Satellite Winds

This activity is adapted from:
Bigelow Marine Lab “Scattering Light” activity:
http://www.bigelow.org/virtual/handson/scattering.html
UW Madison website for Satellite Meteorology:
http://cimss.ssec.wisc.edu/satmet/index.html
NASA Jet Propulsion lab “Catch the Wind: the QuikSCAT Story”

Introduction:

In SMILE we have talked about the different ways satellites get information. We know that they usually rely on detecting light/energy from the Earth’s surface. But satellites are also used to measure things like wind speed and direction. Knowing how satellites get their information, how do you think they accomplish this? In this activity students will explore properties of light and how it scatters, and apply this to satellite technology.

Materials:
(Materials in bold are provided by SMILE)
prism?
Flashlights (from summer Remote Sensing activity)
aluminum foil
ruler
overhead marker

Copies:
   Satellites vs. Weather Balloons overhead
   Cloud transparencies
   Beaufort Scale
   Wind Barbs
   Hurricane
   Scatterometer Subsystems

Background:

Data about wind speed and direction is collected at weather stations on land and by buoys or ships over the ocean. Meteorologists have also used weather balloons to collect data about wind speed and direction. The introduction of satellite data, and especially wind-detecting satellites such as the QuikSCAT, allow for much more comprehensive data.
Typical Weather Balloon Coverage

Satellite Wind Data Coverage

**Reading Wind Data**
Show students the overhead of weather balloon data vs. satellite data. The difference in density of data points is dramatic. What do the symbols designate?

Wind data is represented by wind *barbs*. Pass out the handouts about the Beaufort Scale and Wind Barbs to pairs of students. Why is the Beaufort Scale especially useful for sailors? Pass out the Hurricane handout and have students interpret the barbs.
**Satellite Wind Data**

Encourage the students to discuss how satellites “see” winds. A good hypothesis is that satellite images of cloud formations from different time intervals are compared to observe how the formations are moving. This is in fact one way to determine atmospheric wind speed and direction from satellites. What are some drawbacks to this method? (Wind speed and direction can vary over an area, would require lots of observations/calculations; cloud formations may change shape, form and disappear making them hard to track; what about areas without cloud cover?)

Activity: Atmospheric Winds

The airplane below is traveling in a straight line at a constant speed. Its speed is the distance traveled divided by the time interval. If we know how far it is traveling in a given time, we can determine its speed.

We can calculate this speed if we have two snapshots of the plane separated in time as illustrated by the following two images:

The image below was taken two seconds later, after the plane traveled 400 meters. Thus, the airplane speed is 200 meters per second. Notice the distance is measured from the same spot on the plane, in this example from the nose.

In the above example the plane traveled in a straight line during the time we tracked it.

What happens if the object we are tracking does not travel in a straight line? If we follow the airplane example and use a straight line, our calculation of the average speed would be incorrect. Why? Visualize tracking a car moving over a curved road. Again we start our clock when we take our first image.
Of course, the car did not travel in a straight line! To calculate the speed of the car we have to know the path the car traveled. For a car this is easy, since a car typically drives along the road. So, we can calculate the distance the car traveled by measuring the length of the roadway between the two car images. The length of road the car traveled in 15 minutes is 8 miles, so the true average speed of the car is 8/15 miles per minute, or 32 miles per hour. What might be problems in tracking the movement of clouds from satellites?

A problem we have in tracking clouds is that we do not know the path they take (there are no roads in the sky for us to follow!). In fact, if we can determine the path they take we can determine the wind direction. Watch the image of the car on the previous page and imagine that you did not have the roadway to help determine the car's path. So without a roadway, how can we determine the path? A good way to determine the path of the car is to track two images of the car that are close in time.

The same thinking applies to clouds. Because we do not have a road to help us determine the cloud's path, we view two images of a cloud that are close in time. Long time intervals are not good for tracking clouds that are changing rapidly. Short time intervals (1 to 15 minutes) are best when clouds are moving quickly.

In tracking clouds we have additional problems besides not knowing the actual path. What are some other problems we might encounter when tracking clouds to determine wind speed and direction?

You can compute the wind speed by dividing the distance between targets by the time between the images. Identify the same cloud features on each of the transparency images. Since we know the images were taken half an hour apart, we can then use the image scale and compass to calculate wind speed and direction. Be sure to check your units! (Do you want your speed to be in miles per hour, kilometers per hour, or kilometers per minute?)
A sequence of GOES images, separated by 15 or 30 minutes, are used to compute winds from satellite images. Satellite meteorologists are able to generate winds at different levels of the atmosphere all around the globe. This is particularly useful over the oceans where conventional weather observations are not possible. While it's true that buoys and ships send in weather observations they simply can't contribute anywhere near the coverage offered by satellites.

The accuracy of weather forecasts improved dramatically during the 1990's due to the addition of satellite derived winds in forecast models. This has been especially crucial to the timing and location of where a hurricane makes landfall.

**Scattering Light**

Satellite-derived wind data is especially important over the ocean. This is because the oceans represent large areas where there is relatively little *in situ* (on site) data. There is another way satellites can detect winds. It relies on a property of light: that it can be scattered.

