Does it Make “Sense”?  

**Concept Statement:** Remote sensing is the acquisition of information about an object or phenomenon by passive or active sensing devices not in physical or intimate contact with the object. Remotely sensed information is often processed into data that is useful for a variety of engineering and scientific applications.

Summer Engineering Academy 2008  
Engineering in Practice - University of Oklahoma  
Developed by Jesse Bell, Evan Tromble, and Tiffani Wilke
List of Materials Needed:

Introduction:

Demonstration of thermal imaging camera-Norman Fire Department
Person of contact: Deputy Chief Bailey, 292-9780

Exploration A:
Each of the following is required per group:
- Graph paper, 2 pieces
- Pencil
- Metric ruler

Each of the following is required per class
- Numbered index cards *(the numbers will correlate with the number of objects used)*
- 2 or 3 scales
- Snickers bar
- Oreo cookie
- Reese's Peanut Butter Cup
- Can of Pop
- Bottle of Water
- Sandwich Crackers (Cheese or Peanut Butter)
- Banana
- Package of pop-tarts
- Hershey's Bar
- Tootsie Roll Pop
- Carrot
- Capri-Sun
- Coconut
- Pineapple
- Cantaloupe

Exploration B:
Each of the following is required per group:
- Computer with:
  - Internet access
  - Radar images
- Calculator

Concept Application (A, B, and C):
Each of the following is required per group:
- Computer with:
  - Internet access (Application A, B, and C)
  - PowerPoint (Application A and C)
  - ArcMap software (Application A)

Authentic Assessment:
- Remote sensing or not game
- Severe weather parameters game

Activity Time Frame:
This set of activities takes approximately six hours to complete. Exploration A and B take approximately an hour each to complete. Each of the three applications requires 45 minutes to finish. The field trip component can take anywhere from a half hour to an hour.
Environmental Setting:
The explorations for this lesson could be done in any classroom setting. For each of the application activities, a room with computers and internet access is required. The field trip portion of this lesson requires a trip to the National Weather Center in Norman, Oklahoma. This is where the mobile radar trucks are housed.

PASS Standards:
Science Processes and Inquiry: Physics

Process Standard 1: Observe and Measure
1. Identify qualitative and quantitative changes given conditions before, during and after an event.
2. Use appropriate tools when measuring objects and/or events.
3. Use appropriate System International (SI) units and SI prefixes when measuring objects and/or events.

Process Standard 2: Classify
1. Using observable properties, place an object or event into a classification system.

Process Standard 4: Interpret and Communicate
1. Select appropriate predictions based on previously observed patterns of evidence.
2. Report data in an appropriate manner.
3. Interpret data tables, line, bar, trend, and/or circle graphs.
4. Accept or reject hypotheses when given results of a physics investigation.
5. Communicate or defend scientific thinking that resulted in conclusions.

Process Standard 5: Model
1. Interpret a model which explains a given set of observations.
2. Select predictions based on models.
3. Compare a given model to the physical world.

Process Standard 6: Inquiry
3. Use a variety of technologies, such as hand tools, measuring instruments, and computers to collect, analyze, and display data.
4. Inquiries should lead to the formulation of explanations or models. In answering questions, students should engage in discussions and arguments that encourage the revision of their explanations, leading to further inquiry.

Content Standard: Physics
Standard 3. Interactions of Energy and Matter
1. Waves have energy and can transfer energy when they interact with matter. Sound waves and electromagnetic waves are fundamentally different.

Lesson Objectives:
- Students will determine the identity of unknown objects using active and passive “remote sensing” techniques.
- Students will estimate rainfall amounts using RADAR in WeatherScope and a Z-R relationship.
- Students will compare rainfall estimates to actual rainfall data.
- Students will process remotely sensed data to evaluate land use and carbon sequestration.
- Students will use internet websites to explore various remote sensing applications.
- Students will use previous examples of severe weather in RADAR images to determine whether or not severe weather is likely based on other RADAR images.

Vocabulary Terms:
- Active Remote Sensing - energy is emitted in order to scan objects or areas and the radiation that is reflected or backscattered back is measured
- ArcMap – ArcGIS software that is used as a tool for creating and analyzing spatial data
- Bow Echo - radar echo which is linear but bent outward in a bow shape. Damaging straight-line winds often occur near the “crest” or center of a bow echo. Areas of circulation also can develop
at either end of a bow echo, which sometimes can lead to tornado formation.

- Carbon Sequestration – the storage of carbon dioxide from the atmosphere into various geological and oceanic (missing something Jesse?) into stored carbon

- Cholera - any of several diseases of humans and domestic animals usually marked by severe gastrointestinal symptoms

- Cumulonimbus Cloud - a cloud characterized by strong vertical development in the form of mountains or huge towers topped at least partially by a smooth, flat, often fibrous anvil. Also known colloquially as a “thunderhead.”

- Decibel (dB) - a logarithmic unit that expresses the magnitude of a physical quantity

- Downburst - a strong downdraft resulting in an outward burst of damaging winds on or near the ground. Downburst winds can produce damage similar to a strong tornado. Although usually associated with thunderstorms, downbursts can occur with showers too weak to produce thunder.

- Electromagnetic Spectrum - the entire range of wavelengths or frequencies of electromagnetic radiation ranging from gamma rays to the longest radio waves and including visible light

- Geographic information system (GIS) – a system for capturing, analyzing and presenting spatial data. Computer-based tool that is used to interpret remotely sensed data.

- Hook Echo - a radar reflectivity pattern characterized by a hook-shaped extension of a thunderstorm echo, usually in the right-rear part of the storm (relative to its direction of motion). A hook often is associated with a mesocyclone, and indicates favorable conditions for tornado development.

- Knots - a nautical unit of speed equal to the velocity at which one nautical mile is traveled in one hour. Used primarily by marine interests and in weather observations. A knot is equivalent to 1.151 statute miles per hour or 1.852 kilometers per hour.

- Land cover - the physical material at the surface of the earth

- Land use - the human modification of natural environment into built environment

- Land-use change - the change, over time, of land use in an area

- Lyme Disease - an acute inflammatory disease that is caused by spirochete transmitted by ticks

- Mesocyclone - a storm-scale region of rotation, typically around 2-6 miles in diameter and often found in the right rear flank of a supercell (or often on the eastern, or front, flank of an HP storm). The circulation of a mesocyclone covers an area much larger than the tornado that may develop within it.

- Mesonet - a regional network of observing stations (usually surface stations) designed to diagnose mesoscale weather features and their associated processes.

- Net Primary Production (NPP) – the rate that ecosystem plants are able to produce chemical energy. Basic definition is the amount of mass of carbon per unit of area per year.

