GLACIERS

An educational curriculum guide on glacier resources.

Prepared by the
Views of the National Parks team
and their partners at the
University of Colorado at Denver.

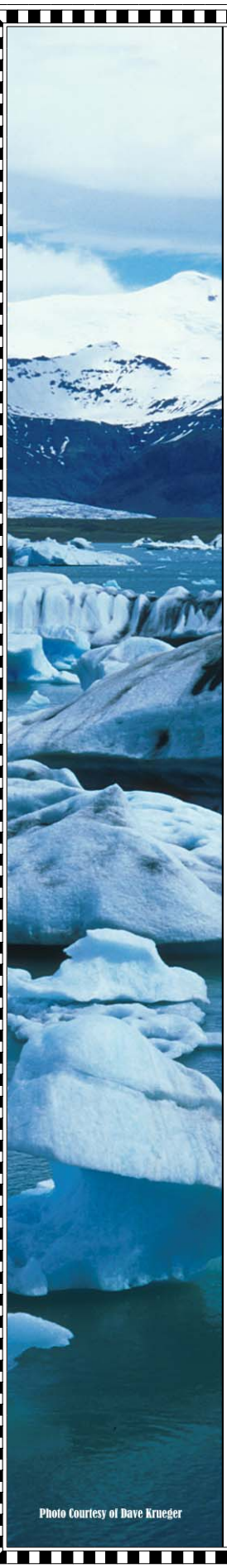
FOREWORD

"Views of the National Parks" (Views) is a multimedia education program that presents stories of the natural, historical, and cultural wonders associated with America's parks. Through the use of images, videos, sounds and text, Views allows the public to explore the national parks for formal and informal educational purposes. By employing the resources of the parks for educational purposes Views hopes to increase public awareness, interest and appreciation of our parks, while helping to satisfy the need for authentic education.

Nationwide interest in the National Parks makes them easy to fit into the growing demand for more authentic and meaningful curricula. In fact, "virtually all the standards documents that have been published over the past decade entreat teachers to involve students in tangible, genuine, authentic, real-world materials and experiences."[1] The motivation for creating educational curriculum guides that support the Views Program was to connect formal education topics to real-world experiences and to offer students a real-world connection to standards-based curricula.

This educational curriculum guide is meant to compliment the Views **Glacier Knowledge Center,** and the intended audience is studentsat the middle and high school grade levels. This guide aligns national park resources pertaining to glaciers with National Education Standards through interactive inquiry-based activities

1 Best Practice: New Standards for Teaching and Learning in America's Schools; 2nd Edition. Zemelman, Daniels, and Hyde. Copyright 1998 by S. Zemelman, H. Daniels, and A. Hyde.



and instructional lesson plans. There are teacher copies and answer keys for all applicable activities. This guide was developed as an introduction to glaciers, and all activities are designed to be used together in a 2-week unit. Activities, although designed as a unit, may also be used independently at a teacher's discretion.

This curriculum guide was developed by Kristen Lucke with support from the rest of the Views team: Bruce Nash, David Krueger, and Erika Matteo. We would like to thank Dr. Mike Marlow, professor of Education and Human Development at the University of Colorado at Denver, for providing professional and educational support. We would also like to thank Jim F. Wood of the NPS Geologic Resources Division for editing this curriculum guide. For more information concerning this guide or the Views program, or to request a Views DVD, contact:

