Kids as Airborne Mission Scientists

Lesson overview: Analyzing Images- How do I evaluate coral reefs in Hawai'i?

FRAME	INFORM	EXPLORE	TRY	SUPPORT
Students view the AVIRIS image of Kailua Bay and begin to think about the process of analyzing data.	Students are divided into two teams to participate in activities to learn how to analyze remote sensing images.	Students are divided into teams to evaluate the state of coral reefs in Kailua Bay while analyzing the DMSV images, classification maps, and pie chart.	Students determine whether there has been a change in the state of coral reefs in Kailua Bay over time	Support materials for the teacher include ideas to promote student reflection, sample answers to activities, and extension of ideas.

Click on FRAME, INFORM, EXPLORE, TRY, or SUPPORT above to view the detailed lesson plan.

Lesson context: This lesson prompts students to analyze and interpret actual remotes sensing images based on the understanding of remote sensing. Students will participate in activities to analyze the state of coral reefs in Kailua Bay by examining various images including DMSV images, classification maps, and pie charts. Finally they will analyze the images collected at the different times to determine whether there has been loss of living coral in the past years.

Key science concepts:

- Electromagnetic radiation
- Visible image
- Image color combination
- Temporal resolution

Links to teacher resources:

- The electromagnetic spectrum
- What is remote sensing? (under development)
- Tutorial for image analysis in remote sensing
- Temporal resolution

Problems addressed in this lesson:

1. How can we analyze the coral reefs of Kailua Bay in remote sensing images?

- What is a classification map?

Activity bursts:

- Analyzing visible and mid infrared remote sensing images(Optional)
- Analyzing actual NASA remote sensing images:
    - Visible image:
        - DMSV image [1] , [2]
        - AVIRIS Image [1] , [2]
        - Landsat Image[1], [2]
    - Classification map:
        - DMSV image, AVIRIS Image, Landsat Image
    - Pie chart:
        - DMSV image, AVIRIS Image, Landsat Image.

Links to other resources:

Lesson	Teacher	Students
FRAME	AVIRIS http://makalu.jpl.nasa.gov/aviris.html	AVIRIS http://makalu.jpl.nasa.gov/aviris.html
INFORM	Watching Over Our Planet from Space Kit http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/youthkit/intro_e.html	Watching Over Our Planet from Space Kit http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/youthkit/intro_e.html
	The electromagnetic spectrum http://imagers.gsfc.nasa.gov/ems/waves3.html	The electromagnetic spectrum http://imagers.gsfc.nasa.gov/EMS/waves3.html
	What is remote sensing? (under development) http://www.pgd.hawaii.edu/~scott/rsens1.htm	What is remote sensing? (under development) http://www.pgd.hawaii.edu/~Scott/rsens1.htm
	Fundamentals of remote sensing http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/fundam/fundam_e.html	Fundamentals of remote sensing http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/fundam/fundam_e.html