- NEXRAD - NEXt-Generation Weather RADar. Technologically-advanced weather radar being deployed to replace WSR-57 and WSR-74 units. NEXRAD is a high-resolution Doppler radar with increased emphasis on automation, including use of algorithms and automated volume scans. NEXRAD units are known as WSR-88D.
- NWS - National Weather Service
- Passive Remote Sensing - detection of natural energy that is emitted or reflected by the object or area being observed
- Radar - acronym for RAdio Detection And Ranging. An electronic instrument used to detect distant objects and measure their range by how they scatter or reflect radio energy. Precipitation and clouds are detected by measuring the strength of the electromagnetic signal reflected back.
- Radar Echo - a general term for the appearance, on a radar display, of the radio signal scattered or reflected from a target.
- Radial Velocity - component of motion toward or away from a given location. As "seen" by Doppler radar, it is the component of motion parallel to the radar beam. (The component of motion perpendicular to the beam cannot be seen by the radar. Therefore, strong winds blowing strictly from left to right or from right to left, relative to the radar, can not be detected.)
- Reflectivity - measure of the reflected radar signal
- Seroprevalence - the frequency of individuals in a population that have a particular element in their blood serum
- Severe Thunderstorm - a thunderstorm which produces tornadoes, hail 0.75 inches or more in diameter, or winds of 50 knots (58 mph) or more. Structural wind damage may imply the occurrence of a severe thunderstorm.
- Squall Line - a solid or nearly solid line or band of active thunderstorms
- Storm Relative Motion - images that show the flow of the wind with the actual motion of the storm subtracted out. This motion is removed to make the view of the wind relative to the storm. In effect, what is seen is the wind's motion as if the storms were stationary.
- Straight Line Winds - generally, any wind that is not associated with rotation, used mainly to differentiate them from tornadic winds.
- Supercell - a thunderstorm with a persistent rotating updraft. Supercells are rare, but are responsible for a remarkably high percentage of severe weather events - especially tornadoes, extremely large hail and damaging straight-line winds.
- Three Body Scatter Spike - a phenomenon that occurs primarily when large hail is forming in the atmosphere. Since the hail is so large and so reflective, a significant amount of the energy of the radar beam reflects off the hail and down towards the ground. The energy then bounces off the ground and again hits the reflective hail which again scatters the energy, part of which is received a second time by the radar. So instead of the hail producing a single radar return, it can produce multiple returns along the same radial as energy is bounced off the ground and again off the hail.
- Thunderstorm - produced by a cumulonimbus cloud, it is a microscale event of relatively short duration characterized by thunder, lightning, gusty surface winds, turbulence, hail, icing, precipitation, moderate to extreme up and downdrafts, and under the most severe conditions, tornadoes.
- Tornado - a violently rotating column of air in contact with the ground and extending from the base of a thunderstorm. A condensation funnel does not need to reach to the ground for a tornado to be present; a debris cloud beneath a thunderstorm is all that is needed to confirm the presence of a tornado, even in the total absence of a condensation funnel.
• Tornado Vortex Signature (TVS) - doppler radar signature in the radial velocity field indicating intense, concentrated rotation - more so than a mesocyclone. Like the mesocyclone, specific criteria involving strength, vertical depth, and time continuity must be met in order for a signature to become a TVS. Existence of a TVS strongly increases the probability of tornado occurrence, but does not guarantee it. A TVS is not a visually observable feature.

• Weather Surveillance Radar (WSR-88D) - the newest generation of Doppler radars, the 1988 Doppler weather radar. The radar units, with help from a set of computers, show very detailed images of precipitation and other phenomena, including air motions within a storm.

Resources:
http://cdiac.ornl.gov/trends/emis/usa.htm
http://www.nasa.gov
http://www.cdc.gov/ncidod/eid/vol6no3/beck.htm
http://www.srh.noaa.gov/oun/severewx/glossary4.php#Glossary
http://www.weather.com/glossary/t.html
http://www.spc.noaa.gov/faq/tornado/#About
http://www.education.noaa.gov/cweather.html
http://www.mesonet.org/sites/
http://www.letxa.com/anomalytbbs.php
http://upload.wikimedia.org/wikipedia/commons/thumb/e/e8/Three-body-scattering.PNG/300px-Three-body-scattering.PNG


Technology Component:
• Exploration B
  • Computers
  • WeatherScope
• Application A
  • Computers
  • ArcMap
  • ArcGIS
• Application B
  • Computers
  • Internet websites
• Application C
  • Computers
  • Internet websites (archived weather images)

WebQuest: Applications A, B and C:
**Engineering Application:**
Remote sensing is an inter-disciplinary process that encompasses many fields of engineering and sciences.

**Assessment Tools:**
- Is it remote sensing or not?
- Severe Weather Update!
Does it Make “Sense”?  

INTRODUCTION  
Demonstration of thermal imaging camera-Norman Fire Department  
Person of contact: Deputy Chief Jim Bailey, (405) 292-9780  

EXPLORATION  
Exploration A: What Kind of Food Is It?  
Materials:  
Each of the following is required per group:  
- Graph paper, 2 pieces  
- Pencil  
- Metric ruler  
Each of the following is required per class:  
- Numbered index cards  
- 2 or 3 scales  
- Snickers bar  
- Oreo cookie  
- Reese's Peanut Butter Cup  
- Can of Pop  
- Bottle of Water  
- Sandwich Crackers (Cheese or Peanut Butter)  
- Banana  
- Package of pop-tarts  
- Hershey’s Bar  
- Tootsie Roll Pop  
- Carrot  
- Capri-Sun  
- Coconut  
- Pineapple  
- Cantaloupe  

Procedures:  
1. Passive  
   a. Designate one person as the “runner” and the other as the “receiver.”  
   b. The “runner” must select a numbered index card from the table in the science prep room and get the associated item from the instructors. The identity of the item is not to be revealed to the “receiver.”  
   c. One physical parameter at a time, the “runner” must provide pieces of information to the “receiver.” A list of potential physical parameters can be found below. You cannot tell the “receiver” what the object is, what it does, or what it is used for.  
   d. The “receiver” must process the data and draw the item on the graph paper provided. This sequence of the “runner” providing one piece of information at a time to the “receiver” ends as soon as the “receiver” correctly draws and identifies the item.  
   e. The “receiver” is allowed one guess each time the “runner” brings them a piece of information.  
2. Active  
   a. Switch roles. The “runner” becomes the “receiver” and vice-versa.  
   b. The new “receiver” must select a number off the list of available numbers listed on the board and tell the new “runner” what the number is.  
   c. The “runner” must get the corresponding numbered index card off the table in the science prep room and the associated object from an instructor. The identity of the item is not to be revealed to the “receiver.”  
   d. The “receiver” must request two pieces of information to be collected by the “runner.” The request should be either i) from the list provided below or ii) approved by an instructor.  
   e. The “receiver” must process the data and draw the item on the graph paper provided. This sequence of the “receiver” requesting data and the “runner” providing the information ends as soon as the “receiver” correctly draws and identifies the item.  
   f. The “receiver” is allowed one guess each time the “runner” brings them two pieces of information.
Note: In this exploration the students will be using collected data to determine the identity of the unknown object. There are no answers for this exploration. Students will have finished the exploration when they correctly identify their object. It is recommended to turn this into a game and offer a prize to the winning group. A list of possible questions the students could ask can be found below.

