Understanding weather satellite images:
Snapshots of the Earth from space

We have discussed how solids, liquids, and gases absorb, emit, and reflect electromagnetic radiation at various wavelengths. Just as this fact allows our eyes to observe a hot electric stove burner or a cloud of smoke in the sunshine, it creates a vital way for scientists to observe the atmosphere and oceans. In this activity we will focus on the three most common and important types of images that we can get from weather satellites, which together can tell us a tremendous amount about the state of the atmosphere.

Visible channel images:

This kind of image shows sunlight that is reflected and recorded by the satellite. It is usually the easiest to interpret because it mimics what you would see if you were in a space shuttle. Clouds, snow, and ice reflect the most light and appear whitest in these images. Thin clouds, however, reflect less sunlight and appear darker – if at all. The oceans generally appear dark, unless there is an extreme angle with the sun (i.e., sunrise or sunset). Sandy desert areas reflect some sunlight when there are no clouds present, and may appear gray.

The time of day is also apparent in visible-channel images. Parts of the Earth where it is night are completely dark, and where it is daylight the features are sharpest and best illuminated. The "terminator" is the border between the areas of day and night on the Earth. Since the sun rises in the East and sets in the West, in these images the places with a black line close by on the left have just experienced sunrise and are in the morning, while those with the black line/terminator to the right are in the evening and approaching sunset.

Window channel infrared images:

In these images the source of radiation is not the sun, but features of the Earth and atmosphere themselves. Black in these images represents the greatest radiative flux at this wavelength, and white indicates the least flux. Since water (both bodies of water and water droplets) and land essentially act as blackbodies, we can judge their temperature from how much radiation they emit. Warmer objects emit more radiation, and colder objects emit less. Thus, the warmer land and water areas appear darkest in these images, while objects that are higher up in the atmosphere and colder will appear whiter.

One advantage of infrared images is that they can be taken at any time of the day or night, since they do not rely on sunlight as a source of radiative flux. Additionally, the radiation detected in the window channel is not much affected by gases in the atmosphere, so we see the actual flux emitted by the Earth's surface (in clear conditions) or by particles suspended in the atmosphere (clouds, when present).

*Water vapor channel infrared image*s:

Water vapor is a gas that is invisible to our eyes but absorbs and emits electromagnetic radiation at certain well-known wavelengths that satellites can detect. In these images, red indicates the least radiative flux and blue indicates the most radiative flux at this wavelength. There are two factors that contribute to the amount of outgoing radiative flux here. The first is the amount of water vapor in the atmosphere. When there is more water vapor present in the atmosphere, it absorbs more of the outgoing radiation from the surface and allows less flux at this wavelength for the satellite to sense. The second important factor is the temperature of the

water vapor. Hotter materials emit more radiation than cold ones, so that if there is water vapor in the upper, colder part of the atmosphere, it will emit very little flux to space. Clouds also absorb and emit infrared radiation in the water vapor channel, and the reddest areas of the image correspond to clouds.

Summary table

Type of image	**Radiation source**	**Color scale**	**Physical interpretation**	**Examples**
Visible channel	Sunlight	Blacker: less reflected sunlight Whiter: more reflected sunlight	Reflection of solar radiation, cloud location, land use, intuitive overview	Storm systems clearly visible; deserts visible (daytime only)
Window channel infrared	Emission from Earth's surface or cloud particles	Blacker: more radiative flux Whiter: less radiative flux	Temperature of Earth's surface or suspended particles (clouds); height in atmosphere of cloud tops	Deep clouds, such as thunderstorms, show up very white; low-level clouds are gray
Water vapor channel infrared	Emission from Earth’s surface, clouds, and water vapor in the atmosphere	Blue: more radiative flux Red: less radiative flux	Moisture/clouds in atmosphere; temperature in atmosphere	Dry air over deserts appears blue; very moist air and clouds appears red

Time zones and Greenwich Mean Time

Because satellite images are taken frequently and used by scientists all over the world, it is easier to use only one time zone to record when the image was taken. The time on these retrievals is given in Greenwich (England) Mean Time (also called "GMT," "Z," or "UTC"), but it is useful to know what the local time is at a particular location.

San Diego is in the GMT –8 time zone, meaning that when it is 12 noon Greenwich Mean Time, it is 4 am Pacific Standard Time (5 am Pacific Daylight Time) in San Diego. The table below gives the time zones of some other major cities in the images you will analyze.

City	Time Zone
San Diego	GMT –8
London	GMT
Tokyo	GMT +9
New York	GMT –5
Honolulu	GMT –10
Bombay	GMT +5:30

Add one hour to convert standard time to daylight time.

Activity

Each of the five groups will analyze satellite images from a different part of the world. Below are some questions about each type of image so that you can apply what we have discussed to an analysis of the Earth's atmosphere. In addition to answering the questions in their lab notebooks, each group should pick one feature from their maps that is especially pronounced to present to the others. You should be able to say what the feature means as far as radiative flux reaching the satellite in the part of the spectrum you are examining.

Local time

For each image, the date and Greenwich Mean Time is written in the upper-left corner. For your own reference, use the tables above to convert this to the date and time in San Diego and in the appropriate local city for the sector of the globe seen in the image.

Visible channel images

1. In the visible images, why is part of the image completely dark and part of the image light? How does this relate to the time in the local city you identified above?
2. What things are the whitest areas in the visible image? Why do they appear white?
3. What things are the darkest areas in the daytime part of the image? Why are these dark?
4. Are any of the cloudless land areas that are not very dark? If so, what do these represent?
5. Based on what you see in the images, what changes in the land surface and atmosphere could lead to changes in how much solar radiation is reflected back to space by our planet?

Window channel IR images

1. Identify the whitest areas in your group's infrared images. What does a very white area mean in terms of infrared radiative flux detected by the satellite? What do you think is causing these bright white areas?
2. Are there any areas that are bright white in the infrared images that correspond to clouds in the visible image? Do you expect that these are low down or high up in the atmosphere?
3. Are there any areas that appear as clouds in the visible image but are not very white in the IR image? Do you expect that these are low down or high up in the atmosphere?
4. Are there any differences in the brightness of land areas between the two infrared images your group has? How does this relate to the local time of day?

Water vapor channel IR images

1. What areas in the image have the least atmospheric water vapor?
2. What areas in the image have more water vapor?
3. Why do you think there is correspondence between white areas in the IR images and red areas in the water vapor retrievals?

Cloud Fraction

1. What channel would you look at to estimate the fraction of the image covered by all types of clouds? Develop a group consensus for the numerical value of the fraction of your view of the Earth that is covered by all types of clouds.
2. What channel would you look at to estimate the fraction of the image covered by only high-level clouds? Develop a group consensus for the numerical value of the fraction of your view of the Earth that is covered by high-level clouds.