	Tutorial for image analysis in remote sensing http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/indexe.html	Tutorial for image analysis in remote sensing http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/indexe.html
	Why images have different colors? http://satftp.soest.hawaii.edu/space/hawaii/vfts/oahu/rem_sens_ex/rsex.spectral.1.html	Why images have different colors? http://satftp.soest.hawaii.edu/space/Hawaii/vfts/Oahu/rem_sens_ex/rsex.spectral.1.html
	How do spacecraft send us data? http://satftp.soest.hawaii.edu/space/Hawaii/vfts/Oahu/rem_sens_ex/rsex.spectral.2.html	How do spacecraft send us data? http://satftp.soest.hawaii.edu/space/Hawaii/vfts/Oahu/rem_sens_ex/rsex.spectral.2.html
	Why satellite images have the colors that they do http://satftp.soest.hawaii.edu/space/Hawaii /vfts/Oahu/rem_sens_ex/old.page.2.html	Why satellite images have the colors that they do http://satftp.soest.hawaii.edu/space/Hawaii /vfts/Oahu/rem_sens_ex/old.page.2.html
	Making a color image http://satftp.soest.hawaii.edu/space/Hawaii/vfts/Oahu/rem_sens_ex/rsex.spectral.3.html	Making a color image http://satftp.soest.hawaii.edu/space/Hawaii/vfts/Oahu/rem_sens_ex/rsex.spectral.3.html
	Image color combinations http://satftp.soest.hawaii.edu/space/Hawaii/vfts/Oahu/rem_sens_ex/rsex3.honolulu.html	Image color combinations http://satftp.soest.hawaii.edu/space/Hawaii/vfts/Oahu/rem_sens_ex/rsex3.honolulu.html
	Additional types of data http://satftp.soest.hawaii.edu/space/Hawaii/vfts/Oahu/rem_sens_ex/rsex.honolulu.html	Additional types of data http://satftp.soest.hawaii.edu/space/Hawaii/vfts/Oahu/rem_sens_ex/rsex.honolulu.html
	Selecting color combinations http://satftp.soest.hawaii.edu/space/Hawaii/vfts/Oahu/rem_sens_ex/rsex.spectral.4.html	Selecting color combinations http://satftp.soest.hawaii.edu/space/Hawaii/vfts/Oahu/rem_sens_ex/rsex.spectral.4.html
EXPLORE	Explanation of classification maps http://lee1.en.a.u-tokyo.ac.jp/Rs&gis/Engl/c3_6_2.htm	Explanation of classification maps http://lee1.en.a.u-tokyo.ac.jp/Rs&gis/Engl/c3_6_2.htm
	Ground truth explanation http://asd-www.larc.nasa.gov/SCOOL/groundtruth.html	Ground truth explanation http://asd-www.larc.nasa.gov/SCOOL/groundtruth.html
TRY	The image http://earthobservatory.nasa.gov/Study/Coral/coral2.html	The image http://earthobservatory.nasa.gov/Study/Coral/coral2.html

Kids as Airborne Mission Scientists

Analyzing Images: How do I evaluate coral reefs in Hawaii?

Related subject area: Science

Overall problem: Which activities (if any) around the coral reefs of Kailua Bay should be restricted to insure their lasting protection?

Relationship of problem in this lesson to the overall problem: In order to make a recommendation about restricting activities around the coral reefs, students need to learn how to analyze and interpret remote sensing images collected over Kailua Bay. During this lesson, students will develop an understanding of the process of analyzing data and actually analyze various images of coral reefs in the Kailua Bay in order to evaluate their health.

Estimated time required: 2 to 3 class periods

Student outcomes/objectives:

- Given classification categories, students will be able to interpret coastal features within different remote sensing images.
- Students will be able to analyze the health of Kailua Bay coral reefs from remote sensing images.

Prerequisite skills or knowledge:

- Basic Internet skills
- Basic reading and writing skills

Teacher preparation:

- Print Student Journal /Activity sheets for these activities.
- Bookmark appropriate websites for students.
- It is highly recommended that teachers review the last lesson, "Collecting data" as they prepare this lesson and review the remote sensing tutorial website in order to gain a basic understanding of remote sensing.

Student reflection and assessment: Student reflection activity | Assessment

Education standards supported by this lesson:

National Science Education Standards | Project 2061 Benchmarks

National Standards for School Mathematics | National Technology Standards | National Geography Standards

Cross-curricular connections to National Education Standards for this lesson:

Math | Technology | Geography

Teacher activities		**Student activities**

FRAME the lesson by showing the collected AVIRIS images. The mission has already been planned and flown. Now they will review and analyze the data gathered.
 	
Provide students with AVIRIS image and the image of the study area.
 	
• **Ask** students
    ○ Where is the location of the larger AVIRIS image??
    ○ Where is the study area of KaAMS mission?
    ○ How did we collect these images? Which remote sensing instrument was used? Which aircraft was chosen for collecting these images?
 	
Teacher Note:
 	
It may help to show the students the Landsat image (http://www.higp.hawaii.edu/kaams/lpreef/cr_analyze/image_files/landsat.htm) to help them with locating where exactly the AVIRIS image is.
 	
Prompt students to begin to think about why they need to analyze the data.
		Student activity:
		
		• Students view the image.
		
		Sample student responses:
		
		• Eastern part of Oahu island
		• Kailua bay
		• AVIRIS was chosen as the remote sensing instrument. ER-2 was chosen as the aircraft for the Kailua Bay coral reef mission.
		• We can distinguish sand and fossil reefs from the living coral reef.
		
		• Which activities (if any) should be restricted around the coral reefs of Kailua Bay to insure their lasting protection?
		• We have to know the health of the coral reefs in Kailua Bay in order to make a recommendation to Congress.
		• . It is difficult to evaluate the state of the coral reefs in Kailua Bay without

• What is the main problem to be answered in KaAMS mission? • Why do we need to analyze the data? • What is the state of coral reefs in Kailua Bay? Can you evaluate the state of coral reefs in Kailua Bay with these images? • How can you evaluate these images? It is important to point out that in order to solve problems like the evaluation of coral reefs in Kailua bay, scientists need to interpret the data collected and analyze it based on the scientific process. The students will now learn how to analyze remote sensing data. **Teacher reference** • AVIRIS		any criteria that distinguish healthy vs. non-healthy coral reefs. Also, a single image without a base for comparison makes it difficult to make statements about the health of the corals (we need at least 2 images to compare). • We can evaluate the health of the coral reefs with ground truth photographs, remote sensing images, and further analyses of these data.
Teacher activities		**Student activities**
Inform students that they will be split into groups to examine the concepts related to analyzing remote sensing data. **Teacher Note:** The aim of remote sensing image analysis in this part is to prepare students for interpreting the data. You can skip this activity if you don't have enough time to do it. **Activity 1: Interpreting and analyzing remote sensing images (Optional activity).** **Break** students into several teams and have them explore one of the following activities and record their findings on **Activity sheet: Watching over our planet from space (AI-1).** You can download the entire Watching Over Our Planet from Space Kit		Student activity: • Students work in groups to complete one of the activities. • Complete student worksheet **Activity sheet: Watching over our planet from space (AI-1).**

(http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/youthkit/intro_e.html) or only the sections you choose.

Teacher Notice: The images in the following activities are mid or near infrared images not visible images. These images will be used to stimulate students' interest in interpreting images. Be sure that students analyze the collected visible images for the Kailua Bay coral reefs mission.

- #1 : Which is which (3.1) http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/youthkit/downld_e.html) : Matching images with a description of features
  # 2 : Find it (3.2) http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/youthkit/downld_e.html): Finding and determining the location of features on an image
  # 3: Measure this (3.3.a) http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/youthkit/downld_e.html): Measuring distance

  Optional Activity: For advanced data analysis, you may want to choose the following two activities.

- #1 Forest fire activity (3.7) http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/youthkit/downld_e.html): : There are many forest fires every year. Satellite images can be used to map the type of vegetation, sources of water and areas that are difficult to travel over. In this satellite image, various colors show various areas. Student can identify the color of forest fire by analyzing the image.

- #2: At a mine site(3.11) http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/youthkit/downld_e.html): : Students can see what happens at a mine site while interpreting images.

Spectral band combinations were used to show healthy and less healthy vegetation at this site. **Teacher notes**: • Teaching time for each activity is anywhere from 15-25 minutes. • It may take a several minutes to download these files. (This file requires Acrobat Reader 4.0 or later. You can download v4.0 for free from: http://www.adobe.com/products/acrobat/readstep2.html). • Before teaching this activity, it is necessary to consider the time to download the file. You may want to identify the activities that students will complete and download the materials in advance. • It is highly recommended that you print the student activity sheets in advance. • Answers to these activities are provided. **Ask** each team to briefly share the results from their investigation with the rest of the class. It may be useful to have them refer during their presentations to **Activity sheet: Watching over our planet from space (AI-1).** **Debrief** the "Watching Over Our Planet from Space" activities by asking each team to briefly describe the difference between mid-infrared images and visible images and why the colors in mid infrared images are not like visible images? See **Activity sheet: Summary (AI-2).** **Teacher resources for these activities**: • The electromagnetic spectrum		• Students examine the websites.

- What is remote sensing? (under development)
- Fundamentals of remote sensing (http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/fundam/fundam_e.html)
- Tutorial for image analysis in remote sensing (PN: site url change, http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/fundam/chapter4/chapter4_1_e.html

Activity 2: Exploring the concepts of image color combination (Optional activity).

To explore why remote sensing image have the different colors, you may want to have students to examine the following websites.

- #1 Why satellite images have different colors?
- #2 How do spacecraft send us data?
- #3 Why satellite images have the colors that they do
- #4 Making a color image
- #5 Image color combinations
- #6 Additional types of data

Have students choose the band they will use by Selecting color combination.

Teacher activities		Student activities
Explore the collected data by participating in activities that evaluate the state of coral reefs images in Kailua Bay. Students analyze the state of coral reefs in Kailua Bay based on classification maps. **Remind** students about the AVIRIS image		Sample activity

and Study Area image collected.		• Students view the image.
Prompt students to think about why they need to have ground truthing images to evaluate the coral reefs in Kailua Bay. • Can we determine the state of coral reefs with these two images? • If not, which data do we need? Which resolution images do we need to have? • How can we get the high resolution image?		Sample student responses: • Yes/ NO • We need a higher resolution image. • We can take high-resolution images when collecting images. Or we can also take ground truth photographs as well.
Breaks students into several groups.		
Have each team explore the ground truthing image including ground truthing photographs.		Sample activity • Students view the image.
Teacher Note: Ground truth photographs are not remote sensing images. They are collected when more detailed investigation is required.		
Ask each group to explore the state of coral reefs in Kailua Bay and write the results of their investigation in the **Student activity sheet: Exploring the state of coral reefs with ground truth photographs (AI-3).**		• Students write the results of their investigation in the **Student activity sheet: Exploring the state of coral reefs with ground truth photographs (AI-3).**
Prompt students to think about whether there is a better way to evaluate the state of coral reefs and introduce **the concept of classification** and let them know they will use four categories as a classification scheme.		• Students read **the concept of classification.**
Ask each group to decide where each ground truth photograph will be placed among four categories and write their answers in the **Student activity sheet: Deciding the classification categories (AI-4).**		• Students write the results of their investigation on the **Student activity sheet: Deciding the classification categories (AI-4).**
Ask each group to present their results. • Each team presents their		

investigation results. **Provide** students with (1) DMSV image for the study area, (2) the classification map of study area, and (3) pie chart. **Ask** students to discuss the similarities and differences between their classification categories and the actual classification categories. **Summarize** the lesson and introduce the next step: analyzing the change of the state of coral reefs in Kailua Bay. **Teacher Resources:** • • Supervised classification (http://lee1.en.a.u-tokyo.ac.jp/Rs&gis/Engl/c3_6_2.htm • Ground truth explanation		• Each group presents their exploration results. • Students view the image. • Students discuss the similarities and differences between their classification categories and the actual classification categories.
Teacher activities		**Student activities**
Try using their new knowledge while analyzing the change of the Kailua Bay coral reefs in a temporal resolution activity. **Have** students to look at the image that shows the decline of coral reefs in the past 25 years in the coast of Florida (Please just use the picture which is located in the middle of text for this activity. Texts/ contents of this site are not directly related to this lesson.) **Prompt** students to think about whether there has been a dramatic decline in health and extent of the coral reef in Kailua Bay in the past years. If so, how can they monitor the changes? **Ask** students to remember the concept of temporal resolution that they learned in the lesson 'How do I plan a remote sensing		Students activity • Students view the image Sample students answers: • There is not a change in the past years. • There is a dramatic decline in the Kailua Bay coral reefs. In order to do so, we can compare the data taken at the different times.

mission' (please see the EXPLORE part for understanding temporal resolution) and explain that they will be participating in a temporal resolution activity for evaluating the change of the state of Kailua bay coral reefs.
 	
Show the three visible images of Kailua Bay that were collected at different times.
 	
• January 10, 1998
  ○ (1) DMSV_color_mosaic
  ○ (2) DMSV_RGB_subset_Kailua
• February 12, 2000
  ○ (1) Landsat_color_mosaic
  ○ (2) Landsat_RGB_subset_Kailua
• April 12, 2000
  ○ (1) Aviris_color_mosaic
  ○ (2) Aviris_RGB_subset_Kailua
  ○
 	
Ask students if there has been a change in the state of coral reefs in the past two years. If they can't see a change, prompt students to think about what they need to look at in order to evaluate the change.
 	
Break students into their same groups and have each group explore the classification mapsand pie charts.
 	
• January 10, 98 (DMSV image)
  ○ classification map
  ○ Pie chart
• February 12, 2000 (Landsat image)
		Student activity:
		
		• Students view the Kailua Bay coral reef images collected at different times.
		
		Sample students answers:
		
		• We can't see any changes with these images. We also need classification maps.
		
		Sample student activity:
		
		• Each group explores the classification maps and pie chart for evaluating the change in coral reefs since 1998.
		
		• Each group writes the result of their investigation on the **Activity sheet:**

◦ classification map ◦ Pie chart • April. 12. 2000 (AVIRIS image) ◦ classification map ◦ Pie chart **Ask** each group to compare the classification maps in order to find out whether there has been a change in the past years and write the results of their investigation on the **Activity sheet: Investigating the changes in the state of coral reefs in Kailua Bay since 1998 (AI-5).** **Ask** students to present their results of investigations to the class. **Prompt** students to thinks about why they need to collect another AVIRIS image. **Ask** students to predict possible changes to the state of coral reefs when new AVIRIS data are collected and analyzed . **Teacher Note:** When new, clear AVIRIS images are collected, students should analyze the new data to find the change of the state of coral reefs in the past year. **Debrief** the activity: How do you evaluate the state of Kailua Bay coral reefs? Let students describe the process they went through and critical elements they considered to evaluate the state of coral reefs.		**Investigating the changes in the state of coral reefs in Kailua Bay since 1998 (AI-5).** Sample student answers: • The AVIRIS (April 12th, 2000) image has clouds and cloud shadows in it. Due to the clouds and shadows, the percentage of living coral in this image are not very accurate because some of the reef is covered. It will be better to collect another AVIRIS data set without clouds or cloud shadows in it.

Student reflection activity:

- Prompt students to think about the process and elements for evaluating the state of coral reefs in remote sensing data images.

- Prompt students to record how they analyzed the remote sensing images for evaluating the state of coral reefs in Kailua Bay.
- Prompt students to think about why they need to have classification maps and pie charts for evaluating the state of coral reefs of Kailua Bay.
- Prompt students to think about which data images are required to evaluate whether there has been a change in the state of coral reefs in Kailua Bay.

Assessment:

- Students differentiate between DMSV images, AVIRIS image, and Landsat images.
- Students define the classification scheme that they will use for the KaAMS mission.
- Students decide the classification categories of ground truthing photographs.
- Student investigate the changes of the state of coral reefs in Kailua Bay.

Ideas for math lesson connections

1. Students create a chart which compares the information gathered from classification images of the coral reefs.

Related National Education Math Standards

- Number and operations
- Measurement

Ideas for geography lesson connections

1. Students learn how to read classification maps and practice skills by examining a classification map.
2. Students apply the information learned from the classification map to interpret the present and plan for the future of the region surrounding Kilauea.

Related National Education Geography Standards

1. The World in Spatial Terms (1)
2. Places and Regions (4)
3. The Use of Geography (18)

Ideas for technology lesson connections

1. Word processing: Students create their own electronic journal for keeping notes on KaAMS project.

2. Database: Students create a database of vocabulary words and terms they will learn throughout KaAMS.

3. Graphics: Students create pictures of Hawaiian Islands, remote sensing missions, aeronautics.

4. Presentation software: Students create a short presentation on their understanding of airborne remote sensing.

5. Web development: Students begin to develop a web-site to report their progress and what they learn during the KaAMS project.

Related National Education Science Technology Standards

1. Nature of Technology (1)

2. Technology and Society (5)

3. Abilities for a technological World (12)

4. The Designed World (17)

Activity sheet: Watching over our planet from space (AI-1)

Name: ____

1. Activity name ______________________

   Find It!

2. Briefly describe the activity you completed:

   In this activity we used number coordinates to find different features in a Landsat satellite image

3. What objects and/or features did you observe in the images in your activity?

   roads, farmland, rivers, vegetation, lakes, islands, ponds

4. Why are these images important? (What did they tell you?)

   This image could be used to investigate land use, crop health, and ecological and geographical studies.

Teacher Answer Keys for the activities from Watching over our planet from space

3.1 Which is Which ?

a) 2 b) 7 c) 12 d) 9 e) 8 f) 10 g) 5 h) 10 i) 4 j) 11 k) 3 l) 6 m) 1

3.2 Find It

1) C: (7.7, 6.1) 2) A: (5.2, 2.6) 3) B: (4.8, 6.7) 4) A: (8.2, 4.2)

5) D: (5.7, 8.0) 6) B: (5.5, 6.4) 7) D: (5.3, 5.0)

3.3a Measure This

(northern Saskatchewan)

1) D: (2.0, 0.5) 2) A: light pink 3) C: less than 1 km long

4) A: 17 km 5) B: less than 1 square km 6) D: 10 km

3.7 Forest Fire

Task #1 Approximately 16 km

Task #2 Closest Lake is at: (2.1, 2.1). Next closest lake is at: (0.7, 3.7)

3.8 At a Mine Site

1)(4.5, 2.7) 2) (2.0, 6.0) 3) (6.5, 6.7) 4) (4.6, 3.2)

5) (3.7, 3.7) 6) (6.5, 8.1) 7)(4.1, 8.8)

Activity sheet: Summary (AI-2)

1. What is the difference between visible and infrared images?

The light which our eyes - our "remote sensors" - can detect is part of the visible spectrum. It is important to recognize how small the visible portion is relative to the rest of the spectrum. Therefore visible images are essentially images of what our eyes would detect. The visible wavelengths cover a range from approximately 0.4 to 0.7 mm. There is a lot of radiation around us which is "invisible" to our eyes (i.e. infrared radiation), but can be detected by other remote sensing instruments and used to our advantage. The infrared wavelengths cover a range from approximately 0.7 to 100 mm.

Reference:
http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/fundam/chapter1/chapter1_3_e.html

2. Why are colors in infrared images different from those in visible images?

Visible radiation is the only portion of the spectrum we can associate with the concept of colors. Therefore, they are sometimes referred to as true-color images. Visible images are essentially a representation of what our eyes see. Infrared images cannot be seen with our eyes but must be detected by certain remote sensing instruments. Colors in an infrared image do not correspond to anything our eyes detect. Therefore, they are sometimes referred to as false-color images.
To see how color images are created refer to:
http://satftp.soest.hawaii.edu/space/hawaii/vfts/oahu/rem_sens_ex/rsex.spectral.3.html

Activity Sheet: Exploring the state of coral reefs with ground thruth photographs (AI-3)

Activity Sheet: Exploring the state of coral reefs with ground truthing photographs

1. What is your mission?

   To write a recommendation based on the evaluation of the state of coral reefs in Kailua Bay.

2. Where is the study area?

   Kailua Bay

3. Evaluate the eight detailed coral reef images and determine whether they are healthy. Write why you believe this is so.

Image	Are coral reefs healthy in this area?	Why?
1	Yes	There is complete coral cover.
2	Not sure	There is a coral surrounded by low-lying algae and sand.
3	No	There is a sand.
4	Yes	There is compete coral cover.
5	Not sure	There is a coral surrounded by low-lying algae and sand.
6	Yes	There is complete coral cover.
7	No	There is a sand and fossil reefs.
8	Medium	The image show that there are half sand and half coral reef.

4. Write a conclusion about the state of coral reefs in Kailua Bay.

   The coral reefs of Kailua Bay look healthy overall. However we are still not sure because we don't have any criteria to evaluate the state of coral reefs.