Suggested Questions:

- What is the maximum height of the object?
- What is the maximum width of the object?
- What is the maximum length of the object?
- What is the minimum height of the object?
- What is the minimum width of the object?
- What is the minimum length of the object?
- Do the maximum width and length occur at the same height?
- What is the object’s mass?
- What color is the object?
- Is the color of the object uniform?
- What is the object’s texture?
- Is the texture of the object uniform?
- At a height of ____ what is the maximum width and maximum length?
- Where along the width at a height of ____ does the maximum length occur?
- Where along the length at a height of ____ does the maximum width occur?
- At a height of ____ where along the maximum width does the maximum length occur?
- At a height of ____ where along the maximum length does the maximum width occur?
- Is the object hollow or solid?
- If the object is hollow or partly hollow what is the wall thickness?
- What state of matter is the object?
Teacher's Guide-Does it Make "Sense"?

Concept Development A:
1. When you were the “receiver” and trying to determine the identity of the mystery object how did you get information about it? (Give a detailed description.)
   The runner gave me pieces of specific information, such as mass, length, color, etc., after going to and examining the object. In the passive portion, the “runner” decided which information to give the “receiver”, whereas in the active portion, the “receiver” requested information for the “runner” to obtain and relay back.

2. When you were the “receiver” what did you do with the information about the object?
   I recorded it. In the active portion, I used it to determine what else I needed. In each case, the receiver processes the information and uses it to try to draw the object and figure out what it is.

3. When you were the “receiver” what did the information help you do?
   The information helped me figure out the identity of an object I couldn’t see.

4. Electromagnetic waves, similar to radio and X-ray waves, have the same job as the “runner” did in this activity. This allows us to use electromagnetic waves instead of the “runner”. Describe how you could have used them to perform the passive and active tasks given in this activity.
   In passive remote sensing, the receiver takes in the EM waves and uses them to gain information about an object or area. In active remote sensing, the remote sensing device sends out particular EM waves and then receives the waves that come back to gain information about an object or area.

Exploration B: Rainfall from Remnants of Tropical Storm Erin

Materials:
Each of the following is required per group:
- Computer with:
  - Internet access
  - WeatherScope
  - Radar images
  - Google Earth
- Calculator

Procedures:
1. Your instructor will give you 12 mesonet site options to choose from. Pick one of the locations and record the name of the mesonet site in the appropriate location in Tables 1-2 below.
2. Go to http://www.mesonet.org/sites/
3. Scroll over the map to find the location you have selected.
4. To find the lat/long coordinates of your selected Mesonet station, click on the location on the map.
5. Record the lat/long coordinates in the appropriate location in Tables 1-2. (You will record the two digits to the left of the decimal place and three digits to the right of the decimal place.)
6. Open the radar loop labeled tropical storm Erin-composite radar in the remote sensing folder on the desktop.
7. Right click on the colored box in the left corner and then click on the show inspector. This will bring up a reflectivity guide.
8. Find the EXACT pixel in the WeatherScope image that corresponds to the latitude and longitude of your Mesonet station. To help do this, you should zoom in on your location by using the left touch pad button.
9. Advance through the images in the loop by pressing the “Page Up” button.
10. For each image, record the reflectivity (in dBZ - decibels of reflectivity) at the location in the appropriate place in Table 1.
11. Using the following equation, convert the decibels of reflectivity (dBZ) to the total reflectivity values and record the values in Table 1:
11. Using the following equation, convert the total reflectivity values to the corresponding rainfall rates and record the values in Table 1:

\[
\text{Rainfall Rate (mm/hr)} = \left( \frac{\text{Total Reflectivity}}{200} \right)^{\left(\frac{1}{1.6}\right)}
\]

12. Fill in Table 2 using the data in Table 1.

1. Calculate the time (in minutes) between consecutive images.
2. Divide the time (in minutes) by 60 (minutes per hour) to determine the time (in hours).
3. Average the rainfall rates for each pair of consecutive images.
4. Multiply the time (in hours) by the average rainfall rate (in mm/hr) to obtain the rainfall accumulation during that time increment.
5. Add all the accumulation values together to get the total rainfall accumulation for your location over the time span of these images.

Example Calculation: An image shows 65 dBZ at my location at a given time.

Total Reflectivity = \(10^{\left(\frac{\text{decibels of reflectivity}}{10}\right)} = 10^{\left(\frac{65}{10}\right)} = 10^{\left(6.5\right)} = 3162280\)

Rainfall Rate (mm/hr) = \(\left(\frac{3162280}{200}\right)^{\left(\frac{1}{1.6}\right)} = 15811.4^{\left(\frac{0.625}{0.625}\right)} = 421.072\) mm/hr

Just fyi: 421.072 mm/hr * (1 cm / 10 mm) = 42.11 cm/hr
42.1072 cm/hr * (1 in / 2.54 cm) = 16.58 in/hr
Table 1. Data for each time/image for the storm event.

<table>
<thead>
<tr>
<th>Mesonet Station:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lat/Lon:</td>
<td>5.236° N / 97.465° E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Image</td>
<td>Time</td>
<td>Decibels of Reflectivity (dBZ)</td>
<td>Total Reflectivity TR = 10^{(decibels of reflectivity / 10)}</td>
</tr>
<tr>
<td>1</td>
<td>1:36 AM</td>
<td>40</td>
<td>10000</td>
</tr>
<tr>
<td>2</td>
<td>1:51 AM</td>
<td>45</td>
<td>31623</td>
</tr>
<tr>
<td>3</td>
<td>2:06 AM</td>
<td>40</td>
<td>10000</td>
</tr>
<tr>
<td>4</td>
<td>2:21 AM</td>
<td>35</td>
<td>3162</td>
</tr>
<tr>
<td>5</td>
<td>2:36 AM</td>
<td>35</td>
<td>3162</td>
</tr>
<tr>
<td>6</td>
<td>2:51 AM</td>
<td>40</td>
<td>10000</td>
</tr>
<tr>
<td>7</td>
<td>3:06 AM</td>
<td>35</td>
<td>3162</td>
</tr>
<tr>
<td>8</td>
<td>3:21 AM</td>
<td>35</td>
<td>3162</td>
</tr>
<tr>
<td>9</td>
<td>3:36 AM</td>
<td>45</td>
<td>31623</td>
</tr>
<tr>
<td>10</td>
<td>3:51 AM</td>
<td>35</td>
<td>3162</td>
</tr>
<tr>
<td>11</td>
<td>4:06 AM</td>
<td>40</td>
<td>10000</td>
</tr>
<tr>
<td>12</td>
<td>4:21 AM</td>
<td>40</td>
<td>10000</td>
</tr>
<tr>
<td>13</td>
<td>4:36 AM</td>
<td>50</td>
<td>100000</td>
</tr>
</tbody>
</table>
Table 2. Processing of data to compute total rainfall accumulation.

