Mrs. Richards' Lesson Plan

Scientific Literacy - Lightning

OBJECTIVES

1. Students will learn how to read scientific material by reading about the research being conducted by Dr. Rob Cifelli from the Colorado State University.
2. Students will learn new scientific terminology by reading scientific material and researching definitions of new words.
3. Students will learn how radar can be used to determine lightning potential of a cloud by reading about the research being conducted on the R/V Ronald H. Brown on a research cruise from San Diego, CA to the Galapagos Islands, Ecuador.
4. Students will demonstrate comprehension of scientific writing by illustrating part of the document they will be reading.
5. Students will practice note-taking skills by summarizing each paragraph in the attached research overview.

AGE

Grades 8-12

TIME ALLOWANCE

1-2 hours (3 class periods)

MATERIALS

- Copies of the research overview for each student
- Color pencils or makers
- 2 colors of highlighter for each student
- Overhead transparency diagram of the cross section of a cloud.

INSTRUCTION:

DAY 1

1. Hand out a Research Overview to each student. They should read the article silently to themselves. With one color highlighter, students should highlight

all words that they don't understand (new terminology). With the second highlighter, students should highlight the key phrases and ideas in each paragraph. Allow students enough time to fully read the article.

2. For homework, students should research and document the definitions of all new words that they highlighted.

DAY 2

3. Now that each student has read the article and defined all new terminology, they will write in their notebooks a one-sentence summary of each paragraph.
4. To exercise both the left and right sides of the brain, students will draw a diagram, illustration, poem, cartoon, etc. that reflects understanding of the lightning discussion in the document. Whatever creative form they use to demonstrate understanding should be done in color, and be detailed enough to clearly show that they understood what they read. Remind students that they may have to read the article several times to achieve comprehension.

DAY 3

5. Assign the students to groups of 4-6. Each group member will share their summary sentences and drawings. Using inspiration from each other, each group will generate new summary sentences and an illustration for the research overview, which they will document on newsprint.
6. Each group will present their newsprint to the class. By viewing the work of other groups, hopefully each student will learn something that they may have missed when they read the article.
7. In their notebooks, students should write 2 things that they learned from each group presentation.
8. Finally, the teacher will present and explain the diagram included in this lesson. By doing this last, the students will have a better understanding of what it means, since they should now be intimately familiar with the research overview that pertains to the diagram.

EVALUATION / ASSESSMENT

Teacher will circulate among students to provide assistance and make sure they are on track.

Teacher will check to see that all highlighted words have been defined in writing.

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Teacher will assess summary sentences and drawings for completeness and level of thought involved (did the student take the assignment seriously?)

RESEARCH OVERVIEW

USING RADAR TO UNDERSTAND CLOUDS AND STORMS

This article was written by Jennifer Richards, Earth Science Teacher and NOAA Teacher at Sea, during a research cruise on the Ronald H. Brown from San Diego, CA to the Galapagos Islands, Ecuador from September 5- October 6, 2001. http://www.ogp.noaa.gov/epic

INTRODUCTION

As the Teacher at Sea on a research cruise from San Diego, CA to the Galapagos Islands, Ecuador, I had the chance to meet with a wide range of scientists studying climate and ocean-atmosphere interactions. This research overview includes information about the research and data collected by three radar scientists from Colorado State University (Ft. Collins, Colorado) and a partner scientist from NASA (Huntsville, Alabama). These scientists are meteorologists who are studying the internal structure of storms over tropical oceans using radar and weather balloons. As radar scientists, they are using pretty sophisticated radar equipment and software for their research.

Although all four members of this group - Dr. Rob Cifelli, Dr. Walt Petersen, Mr. Bob Bowie and Dr. Dennis Boccippio (from NASA)- are very nice scientists with a great sense of humor, from my perspective, they are somewhat the villains on the ship. These scientists are hoping we will encounter storms- lots of them- the bigger, the better. Have any of you seen the movie "The Perfect Storm?"

RESEARCH BACKGROUND

Here’s some background information that will help you understand the research this group is working on. Storms on land and storms on the ocean tend to be about the same size vertically, but the way they function internally is quite different. On land, storms can be generated over pretty short periods of time, and can run themselves out pretty quickly. A lot of people in the mid-west are familiar with the daily rain storms that hit during summer afternoons- suddenly coming out of nowhere, and then disappearing as fast as they arrived. This is because land is full of heat pockets. You could have rivers, farms, asphalt and concrete highways, homes, and forests, and they all heat and cool at different rates. The differences in the rate of heating cause pressure gradients, which can lead to volatile weather conditions.

The ocean does not contain heat pockets the way the land does, and therefore, the air above the ocean heats more slowly. Pressure gradients in the air above the ocean are not as steep, so when storms are generated over the ocean, they grow slowly over long periods of time, and can become quite large. Do you remember hearing in the news about hurricanes? The weathermen will track hurricanes for many days to see where it is moving and how large it is getting. This is an example of an ocean storm growing slowly to a very large size.

If we can understand how storms form and behave in a certain area, it will help us understand the climate in that area. If you want to learn about the climate of San Diego, California, for example, it's not very hard. You can visit the library and find all sorts of documents about the climate and typical weather conditions. There have been weather stations in San Diego for at least a hundred years, and there is plenty of data that has been collected. There aren't too many surprises.

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PURPOSE OF RESEARCH

But what do we really know about climate over the oceans? Not a whole lot. Storms heat the atmosphere and affect the climate. NASA and NASDA (the Japanese Space Agency) have a satellite called TRMM (Tropical Rainfall Measuring Mission) provides data about storms from very far away, but we don't have oceans full of weather stations to show us exactly what's going on at the surface and in the troposphere. Plus, TRMM can only measure what it sees from the sky- the tops of storms. You have to be on the ocean to see the rest of the storm. And since the satellite passes over each location on earth only twice a day, the data can be up to 12 hours old. When’s the last time you heard of a storm that hadn’t changed in 12 hours?