Why do we need classification maps for each image set?

Sometimes geologists are interested in not only mapping large scale features on land but things hidden to the naked eye such as minerals that are present in rocks on the earth surface. Or in this case since we are studying a coral reef, we may be interested in the make-up of the reef--like the percent living coral cover or the different coral species on the ocean floor. Such information about the chemical or biological make-up of the coral reef cannot be determined just by looking at the color images of the AVIRIS, Landsat or DMSV sensors.

To extract "hidden" information from the data we use classification techniques. Classification clusters pixels (i.e. make classes or categories) based on digital/numerical data "inherent" in the remote sensing images. Rocks with a high iron content give off specific reflectance signals different than rocks high in silica, for example. So we can use their different reflectance signals to cluster the different rock types into categories.

To keep our classification simple, we have not tried to extract detailed information about the different type of algae or coral species. Instead we have clustered the ocean bottom reflectance into 4, easy to work with discrete classes.

For the classification scheme we use in this study, we have four categories:

1. Category 1: Sand (or 0 % living coral)
2. Category 2: 0 - 25% living coral
3. Category 3: 25% - 75% living coral
4. Category 4: >75% living coral (i.e. 75% - 100% living coral.

Activity Sheet: Deciding the classification categories for ground truthing photographs(AI-4)

1. Where will each ground truthing photograph be placed in each of the four different categories? Write the image number in the second column.

Categories	Images	Why?
Sand and fossil reef category	3 and 7	• The ground-truth pictures 3 and 7 (the sand part of the photograph) are examples of ocean bottom-types that would fit into this category. There is no ground-truth photograph of a fossil reef bottom. However, it looks like white colored cement on the ocean floor.
0-25% living coral category	5 and 2	• The ground-truth picture 5 would be an example of a habitat that would fit in this category. In this image, there is one coral colony surrounded by low-lying algae and sand. • Ground-truth picture 2 would also fit in this category. This is a picture of green algae surrounded by sand. When divers dove in this area of the coral reef, they found the ocean floor covered with fields of this type of algae.
25%-75% living coral category	8	• This category has a medium amount of living coral. Ground-truth picture 8 is an example of a habitat that would fall into this living coral category. As you can see from the picture this habitat is about half sand (in what is described as a "groove") and half coral reef (growing on what is described as a "spur").

75% living coral category	1, 4, and 6	• Ground-truth pictures 1, 4 and 6 are examples of habitat the fit into this 75% living coral category. Although these habitats look different, they both have very complete coral cover over the ocean floor. • In ground-truth picture 1, there is a lush coral garden with all the coral colonies of about the same size. The larger coral colonies in this photograph grow in a form called "mounds" while the smaller, low-lying coral grow in a form called "encrusting". There are no "sand fields" or "grooves" filled with sand in this coral habitat, just total coral cover. • The habitat in ground-truth picture 4 also exhibits complete coral cover. This type of coral grows in a different form than those in the habitat in ground-truth picture 1. These corals are "branching" corals. • In ground-truth picture 6, there is also complete coral cover. However, in this habitat, one coral colony is much larger than the rest standing about 3 meters high. This sort of coral colony is called a "bomb". All around the "bomb," lower-lying coral grow completely covering the ocean floor.

2. Write a conclusion about the state of coral reefs in Kailua Bay based on above stated categories.

Based on the total percent area occupied by "percent living coral categories", it looks like there is an overall decrease in area covered by living coral.

Activity Sheet: Investigating the changes in the state of coral reefs in Kailua Bay in the past years (AI-5A)

1. Write the percentages and the areas covered by various categories in the study area.

Table 1.

Data Type	Date	Sand and Fossil Reef		0-25% Living Coral		25-75% Living Coral		>75% Living Coral	
		Percent	Area (m2)	Percent	Area (m2)	Percent	Area (m2)	Percent	Area (m2)
DMSV	Jan/10/98	40	1,646,072	15	617,916	22	893,521	23	924,777
Landsat	Feb./12/00	48	2,036,015	10	400,109	13	558,339	29	1,233,737
AVIRIS	Apr./12/00	44	1,834,006	16	665,460	10	399,700	18	740,740

2. Comparing the state of coral reefs between January, 1998 and February, 2000.

1) Can you compare two these images? If so, which and why?

We can more reliably compare the DMSV data with the Landsat data sets because these data sets were collected on clear days, when there were no clouds over our study area and no obstructive ocean waves.

If you answered Yes to the question 1, please answer the following questions 2 to 4.

If you answered No to the question 1, please skip the answer the following questions 2 to 4.

2) Which categories were increased from 1998 to year 2000?

- The sand and fossil reef category has increased from 40% to 48% in this time. At first this looked like there was a net loss in living coral reef of 8 percent.

- Looking at the individual living coral categories, there was an increase in the >75% living coral category from 23% of the study area in 1998 to 29% in 2000.

3) Which categories were decreased from 1998 year to 2000 year?

- There was also a decrease in the other two living coral categories. The 0-25% living coral category was reduced from an area of 15%

of the total area in 1998 to 10% in 2000. The 25%-75% living coral category had reduced from 22% in 1998 to 13% in 2000.

4) What is your conclusion about the changes since 1998?

- The total percent area occupied by "percent living coral categories" from Table 1 is 60% in 1998 (23%: >75% living coral + 22%: 25%-75% living coral + 15%: 0-25% living coral) and 52% in 2000 (29%: >75% living coral + 13%: 25%-75% living coral + 10%: 0-25% living coral). This looks like there is an overall decrease in area covered by living coral. However, since these categories are "ranges" of living coral, let us find the upper and lower extents of the live coral in these categories.

- We were still concerned about the increase in area for the sand and fossil reef category. Did this mean that was an 8 percent loss of coral reef? To answer this question, we looked more closely at the percent living coral categories to find the range of living coral from the percentages in each category (Table 2).

Table 2. Range of percent area covered by living coral.

Category	1998	2000
>75%	0.23(0.75-1.00)= 17 - 23%	0.29(0.75-1.00) = 22 - 29%
25% - 75%	0.22(0.25-0.75) = 6 - 17%	0.13(0.25-0.75) = 3 - 10%
0 - 25%	0.15(0.00-0.25) = 0 - 4%	0.10(0.00-0.25) = 0 - 3%
Total range of coral cover	23% - 44%	25%-42%

- From the results in Table 2, it is less convincing that there has been a decrease in the area of living coral reef. While there is a 2% increase in the upper limit of living coral from 44% in 1998 to 42% in 2000, there has also been a 2% increase in the lower limit of live coral from 23% in 1998 to 25% in 2000. With a range of living coral on the order of 20%, a 2% difference is not significant enough to say that there has been loss of living coral reef.

3. Comparing the state of coral reefs from February, 2000 to April, 2000.

1) Can you compare two images? If then, why do you think so?

The AVIRIS (April 12th, 2000) image has clouds and cloud shadows in it. Due the clouds and shadows the percent living coral categories in this image are not very accurate because some of the reef is covered. It will be better to collect another AVIRIS data set without clouds and cloud shadows in it. Furthermore, there are waves on the surface of the ocean. Again, the data will be more reliable if collected on a day when the ocean surface is smoother.

2) Which categories were increased from February, 2000 year to April 2000 year?

- There was also a increase in 0-25% living coral categories.

3) Which categories were decreased from February, 2000 year to April, 2000 year?

- The sand and fossil reef category has decreased from 48% to 40% in this time.

- There was also a decrease in the other two living coral categories. The 25-75% living coral category was reduced from an area of 13% of the total area to 10%. The >75% living coral category had reduced from 29% in 1998 to 18% in 2000

4) What is your conclusion of the changes in this time?

- We can't draw our conclusions with these images. The AVIRIS (April 12th, 2000) image has clouds and cloud shadows in it. Due the clouds and shadows, the percent living coral categories in this image are not very accurate. It will be better to collect another AVIRIS data set without clouds and cloud shadows in it and draw the conclusions with those images.