<table>
<thead>
<tr>
<th>Interval</th>
<th>Time (minutes)</th>
<th>Time (hours)</th>
<th>Avg. Rainfall Rate (mm/hr)</th>
<th>Rainfall Accumulation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time (minutes) = (Time2 - Time1)</td>
<td>Time (hours) = (Time2 - Time1) / 60</td>
<td>Avg. RR = (RR1 + RR2) / 2</td>
<td>RA = (Avg. RR) * Hours</td>
</tr>
<tr>
<td>1:2</td>
<td>15</td>
<td>0.25</td>
<td>17.6</td>
<td>4.4</td>
</tr>
<tr>
<td>2:3</td>
<td>15</td>
<td>0.25</td>
<td>17.6</td>
<td>4.4</td>
</tr>
<tr>
<td>3:4</td>
<td>15</td>
<td>0.25</td>
<td>8.57</td>
<td>2.14</td>
</tr>
<tr>
<td>4:5</td>
<td>15</td>
<td>0.25</td>
<td>5.62</td>
<td>1.4</td>
</tr>
<tr>
<td>5:6</td>
<td>15</td>
<td>0.25</td>
<td>8.57</td>
<td>2.14</td>
</tr>
<tr>
<td>6:7</td>
<td>15</td>
<td>0.25</td>
<td>8.57</td>
<td>2.14</td>
</tr>
<tr>
<td>7:8</td>
<td>15</td>
<td>0.25</td>
<td>5.62</td>
<td>1.4</td>
</tr>
<tr>
<td>8:9</td>
<td>15</td>
<td>0.25</td>
<td>14.65</td>
<td>3.66</td>
</tr>
<tr>
<td>9:10</td>
<td>15</td>
<td>0.25</td>
<td>14.65</td>
<td>3.66</td>
</tr>
<tr>
<td>10:11</td>
<td>15</td>
<td>0.25</td>
<td>8.57</td>
<td>2.14</td>
</tr>
<tr>
<td>11:12</td>
<td>15</td>
<td>0.25</td>
<td>11.53</td>
<td>2.88</td>
</tr>
<tr>
<td>12:13</td>
<td>15</td>
<td>0.25</td>
<td>30.08</td>
<td>7.52</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>180</strong></td>
<td><strong>3</strong></td>
<td></td>
<td><strong>37.91</strong></td>
</tr>
<tr>
<td><strong>Actual</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>30</strong></td>
</tr>
<tr>
<td><strong>Error</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>+7.91</strong></td>
</tr>
</tbody>
</table>
Note: In this exploration the students will be calculating rainfall amounts estimated by the radar itself. The teacher should give the students the actual rainfall measurements from the Oklahoma Mesonet location they chose. They should compare their calculated value to the actual value. Some of the sites will have estimated values that are very close to the actual where as other sites will be quite off. This highlights the issues with radar estimated rainfall amounts. There are numerous Z-R equations (which convert reflectivity to rainfall amounts) that can be used. The equation that is used is dependant on the overall weather conditions. Sometimes the Z-R equation used will estimate the situation quite well where as other times it will be far from what actually occurred. Even when the proper Z-R equation is used there are other issues that will affect the estimated value such as raindrop size, the pixilated nature of the radar image, the storm’s distance from the radar, the time between radar scans, etc. Much research is being done on Z-R equations and trying to make them more accurate. Students should be asked what they feel might have caused the error they observed. The teacher should then discuss the sources of error listed above with the students.

Concept Development B:
1. Where did your initial decibels of reflectivity (dBZ) values for this exploration come from?
   The dBZ values come from the radar images on the computer; the values are shown on the inspector bar on the left side of the image.

2. What did you do with these dBZ values? (Describe step by step what you did with the dBZ value.)
   We converted the dBZ values to total reflectivity using the given equation. Then, we calculated rainfall rates based on the total reflectivity values using the Z-R relationship. We then used that rain rate and the amount of time it rained to calculate the total rainfall amount.

3. What did the steps you wrote down in question 2 ultimately allow you to calculate?
   We were able to perform calculations to estimate the amount of rainfall at a given location based on the data collected by the radar.

4. The colors and initial dBZ values do not tell us very much. How does the process you described in question 2 help us?
   We converted the data obtained by the radar to rainfall rates. Rainfall rates are more meaningful and useful than dBZ values and allow us to calculate the total rainfall accumulation over a specific period.

Tying Concepts Together:

Exploration A represents the collection of data while Exploration B represents the processing of information.
1. Describe the general steps represented by each exploration. (Do not give details specific to the activities. Think more general.) (Refer back to question 4 in Concept Development A and question 4 in Concept Development B.)
   In Exploration A, we collected data about an object using a “runner” and it allowed us to figure out the identity of an object we couldn’t see. In active and passive remote sensing, EM waves are received and processed – the difference is that in active remote sensing, EM waves are sent out so they will be returned by the object. In Exploration B, we processed remotely sensed data to convert to a more useful data set.

2. How do the steps for Exploration A and Exploration B described in question 1 fit together?
   They are complementary. The first exploration covers the acquisition of information about an object that you do not have direct contact with. The second exploration covers the process of taking the acquired information and converting it to useful data. Using the concepts learned in Exploration B on data collected using the ideas in Exploration A allow us to use remote sensing for a particular purpose. They fit together to complete the remote sensing picture.
CONCEPT APPLICATION

Application A: Where Does the Carbon Go?

Materials:
PowerPoint presentation about carbon sequestration

Procedures:
1. Go to the ArcMap icon on the desktop and open the program.
2. Go to File and then Open. Double click the Ecosystem_carbon_sequestration_Jesse.txt file on the desktop.
3. View the map of the United States.
4. The scale for the map color is located on the left side of the display. What does the scale indicate?
   The amount of carbon sequestered.
5. What does the color variation mean?
   The amount of carbon sequestration from $\frac{0 \text{ to } 47 \text{ g C}}{m^2}$
6. What are the time units of this scale?
   A one year time period

A PowerPoint presentation will be provided on the formation of carbon sequestration and the model.

7. Based on the information given in the presentation, was carbon sequestration remotely sensed? Explain why or why not?
   Carbon sequestration is not remotely sensed. However, the information used to calculate carbon sequestration is remotely sensed.

8. What factors must be computed to obtain carbon sequestration?
   Temperature, soil moisture, net primary production

9. How was remote sensing information used to construct the model?
   It was compiled and processed to calculate the amount of carbon sequestration.

    $\frac{27 \text{ to } 31 \text{ g C}}{(m^2)(yr)}$

11. How much carbon is sequestered in the Death Valley region of California? (Go to the coordinates of 116° 58'2.659"W, 36° 32'59.764"N)
    Approximately zero

12. How do these values compare? Where is more carbon sequestered?
    The Seattle area sequesters much more carbon than Death Valley does.
13. Here are the average temperature, annual precipitation and predominant vegetation type for both of these regions.