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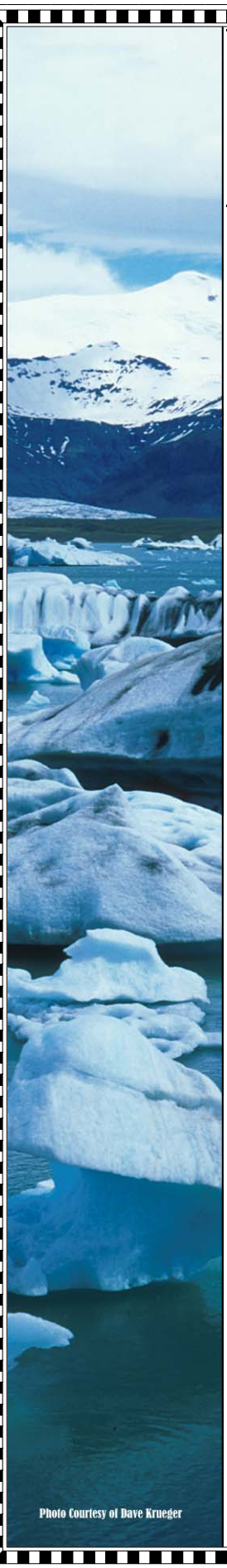

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Day 3: **Glaciers Webquest**

Students will learn key glacier concepts in a webquest using the Views of the National Parks multimedia education program.

Day 4: **Features of Erosion**

Students will learn key features of glacial erosion.

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Students will set up a lab activity that will be completed the following day.

Day 5: **Natural Architects**

Students will demonstrate and understand the processes associated with glaciation in a hands-on activity.

Day 6: **How Glaciers Move**

Students will learn and understand various processes involved with glacial movement and flow.

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Students will learn about the benefits and hazards associated with glaciers in a webquest using the Views of the National Parks multimedia education program.

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Students will work together to draw key glacial features.

Glacier Review Sheet

Students will complete a review sheet that covers key glacial concepts covered in this curriculum guide.

Day 10: **Glacier Quiz Game**

Students will work together in teams to answer glacier related trivia questions.

WHAT HAPPENED HERE?

OBJECTIVE

After completing this introductory lesson to a unit on glaciers, students will be able to use the scientific method to formulate their own hypotheses about landscape formation.

GRADES

Middle or High School students

DURATION

1 50-minute class period

MATERIALS

- *What Happened Here?* worksheet for every student
- Landscape photo for each pair or small group of students
- *Views of the National Parks* (via internet or DVD)
- Computer connected to a large classroom screen

KEY CONCEPTS

Scientific method, inquiry, landscape formation

WHAT HAPPENED HERE?

NATIONAL EDUCATION STANDARDS:

Science

NS.5-8.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.5-8.4 Earth and Space Science

- **Structure of the earth system**

NS.5-8.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of science**

NS.9-12.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.9-12.5 Science and Technology

- **Understandings about science and technology**

NS.9-12.6 Personal and Social Perspectives

- **Natural resources**

NS.9-12.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of scientific knowledge**

WHAT HAPPENED HERE?

DAY 1

Essential Question: *"What formed the landscape in the picture?*

Lesson Description:

1. This lesson uses the "Think-Pair-Share" instructional method in an inquiry-based activity incorporating glaciers with the Scientific Method.
2. This is the first part of a 2-day lesson, and it will take an entire 50 minute class period.
3. This lesson plan was developed as an introductory lesson to a unit on glaciers. As an inquiry-based lesson, the role of the teacher is to guide the students through the activity without giving them the answers. This encourages them to exercise their observation, thinking and reasoning skills.
4. Using the **Views of the National Parks (Views)** program, the teacher will take the class through the Scientific Method Knowledge Center as the students work through the corresponding worksheet.
5. Although this lesson was designed for the teacher to show the website on a large classroom screen, students can also pair up and work together on individual computers.

Preparation:

1. Have enough copies of the landscape picture for each **pair** of students to have one.
2. Have a "What Happened Here?" worksheet for each student.
3. To save time, have the Views program up and running before class.

To get to the Knowledge Center:

1. Go to http://www2.nature.nps.gov/views/
2. Select the Visitor Center.
3. Select the Knowledge Centers.
4. Select the Scientific Method knowledge center.
5. Enter the knowledge center by selecting the "Explore the Scientific Method" option. This brings you to where the lesson and student worksheet begin.

