converts the infrared energy it measures into an electrical signal, which is then converted to a temperature.

How the Thermometer Measures Infrared Energy

Infrared energy has a longer wavelength than visible light. To help you remember that IR waves are **longer** than visible wavelengths think of it this way – the red wavelengths are longer than the blue wavelengths, therefore the infrared wavelengths are even longer than the red in the visible portion of the EM spectrum (and in a similar way, you can remember that ultraviolet waves are smaller than the violet rays in the visible portion). Infrared energy can be measured in three ways: transmitted (go through the material in question), reflected (bounce back) and emitted. IR thermometers measure the emitted energy of objects. IR thermometers use a series of lenses and mirrors to focus the emitted infrared energy onto a detector. The detector converts the emitted infrared energy into an electrical signal, which the thermometer turns into a digital temperature reading. **Emitted** infrared energy is the only energy that can give an accurate surface temperature reading. Most objects have an emitted infrared energy of 0.95 and this is what has been set in the IR thermometer you will use today; however, some objects have a higher or lower emitted infrared energy and therefore temperatures for these materials would be off. This is not of concern to us for the purposes of this lab.

Materials

1. Extech Pocket IR Thermometer
2. An area outside that has concrete, blacktop, and grass
3. If conducting the activity in the classroom:
    a. Concrete, asphalt, grass samples
    b. Strong (100 watt) IR light source (not included)
4. Data tables
5. Activity Handouts
6. Computer with graphing program or graph paper

The Extech Infrared Thermometer

Figure 4: The Extech Infrared Thermometer.
Courtesy: Extech Instruments, http://www.extech.com

Prediction (make a hypothesis)

Which of all the surfaces being measured will have the highest temperature? _______________
Explain your answer:

____
____
____

Which of all the surfaces being measured will heat up the most rapidly? Why?

____
____
____

Procedure

Teams

Form teams of two to four students, one to take measurements and the other records the data (be sure each person does both jobs)

Data Collection

- You will either measure surface materials outside or your teacher has provided you with examples of materials that you can use in the classroom.
- Read the infrared thermometer every 15 seconds and record the temperature.
- Take 20 readings for each surface
- Do this for concrete (sidewalk), blacktop (road), and grass
- Graph the results (either by hand or by using a computer graphing program)
- Compare your data with other teams

IR Lab

Weather Conditions:

____

Air temperature:

____

Surfaces measuring:

____

Which of the surfaces being measured will be the hottest and why?

____

____

Which of the surfaces being measured will heat up the most rapidly? Why?

____

____

Time at start of experiment: ___________

Experiment

#	**Date**	**Time**	**Surface**	**Surface Temp**	**Other Notes**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					

24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45					
46					
47					
48					
49					
50					
51					
52					
53					
54					
55					
56					
57					
58					
59					
60					

Graph Your Results

Notes: