# Using Satellite Thermal Imaging to Monitor Forest Fires

## Objectives

Students will:

- Understand how thermal infrared emissions can be used to measure temperature
- Learn how weather can be tracked by remote sensing satellites
- Apply knowledge of the Electromagnetic Spectrum to real-world scenarios
- Predict fire damage using satellite temperature data
- Analyze real-world data in the form of graphs and NOAA satellite imagery

## Suggested Grade Level

$6^{th}$ - $9^{th}$

## Timeline

45 minutes

## Standards

NGSS Standards

- MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
- MS-PS3-4. Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
- MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- MS-PS4-3. Integrate qualitative scientific and technical information to support the claim that digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.
- MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
- HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

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- HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
- HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

**21st Century Essential Skills**

- Learning Skills (critical thinking, collaboration, communication)
- Literacy Skills (information, media, technology)
- Life Skills (initiative, productivity, social, listening)

**Background**

The electromagnetic spectrum demonstrates the varying range of radiation. On one end of the spectrum, you have long radio wavelengths that have the lowest energy. On the other end of the electromagnetic spectrum, you have short gamma-ray wavelengths, where you have the highest energy. The area where you can see this energy is under visible light.

In 1800, scientist William Herschel discovered that in the visible light spectrum, temperatures from the colors gradually increased from violet to red. He then found infrared radiation (IR) is just beyond the red color. This was an important finding because it proved there were types of light not visible by the human eye.

We use infrared technology for many common purposes. Some useful applications are toasters, remote controls and contactless thermometers. We also use IR for detecting heat signatures in fires, weather patterns and aiding in archaeological sites.

In more advanced uses, NASA uses IR to explore the universe, galaxies and nebulas. The charge-coupled devices (CCD) on space telescopes and cameras provide us with images that were previously unknown to humans. It can detect cold molecules of gas and objects that were normally blocked by space dust due to its longer wavelengths.

This lesson demonstrates how satellites use IR when scanning an area on Earth. It focuses on surveying regions where humans are unable to access due to dangerous situations, like forest fires, or the location is physically impossible to reach, like deep space.

**Vocabulary**

Aerial Satellite imagery, electromagnetic spectrum, infrared radiation, heat index, radiate

**Materials**

- FLIR or IR camera (or download a Near IR app to a handheld device)
- 3-5 household items that radiate heat (i.e. electric blanket, crock pot, heating pad, space heater)
- Plastic tablecloth
- Tables
- Sturdy chair or ladder

**Lesson**

1. Set up your "disaster area" prior to starting the activity. The theme for this lesson is forest fires; however, you can modify the disaster to fit your curriculum (i.e. changing weather patterns or coral reefs). You'll also need time for your items to generate heat so that the FLIR or Near IR app is able to register the heat index.
    a. Download Near IR app onto handheld devices if not using a FLIR
    b. Start with a central location for the start of the fire
    c. Have one or two additional heat sources
    d. Create a fire line
    e. Cover area with plastic tablecloth (see figure one)
2. Explain the electromagnetic spectrum (the range of radiant energy, figure two). Each section of the spectrum emits energy, but only a small sliver is visible with the human eye. Just beyond visible light is infrared radiation (IR), where it's not visible yet it's a form of light.
3. Provide examples of IR (toasters, remote controls and thermometers). Because of its long wavelengths, NASA is able to use IR to detect heat that is reflected off distant stars and dust particles in deep space (figure three).
4. Test the FLIR or IR app on the handheld devices. Find objects that are radiating heat. Can you "see" it? What do the different colors represent? Why are non-living objects (desk or chair) have little or some heat index?
5. Describe the situation. A fire started deep in the forest. It's quickly spreading due the high winds. In order to stop the forest fire from growing, we need to know where it started. Ask students, "If an area is too dangerous or impossible to reach, what can we do to help firefighters survey the area?"
6. Lead discussion to the use of aerial satellite imagery. Satellites use IR imagery when scanning an area to detect a difference in temperature (heat index). It will emit IR light and collect any data that is reflected back to the camera. It won't be a recognizable "picture," but you'll be able to see the varying heat index given off elevation and objects. We also use IR with our satellites to monitor weather patterns or changes in ocean temperatures.
7. Explain to students we're going to replicate how satellites use thermal images to monitor forest fires. We'll be using the FLIR (or handheld device) to scan the disaster area. This is the satellite. Students must gather information from the satellite to determine where the fire started, how intense in the heat index and predict the spread of embers to contain the destruction.
8. Stand on a sturdy chair, table or ladder and aim the FLIR or IR app device above the disaster site; students should not be able to see the disaster area. Take multiple pictures over the course of five minutes. This part of the activity could be teacher-led or

break students up into groups. If you don't have access to IR equipment, you may also follow along using the images attached with this lesson (figures four to eight).

9. Analyze the images. Ask students:
    a. Can you determine the source of the fire? (cabin)
    b. Are there any other sources of heat? (embers spreading in the surrounding area)
    c. Where is the fire line? (the "U" shape outlining the cabin)
    d. What happened when a new heat index appeared (e.g. trees catching fire)? (scale changes with additional temperature; surrounding fire appears cooler for a little bit)
    e. What was the range of temperature generated from this fire? (scale on the right)
    f. How does satellite imagery help scientists, first responders, and the general public understand our environment? (answers will vary)
10. Have students generate a report from their data collected. Summarize the analysis, predict spread of the fire and provide suggestions on containing the disaster.

**Extensions**

1. Explore coral reefs and see how thermal imaging of changing ocean water is affecting the grow of coral reefs.
2. Research how we use IR in the classroom, medical field and/or other uses. Invent a new device that incorporates IR and describe how it will benefit humans.
3. Explore other electromagnetic wavelengths. What are some other regions that allow us to "see" using different wavelengths? How do we use these types of radiation to enhance human life?
4. Visit http://www.discoverspace.org/ for more innovative ideas and resources.

**Resources**

Electromagnetic Spectrum - Introduction. (n.d.). Retrieved August 24, 2020, from https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html

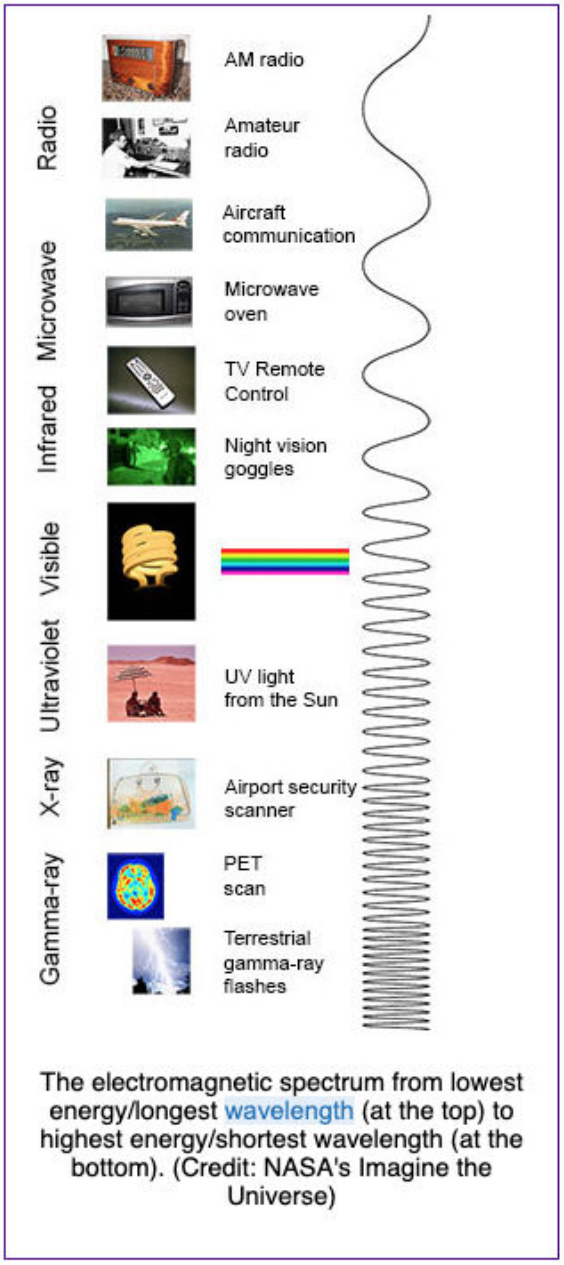
Image - Lagoon Nebula (Visible-light View vs. Infrared View). (n.d.). Retrieved August 24, 2020, from https://hubblesite.org/image/4152/news/3-nebulas

Lucas, J. (2019, February 27). What Is Infrared? Retrieved August 24, 2020, from https://www.livescience.com/50260-infrared-radiation.html#:~:text=Infrared%20radiation%20(IR)%2C%20or,are%20the%20sun%20and%20fire.

Redd, N. T. (2012, September 04). William Herschel Biography. Retrieved August 24, 2020, from https://www.space.com/17432-william-herschel.html

Reflected Near-Infrared Waves. (n.d.). Retrieved August 24, 2020, from https://science.nasa.gov/ems/08_nearinfraredwaves

Figure One: Set Up




The electromagnetic spectrum from lowest energy/longest wavelength (at the top) to highest energy/shortest wavelength (at the bottom). (Credit: NASA's Imagine the Universe)

**Radio:** Your radio captures radio waves emitted by radio stations, bringing your favorite tunes. Radio waves are also emitted by stars and gases in space.

**Microwave:** Microwave radiation will cook your popcorn in just a few minutes, but is also used by astronomers to learn about the structure of nearby galaxies.

**Infrared:** Night vision goggles pick up the infrared light emitted by our skin and objects with heat. In space, infrared light helps us map the dust between stars.

**Visible:** Our eyes detect visible light. Fireflies, light bulbs, and stars all emit visible light.

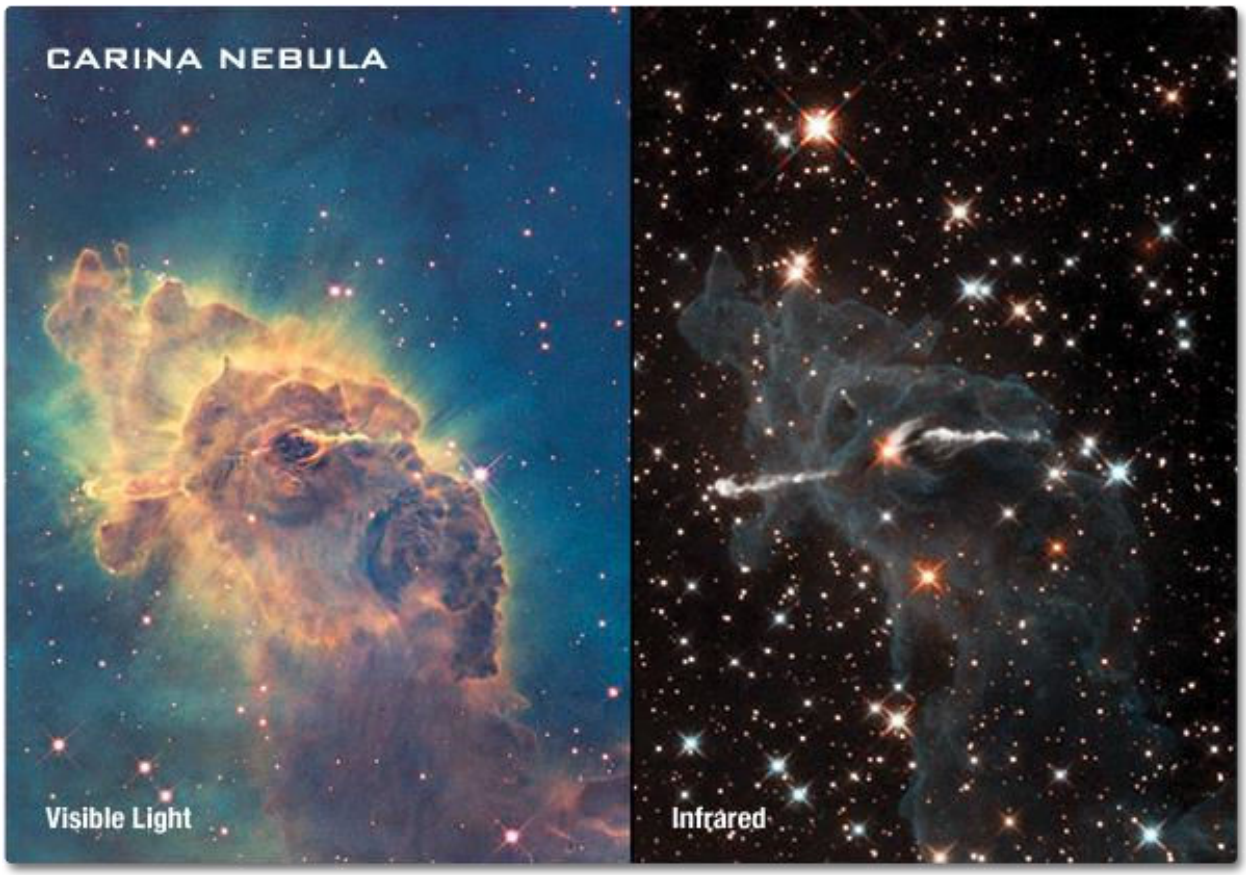
**Ultraviolet:** Ultraviolet radiation is emitted by the Sun and are the reason skin tans and burns. "Hot" objects in space emit UV radiation as well.

**X-ray:** A dentist uses X-rays to image your teeth, and airport security uses them to see through your bag. Hot gases in the Universe also emit X-rays.

**Gamma ray:** Doctors use gamma-ray imaging to see inside your body. The biggest gamma-ray generator of all is the Universe.

https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html

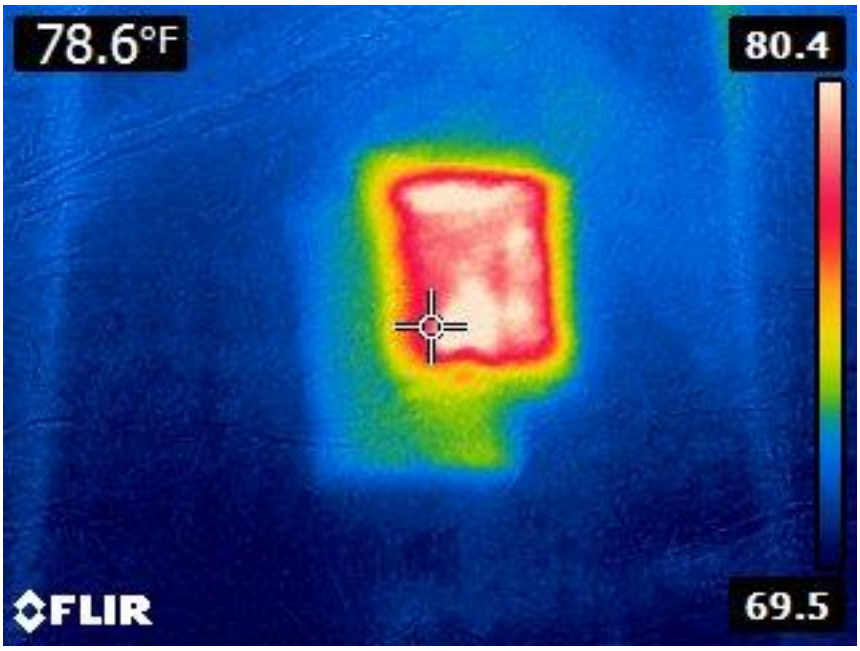
Figure Two: Electromagnetic Spectrum



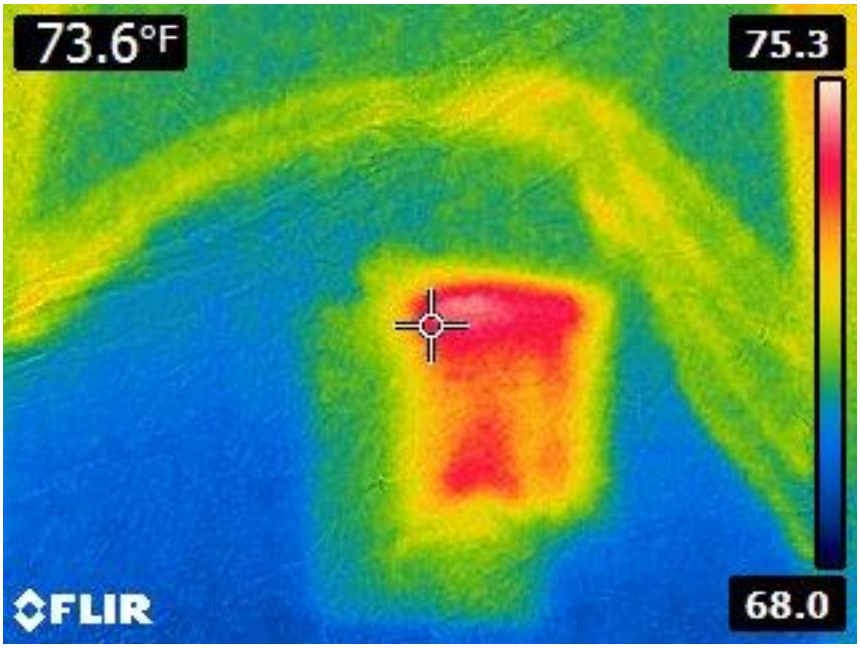

*Credit: NASA, ESA, and the Hubble SM4 ERO Team*

Figure Three: Comparison of images taken with visible light and Infrared radiation

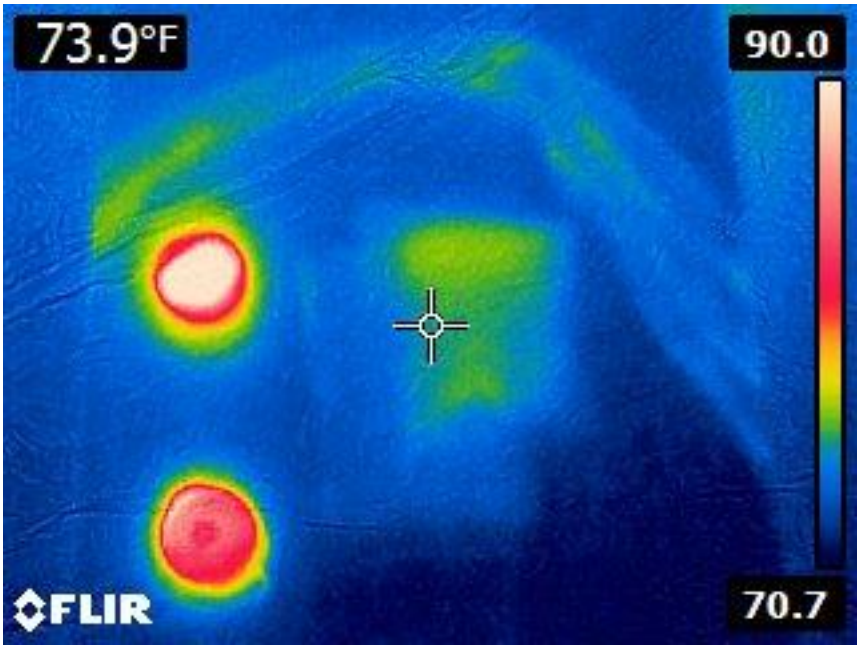
**Thermal Images from our "Satellite" (FLIR images)**
**Figures 4 – 8**



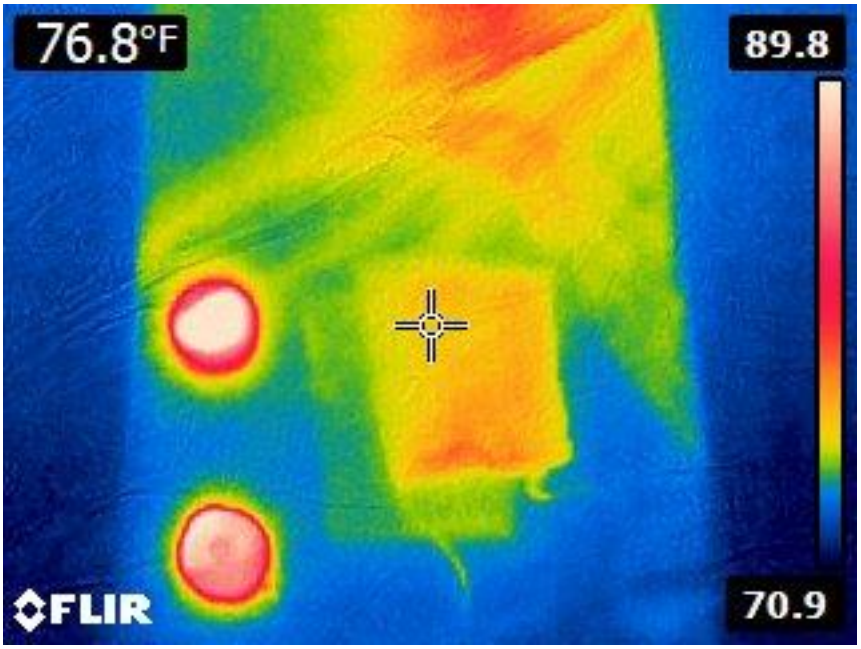

**Start of fire (cabin in the forest)**



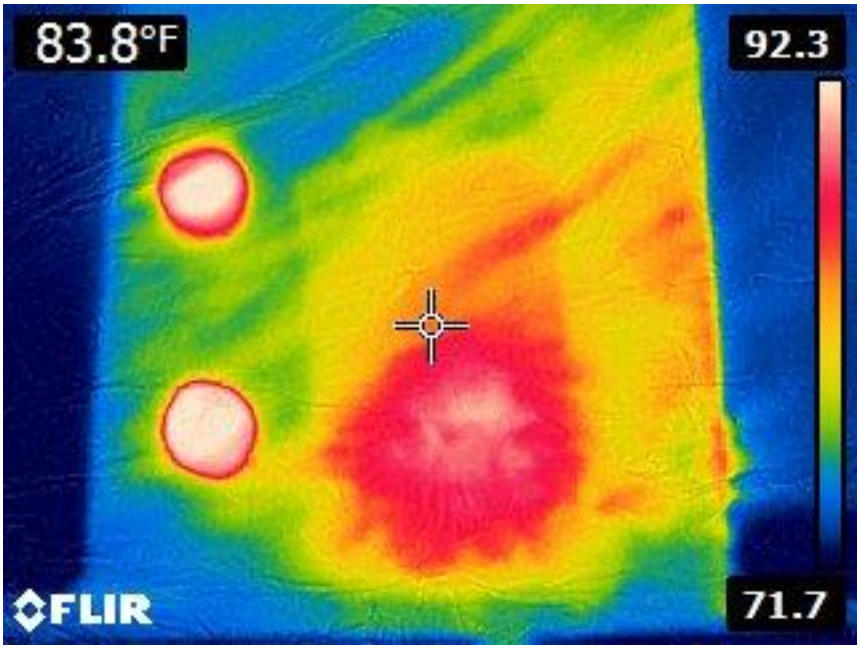

**Start of fire line**




**Add new heat sources (hot spots) causing the change in scale**




**Replicate wind spreading the fire**




**Analyze heat index from all FLIR images**