Suggested Instructional Lesson Plan:

1. Introduction to the lesson	4 minutes
2. Going through the knowledge center	38 minutes
a. Introduction	2 minutes
b. Observation	6 minutes
c. Question	8 minutes
d. Hypothesis	10 minutes
e. Test	10 minutes
f. Conclusion	2 minutes
3. Wrap-Up	3 minutes

DETAILED INSTRUCTIONAL LESSON PLAN

Introduction to the lesson: 2 minutes

1. Begin class by explaining to the students that they will be starting a new unit, but don't give them any specific details.
2. As you pass out the worksheets and landscape pictures, explain that each student is responsible for completing their own worksheet, but they will be working with a partner for parts of the activity.
3. Explain to the class that this activity is meant to encourage them to use their observational skills and to formulate unbiased opinions and ideas based on what they observe, just like real scientists do!
4. Help the class formulate an essential question.

Going through the knowledge center: 40 minutes

Introduction: 2 minutes

1. Read through the slide…don't forget to introduce Betsy!

Observation: 6 minutes

1. Read through the slide
2. "Think-Pair-Share" Activity
   a. Think:
      i. Instruct the students to silently observe the landscape picture.
      ii. Have the students write down 2 to 3 observations, leaving room for a brainstorm session with their partner.
   b. Pair:
      i. Now they will pair up with their partner and talk about what they have observed.
      ii. Together the pairs will come up with a total of 5 observations.
      iii. Have each student put a star next to the observation that they and their partner think will be the best for helping answer the essential question.
   c. Share:
      i. The teacher will select a few students to share their "best" observation with the rest of the class.

Question: 8 minutes

1. Read through the slide
2. "Think-Pair-Share" Activity
   a. Think:
      i. Instruct the students to silently think of 5 different questions, pertaining to their observations, which could possibly lead to answering the essential question.
      ii. The students should write down 2 to 3 questions. Again, they should leave room for what they brainstorm with their partner.
   b. Pair:
      i. Instruct the students to pair up with their partner and talk about what their questions.
      ii. Together the pairs will come up with a total of 5 questions.
      iii. Have each student put a star next to the question that they and their partner think will be the best for helping answer the essential question.
   c. Share:
      i. The teacher will select a few students to share their "best" question with the rest of the class.
      ii. The students should share what their original observation was, and then the question that corresponds to it.

Hypothesis: 10 minutes

1. Read through the slide
2. "Think-Pair-Share" Activity
   a. Think:
      i. Instruct the students to individually formulate 2-3 hypotheses that could explain their chosen question.
   c. Pair:
      i. Instruct the students to pair up with their partner and talk about the hypotheses that they formulated.
      ii. Together the pairs will come up with a total of 5 hypotheses that correspond with their selected question.
      iii. Have the students put a star next to, what they feel, is their best hypothesis.
   d. Share:
      i. The teacher will select a few students to share their "best" hypothesis with the rest of the class.
      ii. The students should share what their original observation and question were, and then the hypothesis that corresponds to them.
      iii. At this point, the teacher should ask each student why and how they formulated their hypothesis. Press them by asking "why" over and over! This will really get them thinking.