<table>
<thead>
<tr>
<th>Environmental Parameters</th>
<th>Seattle, Washington Region</th>
<th>Death Valley California Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Yearly Rainfall</td>
<td>950 mm</td>
<td>53 mm</td>
</tr>
<tr>
<td>Average Yearly Temperature</td>
<td>53° F</td>
<td>77° F</td>
</tr>
<tr>
<td>Vegetation Type</td>
<td>Temperate Rainforest</td>
<td>Desert</td>
</tr>
</tbody>
</table>

14. What are the physical differences (i.e. where does it rain more?)?

*Lots of rain vs. little rain. Forest vs. desert.*

15. Why do you think carbon sequestration is greater in one area than in the other?

*Environmental conditions are different.*

16. Look at the Oklahoma map. What do you notice as you travel from the east to the west?

*Carbon sequestration decreases as you move from east to west.*

17. Why do you think there is this pattern? (Hint: look at the map on the powerpoint slide)

*Rainfall decreases as you move from east to west.*

18. **Double click** on Norman, Oklahoma (97° 2’17.424”W, 35° 4’13.407”N). How much carbon was sequestered?

\[
\text{\( \frac{19 \text{ g C}}{(m^2)} \)}
\]

Here are some actual figures on the carbon sequestered for an area outside of Norman, Oklahoma: \(X_1 = \frac{525.3 \text{ g C}}{(m^2)}\) (2004) and \(X_2 = \frac{543.1 \text{ g C}}{(m^2)}\) (2005)

19. What is the rate of yearly carbon sequestration?

\[
\text{\( \frac{17.8 \text{ g C}}{(m^2)} \)}
\]

20. Why do you think this number does not correlate with the number on the map? Explain.

*Any answer works. However, this is a model and certain assumptions are made. Can the students answer this question reasonably? What’s the real answer?*

21. It is estimated by the United States Department of Energy that US industry produces 1,650,000,000 metric tons of Carbon.

22. According to the model there is 0.22 Pg of carbon sequestered a year. How much carbon is not sequestered by our natural ecosystems? (Note: make sure you do the appropriate conversion; 1 Pg = 1,000,000,000 metric ton.) Where do you think this extra carbon goes?

\[
\text{\( \frac{1 \text{ Pg C}}{\text{yr}} \)}
\]

*It should be about Must stay in the atmosphere.*

23. Why might this unsequestered carbon be a problem?

*Carbon dioxide is a greenhouse gas; thus, unsequestered carbon can lead to global warming.*
Application B: Remote Sensing Webquest

Storm Surge:
Go to the website www.nasa.gov/topics/earth/features/nargis_floods.html and use the information found there to answer the following questions.

1. What event and natural disaster is this page documenting?
   Flooding from Cyclone Nargis in Burma/Myanmar

2. What two parts of the electromagnetic spectrum (light) are used?
   Visible and Infrared

3. What parts of Burma were most affected by this event?
   The southern coast

4. Did NASA have to modify the data (like we did when we converted reflectivity to rainfall rates) to make the remotely sensed quantities useful?
   Answers may vary. The visible and infrared data is combined into one image. Thus, there has been some manipulation. The remotely sensed data is used to determine where the extents of the land and water are and the presented image is the result.

5. How could this remotely sensed information be used?
   The information could be used by aid agencies to determine locations affected by the natural disaster.

6. Is this an example of passive or active remote sensing? Why?
   This info isn't provided on the page, but I believe it is an example of passive remote sensing. The satellite senses the radiation from the Earth without sending anything out.

Rainfall and the Results:
Open each of the following three websites (1) http://trmm.gsfc.nasa.gov/affinity/affinity_3hrly_rain.html
(2) http://trmm.gsfc.nasa.gov/publications_dir/potential_landslide.html and
(3) http://trmm.gsfc.nasa.gov/publications_dir/potential_flood_hydro.html and answer the following questions.

1. What do each of the images show on the first website?
   Latest 3 Hourly Global Rainfall and Latest Week of Global Rainfall Accumulation

2. What information is contained on the second website?
   Locations for potential landslides

3. What information is contained on the third website (look specifically at the image in the middle of the page)?
   Flood potential using a hydrological model

4. What do you notice about the maps of rainfall, locations for potential landslides and locations for potential flooding?
   Locations with large amounts of rainfall over land correspond, generally, to areas with potential for landslides and flooding

5. What is the purpose of maps like these?
   The information can be used to warn residents in areas prone to floods and landslides.
6. Is there a direct correlation between rainfall and flooding or rainfall and landslides? For instance, would 3 inches of rain in one day have the same flood potential no matter where the rain fell? Explain why or why not using examples from the images provided on these websites.

   *No, there isn’t a direct correlation between rainfall and flooding or rainfall and landslides. Specific answers will vary. But, students should be able to find locations with the same amounts of rain that have different flooding/landslide results.*

7. Using your answer to that question, do you think the remotely sensed rainfall (a) is used in calculations to determine locations of potential landslides and floods or do you think that (b) flood and landslide warnings are automatically issued based on rainfall rates? Explain the reasons for your answer.

   *The answer is (a). The rainfall rates are combined with other factors (slope, land use, etc.) to determine locations. The rainfall is most important time variable factor, so that is why it is remotely sensed in real-time and supplied as an input. Calculations of some sort must be done because there isn’t a direct correlation between rainfall and flooding or landslides that can be applied universally.*

**Checking the Weather in Advance:**

Generally, May and June are the wettest months for central Oklahoma. The fall months of September and October also provide a substantial amount of rainfall, on average. If you’ve lived in central Oklahoma for a while and pay attention to the weather, you probably know precipitation is more likely at those times in the year. However, what if you want to take a trip to Australia and are hoping for sunny weather? What if you are chosen for a season of Survivor? How do you know what to expect? Use the maps at the following website to answer the questions below:


1. You have been selected for “Survivor Madagascar”, to be filmed on the north coast of Madagascar (near Mahajanga, Madagascar). If the season is filmed in January and February, what would you expect the daily average rainfall to be (provide your answer in inch/day using the following conversion: 25.4 mm = 1 inch)?

   *Average daily rainfall is around 12-13 mm over that time period, which corresponds to about 0.5 inch/day*

2. What would you expect the daily average rainfall to be if the season was during the months of May and June?

   *Average daily rainfall for May and June is about 2 mm, so you’d expect the average rainfall to be about 0.08 inch/day during those months.*

3. If you were planning a trip to Darwin, Australia (on the north coast of the continent), what month (or months) would you schedule your vacation if you wanted it to be dry?

   *May, June, July, August*

4. What general trends do you notice about global rainfall?

   *Does it rain more over water or over land?*

   *Water*

   *Does it rain more near the equator or at mid-latitudes?*

   *Equator*

   *How does the line of most intense rain move over the course of the year (it may be useful to click on the animation of the 12 monthly mean images for this question)?*

   *The areas of most intense rainfall move north during our summer months and move back south during our winter months.*

   *How could we use satellite data on global rainfall?*

   *Compare weather patterns to historical patterns.*
Human Health:
Look at the following website [www.cdc.gov/ncidod/eid/vol6no3/beck.htm](http://www.cdc.gov/ncidod/eid/vol6no3/beck.htm) and answer the questions below.

Read the section on "Lyme Disease in the Northeastern United States"
1. Are we able to determine using remote sensing whether or not a human has Lyme disease?
   No
2. What is being remotely sensed?
   *The land use (water, evergreen trees/vegetation, sparse deciduous trees, etc.) is remotely sensed.*

What do the author's use as a measure of human risk for Lyme disease?
3. What two factors do the author’s correlate human risk to?
   *The canine seroprevalence rates, the amount of remotely sensed deciduous forest and residential-high vegetation pixels.*

Read the section on "Cholera in Bangladesh"
1. Can we detect cholera remotely?
   No
2. What is being remotely sensed (Figures 2a and 2c on the website)?
   *Infrared radiation and sea surface height*
3. What is the data in Figure 2a used to calculate?
   *Sea surface temperature*
4. Why are sea surface temperature and sea surface height important?
   "Increases in SST and SSH have preceded cholera outbreaks in Bangladesh." Thus, by remotely sensing information to obtain SST and SSH, you can analyze the data and make the necessary people aware of the fact that there might be a potential issue with cholera.