Visible radiation is that part of the electromagnetic spectrum that we can see (like the colors of the rainbow). All visible light is part of the electromagnetic spectrum; the radiation corresponding to the color green travels in a certain wavelength, the radiation corresponding to the color blue travels in a different wavelength. White light is visible radiation. It is composed of all the colors of the visible spectrum; the ingredients of white light are red, orange, yellow, green, blue, indigo, and violet. If we were to shine white light through a prism, we could separate white light into its color components (much like the water particles in the atmosphere separate white light to create a rainbow). Particles in the atmosphere such as dust, gas, and aerosols act to either reflect, refract, or even absorb visible radiation. In other words, light is scattered.

Use the prisms to explore this property of light. How could this property of light be useful for detecting wind using satellites?

**The QuikSCAT Satellite**

The QuikSCAT satellite was launched in 1999. It was intended to replace the NASA Scatterometer (NSCAT) that lost power in 1997. It has a special SeaWinds instrument which uses microwave radar to measure near-surface wind speed and direction. It is able to get accurate data in most weather and cloud conditions. The data it produces helps improve weather forecasting and storm warning and monitoring. In addition to these practical applications, the QuikSCAT has science objectives aimed at better describing the interaction of the ocean and atmosphere and understanding the mechanisms of global climate change.

**How the scatterometer works:**

When light (or any other form of electromagnetic radiation) is reflected from a smooth surface, it bounces off in a symmetrical way.
When wind blows over the surface of the ocean, it makes that surface rough.

**Hypothesis**
When a surface is not smooth, the radiation will be reflected in many directions. Some of the radiation might even come directly backwards towards its source.

**Activity:**
Divide students into groups of two or three. Have them lay out a sheet of aluminum foil (approximately 8” by 12”) on a table. Darken the room, put eyes at the level of the table, and look across the foil. Hold a flashlight next to head and shine it across the foil.

Turn on the lights. Take a second sheet of foil the same size as the first, and crumple it up, then flatten it out again. Put this sheet next to the first sheet, and repeat the procedure with the flashlight, looking first at one piece of foil and then the other. What do you observe?

Turn on the lights. Take a third sheet of foil, the same size, and fold it in half, then in half again, and so on until the strip is approximately .5 inch wide. Unfold this sheet and lay it next to the other two. Repeat the procedure with the flashlight, turning the folded sheet of foil in various directions (through always flat on the table) as you look at it. What do you observe?
Discussion Questions

• Explain your observations in relation to the hypothesis above. Does it seem to be true?
• Explain how your observations relate to how the SeaWinds instrument detects the direction of the wind.

The light that returns to be detected at the source is called backscatter. The amount of backscatter depends on the size and orientation of the waves disturbing the sea surface, as we observed with the foil experiment. These waves are produced by wind. The backscatter can then be used to determine the orientation of the waves, and therefore the sea-surface winds. Backscatter data from the SeaWinds instrument on the QuikSCAT satellite is plugged into an algorithm (a series of equations) that determines the speed and direction of the winds producing the sea surface waves.

Give student pairs the Scatterometer handout.
SeaWinds Scatterometer

The SeaWinds instrument is made up of three main components, known as subsystems. The electronic subsystem creates the radar signal that is sent to the antenna, which then beams it down to the Earth’s surface. The antenna also receives the return signal, or backscatter. The command and data subsystem contains the computer that controls the scatterometer instrument. It supplies engineering telemetry (e.g. temperatures and operating voltages and currents) and science data (backscatter measurements) to the spacecraft, which then transmits the data to ground stations. The CDS also receives commands from the spacecraft. Everything in the scatterometer instrument except the actual rotating antenna dish is redundant, meaning there are duplicate parts in case one fails.

More information about the QuikSCAT and other NASA/JPL Scatterometer missions can be found at: http://winds.jpl.nasa.gov
VOCABULARY

absorb: To take in and make a part of itself reflect - to throw back or be thrown back, as with light, heat, or sound

backscatter: Radar echoes from a target.

electromagnetic: Pertaining to phenomena in which electricity and magnetism are related.

electromagnetic radiation: Electromagnetic waves and, especially, the associated electromagnetic energy.

electromagnetic spectrum: The total range of wavelengths or frequencies of electromagnetic radiation, extending from the longest radio waves to the shortest known cosmic rays. Electromagnetic waves emanate from all forms of radiant energy sources including the Sun, the earth, and even light bulbs.

microwave: A comparatively short electromagnetic wave which has a wavelength between about 0.3 and 30 centimeters.

prism: A optical instrument such as a pyramid of glass. A pyramid has 5 surfaces. When white light is refracted through the first surface within the prism, it is bent to another surface. The light is then reflected back into the air. During the refraction process, the white light is broken up into its constituents wavelengths.

radar: A system using beamed and reflected radio-frequency energy for detecting and locating objects, measuring distance or altitude, and other purposes.

reflect: To turn or throw backwards off a shiny surface (such as a mirror).

refract: To deflect or bend through a surface (such as a window).

scatter: To separate or cause to separate in many directions.

scatterometer: A microwave sensor that is essentially a radar without ranging circuits, used to measure only the reflection or scattering coefficient while scanning the surface of the earth from an aircraft or a satellite.

visible radiation: Relatively shortwave radiant energy. Visible radiation is the radiation that our eyes are sensitive (like the colors of the rainbow). This type of radiation is part of the electromagnetic spectrum.

wind anemometer: A weather instrument to measure the speed of wind.