How do the atmosphere and the ocean interact? How are storms in the tropics different from storms in the mid-latitude regions? What impact does the tropical ocean water have on the air above it? What impact does it have on storms that form over it? That’s where this group from Colorado State University comes into the picture. The R/V Ronald H. Brown is equipped with a Doppler Radar system that uses microwaves to echo off of condensed water, ice crystals, and hail. It can create 3D profiles of storms within 150 km of the ship. A satellite can only see the top of the storm, but the radar system on the ship can see the internal structure of it. And if we happen to be in the middle of a big storm, the radar can see everything going on around us for the duration of the storm (not just once every 12 hours, like the TRMM satellite). These scientists will also be launching weather balloons from the ship to gather additional atmospheric data in the sky above us.

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What can the world hope to learn from the research being done by this group? Well, if we have a better understanding of how storms are behaving in the tropics, we will have a better understanding of the factors affecting ocean climate. Since events such as El Nino originate in the tropical area of the Pacific Ocean, this research may help us better understand what causes seasonal climate changes and El Nino, and provide better forecasting of such events.

RESULTS

Two weeks into the cruise I checked with Dr. Cifelli to see what kind of data results his team has obtained. Preliminary results show that the clouds over the eastern Pacific Ocean are more "electrified" than clouds on the western edge of the Pacific. Let me explain...

One of the things Dr. Rob Cifelli, Dr. Walt Petersen, and Dr. Dennis Boccippio are looking at is the lightning potential in the area, and how it compares with other parts of the world. We have had some spectacular lightning shows during the trip, and the data collected by this team has shown that the clouds in this area are more electrified than clouds in the western Pacific Ocean.

What is an "electrified" cloud? It's a cloud that is ready to produce lightning. Let's look at cloud growth and dynamics to understand how a cloud becomes electrified.

As air moves in updrafts and rises into the sky, what happens to the air temperature? It decreases, of course. The warm tropical air, full of water vapor, rises to the point where condensation occurs and a cloud is formed. If the drafts are strong enough, the air will eventually cool to the freezing point and colder. In this part of the world (10N, 95W) the altitude where the air temperature reaches 0 degrees Celsius is approximately 5 kilometers. Beyond this point the air temperature continues to decrease. When the moisture in the air hits the freezing point, it doesn't all instantaneously turn into ice crystals. There are complex physics that keep some of the water in liquid form, and some of it turns into ice. As the liquid water at this altitude bumps into existing ice crystals, the water freezes to the ice, forming a coating of rime. As the ice grows by this riming process, it can eventually produce particles called graupel (baby hail).

The part of the atmosphere where the temperature is between the freezing point and -40 degrees Celsius is called the "mixed phase" layer. Below -40 degrees any liquid water will spontaneously freeze. The air in the mixed phase layer contains both water and ice. This is the region of the cloud where electric charge is separated and lightning is produced. To have an active mixed phase layer, the cloud updrafts have to lift raindrops above the freezing level high enough and fast enough so the drops don't all freeze right away and they can interact with ice crystals that are already there. After raindrops are lofted into the mixed phase region and interact with the ice particles, graupel forms and descends. As the graupel falls it bumps into small ice crystals which are either moving up or moving down slower than the graupel. Most atmospheric scientists think that the collisions of graupel with small ice crystals in the presence of liquid water separates charge and produces cloud electrification. An electrified cloud that produces lightning is one that contains an active mixed phase layer (lots of collisions between ice and liquid water above the freezing level).

How do you measure the amount of ice crystals in the clouds, so that you know whether a mixed phase layer is present? That's where the radar technicalities come into play. The radar sends out a certain amount of energy, and receives a fraction of that energy back. Water reflects more of the radar signal than ice. When your power return is greater than 30 dBZ above the freezing level, you can be pretty sure you are detecting large ice (graupel) in the cloud. By measuring the amount of time it took for the signal to bounce off the cloud and return to the radar, you can determine how far away that part of the cloud is.

From the data collected on this research cruise so far, the CSU team has been able to infer that the clouds in the tropical eastern Pacific Ocean have a more active mixed phase process relative to other regions in the Pacific, meaning there is more liquid water lifted above the freezing level and it’s there long enough to interact with ice before freezing. This, in turn, allows the charge to separate, and voilá! lightning is produced.

Is this information anything new and exciting? Well, yes! Satellite images have been used for a while to view the tops of clouds, and observers on the ground can view the bottoms of clouds, but you have to know the internal structure of the cloud to understand what type of weather it will produce. If you don't know the temperature and phase of the water in the cloud, you can't expect to accurately predict how it formed, how it dissipates, and how it is interacting with the rest of the atmosphere. Answers to all of these questions are necessary for climate modeling. Most atmospheric scientists believe that electrified clouds produce a different response on the surrounding atmosphere compared to non-electrical clouds.

So, to summarize the discovery (based on preliminary data)... the clouds in this area appear to be more electrified than clouds in the western Pacific Ocean.

The diagram was created by Dr. Walt Petersen from Colorado State University. The image shows the internal structure of a cloud in the tropical eastern Pacific Ocean. The diagram uses cloud data obtained on a research cruise aboard the NOAA ship R/V Ronald H. Brown. You can see from the legend on the right that everything colored yellow or red is returning at least 30 dBZ. Below approximately 5 kilometers these values mean large raindrops (especially the red areas). Above approximately 5 kilometers these values suggest the presence of large ice (graupel). The higher the 30 dBZ line extends above the cloud level, the stronger the cloud updrafts and the more vigorous the storm.