Game 1: Is it “Remote Sensing”?
Application C: Severe Weather Identification

1. Using what you have learned so far, describe how you think a weather radar works.
   Possible answers include the following. The radar sends out electromagnetic waves to air surrounding the dish. These electromagnetic waves hit an object in the air whether it is hail, rain, insects, birds, etc. Part of the electromagnetic wave that hit the object bounces off and back to the radar dish. At this point the return data is processed to determine the identity of the object struck.

2. Briefly describe what is said about how the NEXRAD weather radar works.
   The radar emits a burst of energy. If the energy strikes an object the energy is scattered in all directions. A small fraction of that scattered energy is directed back toward the radar. This reflected signal is then received by the radar during its listening period. Computers analyze the strength of the returned pulse, time it took to travel to the object and back, and phase shift of the pulse.

3. Describe how this website compares/contrasts with how you thought the weather radar works.
   Answers will vary. Hopefully they will say that their explanation was similar to that given on the NWS website.

4. What is the NWS’s definition of a thunderstorm?
   A local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder.

5. A thunderstorm is considered a severe thunderstorm if it contains any of the following conditions.
   a. A tornado
   b. 50 knots (58 mph)
   c. hail with ¾ in or larger diameter

6. What do the colors on a weather radar image represent?
   The colors represent the strength of returned energy to the radar expressed in values of decibels (dBZ).

7. Describe how a weather radar can detect hail.
   Typically, a hailstone is coated with a thin layer of water as it travels through the thunderstorm cloud. This thin layer of water on the hailstone will cause a storm's reflectivity to be greater, leading to a higher dBZ.

8. What is one thing we can look for in a radar image that is a good indicator that hail is falling in an area?
   High dBZ values usually at least 60 to 65dBZ.

9. What is another thing we can look for in a weather radar image that is a good indicator that hail is falling in an area?
   A radar artifact called a “Three-Body Scatter Spike”.

10. Describe what causes the radar artifact that is the answer to question 9.
    This artifact is caused by the radar beam hitting the wet hail, scattering to the ground below, then scattering back upward, and finally being scattered once again by the hail aloft back to the radar.

11. What kind of motions can the radar detect and what is this called?
    The only motion it can "see" is either directly toward or away from the radar. This is called radial velocity as it is the component of the target's motion that is along the direction of the radar beam.
12. What do the 2 types of colors on a velocity radar image represent? 
   In all velocity images, red colors indicate wind moving away from the radar with green 
   colors representing wind moving toward the radar.

13. How is base velocity useful for predicting severe weather? 
   It is useful for determining areas of strong wind from downbursts or detecting the speed 
   of cold fronts.

14. What do the colors on the radial velocity scales indicate? 
   Wind speeds measured in knots.

15. What can we look for on a radial velocity image to let us know that there could be severe winds? 
   The lighter or brighter colors have the strongest wind speeds.

16. What are straight-line winds? 
   They are winds that are not associated with rotation. They are different from tornadic 
   winds.

17. If you had a squall line of storms on a radar image where would you expect to find damaging straight- 
   line winds? 
   Damaging straight-line winds often occur near the "crest" or center of a bow echo.

18. What on a radar image would you look for when determining if a storm had the potential to produce a 
   tornado? 
   A characteristic signature of a possible tornado is the presence of a hook-shaped echo.

19. What is another way of determining if a storm has the potential to produce a tornado? 
   Another way to determine if a storm is tornadic is to examine the radial velocity 
   field. A mesocyclone, the small rotating circulation with its center beneath the 
   updraft of a supercell thunderstorm, is detectable as a velocity couplet.

20. What do storm relative motion images help us look for and why is this important? 
   Storm Relative Motion images are very useful images to look for small scale circulations 
   (called mesocyclones) in thunderstorms. Often, these small scale circulations are areas 
   where tornadoes form.

21. How are small scale circulations indicated? 
   Small scale circulations, from which tornadoes often form, will typically be indicated by 
   strong inbound wind located beside strong outbound wind relative to the radar.

22. Describe what a tornado vortex signature (TVS) is. 
   A couplet oriented so that a concentrated area of radial winds moving away from the 
   radar appears on one side of the beam axis, while a concentrated area of radial winds 
   moving toward the radar appears on the opposite side of the beam axis. When this 
   couplet show exceptionally strong winds, this signature is called a tornado vortex 
   signature (TVS).

Game 2: Should we interrupt Grey’s Anatomy with a “Severe Weather Update”? 

Field Trip: Radar Truck demonstration at the National Weather Center, Norman, OK 
Contact Dr. Michale Biggerstaff at drdoppler@ou.edu or (405) 325-3881
Does it Make “Sense”? 

INTRODUCTION

Norman Fire Department demonstration

EXPLORATION

Exploration A: What Kind of Food Is It?

Procedures:
1. Passive
   a. Designate one person as the "runner" and the other as the "receiver."
   b. The "runner" must select a numbered index card from the table in the science prep room and get the associated item from the instructors. The identity of the item is not to be revealed to the "receiver."
   c. One physical parameter at a time, the "runner" must provide pieces of information to the "receiver." A list of potential physical parameters can be found below. You cannot tell the "receiver" what the object is, what it does, or what it is used for.
   d. The "receiver" must process the data and draw the item on the graph paper provided. This sequence of the "runner" providing one piece of information at a time to the "receiver" ends as soon as the "receiver" correctly draws and identifies the item.
   e. The "receiver" is allowed one guess each time the "runner" brings them a piece of information.

2. Active
   a. Switch roles. The "runner" becomes the "receiver" and vice-versa.
   b. The new "receiver" must select a number off the list of available numbers listed on the board and tell the new "runner" what the number is.
   c. The "runner" must get the corresponding numbered index card off the table in the science prep room and the associated object from an instructor. The identity of the item is not to be revealed to the "receiver."
   d. The "receiver" must request two pieces of information to be collected by the "runner." The request should be either i) from the list provided below or ii) approved by an instructor.
   e. The "receiver" must process the data and draw the item on the graph paper provided. This sequence of the "receiver" requesting data and the "runner" providing the information ends as soon as the "receiver" correctly draws and identifies the item.
   f. The "receiver" is allowed one guess each time the "runner" brings them two pieces of information.

Suggested Questions:
- What is the maximum height of the object?
- What is the maximum width of the object?
- What is the maximum length of the object?
- What is the minimum height of the object?
- What is the minimum width of the object?
- What is the minimum length of the object?
- Do the maximum width and length occur at the same height?
Student's Guide-Does it Make “Sense”?

Name ______________________________ Date ___________________________ Group ___________

- What is the object’s mass?
- What color is the object?
- Is the color of the object uniform?
- What is the object’s texture?
- Is the texture of the object uniform?
- At a height of ____ what is the maximum width and maximum length?
- Where along the width at a height of ____ does the maximum length occur?
- Where along the length at a height of ____ does the maximum width occur?
- At a height of ____ where along the maximum width does the maximum length occur?
- At a height of ____ where along the maximum length does the maximum width occur?
- Is the object hollow or solid?
- If the object is hollow or partly hollow what is the wall thickness?
- What state of matter is the object?

Concept Development A:

1. When you were the “receiver” and trying to determine the identity of the mystery object how did you get information about it? (Give a detailed description.)

2. When you were the “receiver” what did you do with the information about the object?

3. When you were the “receiver” what did the information help you do?

4. Electromagnetic waves, similar to radio and X-ray waves, have the same job as the “runner” did in this activity. This allows us to use electromagnetic waves instead of the “runner”. Describe how you could have used them to perform the passive and active tasks given in this activity.
Exploration B: Rainfall from Remnants of Tropical Storm Erin

Materials:
Each of the following is required per group:
- Computer with:
  - Internet access
  - WeatherScope
  - Radar images
  - Google Earth
- Calculator

Procedures:
1. Your instructor will give you 12 mesonet site options to choose from. Pick one of the locations and record the name of the mesonet site in the appropriate location in Tables 1-2 below.
2. Go to http://www.mesonet.org/sites/
3. Scroll over the map to find the location you have selected.
4. To find the lat/long coordinates of your selected Mesonet station, click on the location on the map.
5. Record the lat/long coordinates in the appropriate location in Tables 1-2. (You will record the two digits to the left of the decimal place and three digits to the right of the decimal place.)
6. Open the radar loop labeled tropical storm Erin-composite radar in the remote sensing folder on the desktop.
7. Right click on the colored box in the left corner and then click on the show inspector. This will bring up a reflectivity guide.
8. Find the EXACT pixel in the WeatherScope image that corresponds to the latitude and longitude of your Mesonet station. To help do this, you should zoom in on your location by using the left touch pad button.
9. Advance through the images in the loop by pressing the “Page Up” button.
10. For each image, record the reflectivity (in dBZ - decibels of reflectivity) at the location in the appropriate place in Table 1.
11. Using the following equation, convert the decibels of reflectivity (dBZ) to the total reflectivity values and record the values in Table 1:
   \[ \text{Total Reflectivity} = 10^{(\text{decibels of reflectivity} / 10)} \]
12. Using the following equation, convert the total reflectivity values to the corresponding rainfall rates and record the values in Table 1:
   \[ \text{Rainfall Rate (mm/hr)} = (\text{Total Reflectivity} / 200)^{1 / 1.6} \]
13. Fill in Table 2 using the data in Table 1.
   1. Calculate the time (in minutes) between consecutive images.
   2. Divide the time (in minutes) by 60 (minutes per hour) to determine the time (in hours).
   3. Average the rainfall rates for each pair of consecutive images.
   4. Multiply the time (in hours) by the average rainfall rate (in mm/hr) to obtain the rainfall accumulation during that time increment.
   5. Add all the accumulation values together to get the total rainfall accumulation for your location over the time span of these images.
Example Calculation:
An image shows 65 dBZ at my location at a given time.

Total Reflectivity = $10^{\text{decibels of reflectivity} / 10} = 10^{65/10} = 10^{6.5} = 3162280$

Rainfall Rate (mm/hr) = $(\text{Total Reflectivity} / 200)^{1/1.6} = (3162280 / 200)^{0.625} = (15811.4)^{0.625} = 421.072$

mm/hr
Just fyi: 421.072 mm/hr * (1 cm / 10 mm) = 42.11 cm/hr
42.1072 cm/hr * (1 in / 2.54 cm) = 16.58 in/hr

Table 1. Data for each time/image for the storm event.

<table>
<thead>
<tr>
<th>Mesonet Station:</th>
<th>Latitude/Longitude:</th>
<th>Total Reflectivity</th>
<th>Rainfall Rate (mm/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$TR = 10^{\text{decibels of reflectivity} / 10}$</td>
<td>$RR (\text{mm/hr}) = (TR / 200)^{1/1.6}$</td>
</tr>
<tr>
<td>Image</td>
<td>Time</td>
<td>Decibels of Reflectivity (dBZ)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1:36 AM</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1:51 AM</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2:06 AM</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2:21 AM</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2:36 AM</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2:51 AM</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3:06 AM</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>3:21 AM</td>
<td>65</td>
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<td>65</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>4:21 AM</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>4:36 AM</td>
<td>65</td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Processing of data to compute total rainfall accumulation.

<table>
<thead>
<tr>
<th>Mesonet Station:</th>
<th>Latitude/Longitude:</th>
<th>Time (minutes)</th>
<th>Time (hours)</th>
<th>Avg. Rainfall Rate (mm/hr)</th>
<th>Rainfall Accumulation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval</td>
<td></td>
<td>Time(minutes) = Time2-Time1</td>
<td>Time(hours) = (Time2-Time1)/60</td>
<td>Avg. RR = (RR1+RR2)/2</td>
<td>RA = (Avg. RR)*Hours</td>
</tr>
<tr>
<td>1:2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:4</td>
<td></td>
<td></td>
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<tr>
<td>4:5</td>
<td></td>
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<tr>
<td>5:6</td>
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<td>6:7</td>
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<td>7:8</td>
<td></td>
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<tr>
<td>8:9</td>
<td></td>
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<tr>
<td>9:10</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>10:11</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>11:12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:13</td>
<td></td>
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<tr>
<td>Total</td>
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<td></td>
</tr>
<tr>
<td>Actual Error</td>
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<tr>
<td>Error</td>
<td></td>
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</tr>
</tbody>
</table>
Concept Development B:

1. Where did your initial decibels of reflectivity (dBZ) values for this exploration come from?

2. What did you do with these dBZ values? (Describe step by step what you did with the dBZ value.)

3. What did the steps you wrote down in question 2 ultimately allow you to calculate?

4. The colors and initial dBZ values do not tell us very much. How does the process you described in question 2 help us?

Tying Concepts Together:

Exploration A represents the **collection of data** while Exploration B represents the **processing of information**.

1. Describe the general steps represented by each exploration. (Do not give details specific to the activities. Think more general.) (Refer back to question 4 in Concept Development A and question 4 in Concept Development B.)

2. How do the steps for Exploration A and Exploration B described in question 1 fit together?
CONCEPT APPLICATION

Application A: Where Does the Carbon Go?

Materials:
PowerPoint presentation about carbon sequestration

Procedures:
1. Go to the ArcMap icon on the desktop and open the program.
2. Go to File and then Open. Double click the Ecosystem_carbon_sequestration_Jesse.txt file on the desktop.
3. View the map of the United States.
4. The scale for the map color is located on the left side of the display. What does the scale indicate?
5. What does the color variation mean?
6. What are the time units of this scale?

A PowerPoint presentation will be provided on the formation of carbon sequestration and the model.
7. Based on the information given in the presentation, was carbon sequestration remotely sensed? Explain why or why not?

8. What factors must be computed to obtain carbon sequestration?

9. How was remote sensing information used to construct the model?

10. How much carbon is sequestered for the Seattle, Washington region? (Go to the coordinates of 122° 20’10.688”W, 47° 13.132”N)

11. How much carbon is sequestered in the Death Valley region of California? (Go to the coordinates of 116° 58’2.659”W, 36° 32’59.764”N)

12. How do these values compare? Where is more carbon sequestered?
13. Here are the average temperature, annual precipitation and predominant vegetation type for both of these regions.

<table>
<thead>
<tr>
<th>Environmental Parameters</th>
<th>Seattle, Washington Region</th>
<th>Death Valley California Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Yearly Rainfall</td>
<td>950 mm</td>
<td>53 mm</td>
</tr>
<tr>
<td>Average Yearly Temperature</td>
<td>53° F</td>
<td>77° F</td>
</tr>
<tr>
<td>Vegetation Type</td>
<td>Temperate Rainforest</td>
<td>Desert</td>
</tr>
</tbody>
</table>

14. What are the physical differences (i.e. where does it rain more?)?

15. Why do you think carbon sequestration is greater in one area than in the other?

16. Look at the Oklahoma map. What do you notice as you travel from the east to the west?

17. Why do you think there is this pattern? (Hint: look at the map on the powerpoint slide)

18. **Double click** on Norman, Oklahoma (97° 2’17.424”W, 35° 4’13.407”N). How much carbon was sequestered?

   Here are some actual figures on the carbon sequestered for an area outside of Norman, Oklahoma: $X_1 = \frac{525.3 \text{ g C}}{(m^2)}$ (2004) and $X_2 = \frac{543.1 \text{ g C}}{(m^2)}$ (2005)

19. What is the rate of yearly carbon sequestration?

20. Why do you think this number does not correlate with the number on the map? Explain.

21. It is estimated by the United States Department of Energy that US industry produces 1,650,000,000 metric tons of Carbon.

22. According to the model there is 0.22 Pg of carbon sequestered a year. How much carbon is not sequestered by our natural ecosystems? (Note: make sure you do the appropriate conversion; 1 Pg = 1,000,000,000 metric ton.) Where do you think this extra carbon goes?

23. Why might this unsequestered carbon be a problem?
Application B: Remote Sensing Webquest

Storm Surge:
Go to the website www.nasa.gov/topics/earth/features/nargis_floods.html and use the information found there to answer the following questions.

1. What event and natural disaster is this page documenting?

2. What two parts of the electromagnetic spectrum (light) are used?

3. What parts of Burma were most affected by this event?

4. Did NASA have to modify the data (like we did when we converted reflectivity to rainfall rates) to make the remotely sensed quantities useful?

5. How could this remotely sensed information be used?

6. Is this an example of passive or active remote sensing? Why?

Rainfall and the Results:
Open each of the following three websites (1) http://trmm.gsfc.nasa.gov/affinity/affinity_3hrly_rain.html (2) http://trmm.gsfc.nasa.gov/publications_dir/potential_landslide.html and (3) http://trmm.gsfc.nasa.gov/publications_dir/potential_flood_hydro.html and answer the following questions.

1. What do each of the images show on the first website?

2. What information is contained on the second website?

3. What information is contained on the third website (look specifically at the image in the middle of the page)?
4. What do you notice about the maps of rainfall, locations for potential landslides and locations for potential flooding?

5. What is the purpose of maps like these?

6. Is there a direct correlation between rainfall and flooding or rainfall and landslides? For instance, would 3 inches of rain in one day have the same flood potential no matter where the rain fell? Explain why or why not using examples from the images provided on these websites.

7. Using your answer to that question, do you think the remotely sensed rainfall (a) is used in calculations to determine locations of potential landslides and floods or do you think that (b) flood and landslide warnings are automatically issued based on rainfall rates? Explain the reasons for your answer.

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**Checking the Weather in Advance:**

Generally, May and June are the wettest months for central Oklahoma. The fall months of September and October also provide a substantial amount of rainfall, on average. If you’ve lived in central Oklahoma for a while and pay attention to the weather, you probably know precipitation is more likely at those times in the year. However, what if you want to take a trip to Australia and are hoping for sunny weather? What if you are chosen for a season of Survivor? How do you know what to expect? Use the maps at the following website to answer the questions below:

http://trmm.gsfc.nasa.gov/trmm_rain/Events/trmm_climatology_3B43.html

1. You have been selected for “Survivor Madagascar”, to be filmed on the north coast of Madagascar (near Mahajanga, Madagascar). If the season is filmed in January and February, what would you expect the daily average rainfall to be (provide your answer in inch/day using the following conversion: 25.4 mm = 1 inch)?

2. What would you expect the daily average rainfall to be if the season was during the months of May and June?

3. If you were planning a trip to Darwin, Australia (on the north coast of the continent), what month (or months) would you schedule your vacation if you wanted it to be dry?
4. What general trends do you notice about global rainfall?
   - Does it rain more over water or over land?

   - Does it rain more near the equator or at mid-latitudes?

   - How does the line of most intense rain move over the course of the year (it may be useful to click on the animation of the 12 monthly mean images for this question)?

   - How could we use satellite data on global rainfall?

**Human Health:**

Look at the following website [www.cdc.gov/ncidod/eid/vol6no3/beck.htm](http://www.cdc.gov/ncidod/eid/vol6no3/beck.htm) and answer the questions below.

- Read the section on “Lyme Disease in the Northeastern United States”

1. Are we able to determine using remote sensing whether or not a human has Lyme disease?

2. What is being remotely sensed?

3. What do the author's use as a measure of human risk for Lyme disease?

4. What two factors do the author's correlate human risk to?

- Read the section on “Cholera in Bangladesh”

1. Can we detect cholera remotely?

2. What is being remotely sensed (Figures 2a and 2c on the website)?

3. What is the data in Figure 2a used to calculate?

4. Why are sea surface temperature and sea surface height important?

**Game 1: Is it “Remote Sensing”?**
Application C: Severe Weather Identification

1. Using what you have learned so far, describe how you think a weather radar works.

2. Briefly describe what is said about how the NEXRAD weather radar works.

3. Describe how this website compares/contrasts with how you thought the weather radar works.

4. What is the NWS’s definition of a thunderstorm?

5. A thunderstorm is considered a severe thunderstorm if it contains any of the following conditions.
   a. 
   b. 
   c.

6. What do the colors on a weather radar image represent?
7. Describe how a weather radar can detect hail.

8. What is one thing we can look for in a radar image that is a good indicator that hail is falling in an area?

9. What is another thing we can look for in a weather radar image that is a good indicator that hail is falling in an area?

10. Describe what causes the radar artifact that is the answer to question 9.

11. What kind of motions can the radar detect and what is this called?

12. What do the 2 types of colors on a velocity radar image represent?

13. How is base velocity useful for predicting severe weather?

14. What do the colors on the radial velocity scales indicate?
15. What can we look for on a radial velocity image to let us know that there could be severe winds?

16. What are straight-line winds?

17. If you had a squall line of storms on a radar image, where would you expect to find damaging straight line winds?

18. What on a radar image would you look for when determining if a storm had the potential to produce a tornado?

19. What is another way of determining if a storm has the potential to produce a tornado?

20. What do storm relative motion images help us look for and why is this important?

21. How are small scale circulations indicated?

22. Describe what a tornado vortex signature (TVS) is.

Game 2: Should we interrupt Grey’s Anatomy with a “Severe Weather Update”?

Field Trip: Radar Truck demonstration at the National Weather Center, Norman, OK