Test: 12 minutes

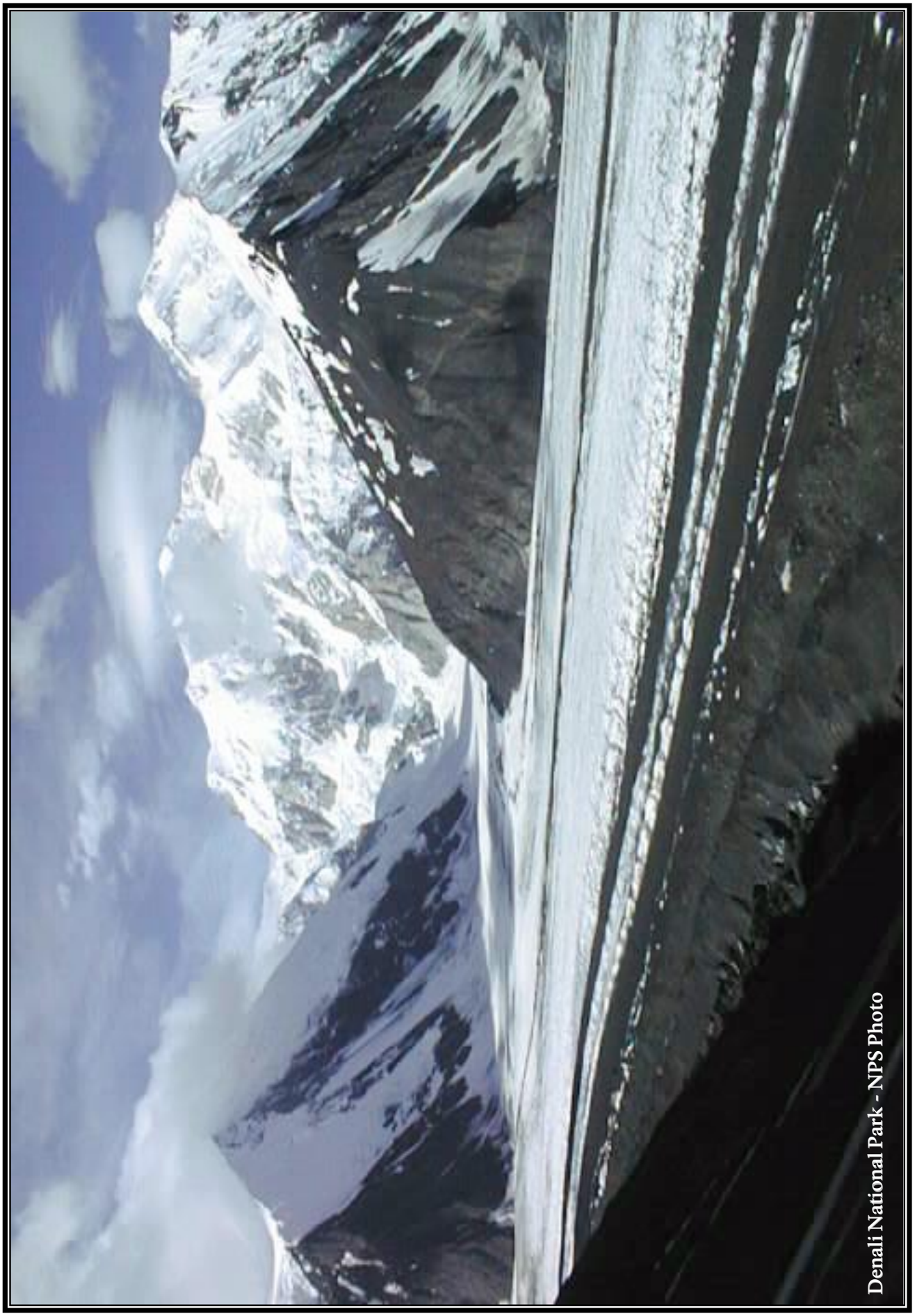
1. Read through the slide
2. "Think-Pair-Share" Activity
   a. Think:
      i. Instruct the students to think about ways that they could test each of their hypotheses.
   b. Pair:
      i. Instruct the students to pair up with their partner and talk about the tests that they came up with.
      ii. Have the students put a star next to, what they feel, is their best test.
   c. Share:
      i. The teacher will select a few students to share their "best" test with the rest of the class.
      ii. The students should share what their original observation, question, and hypothesis were, and then the way that they could test their hypothesis.

Conclusion: 2 minutes

1. Read through the slide.

Wrap Up Activity: 3 Minutes

1. Ask a few of the students to share with the class which hypothesis they thought might best answer the essential question, whether it's the one they thought of or one of their classmates.
2. Ask the students if anyone has an answer to the essential question that is different from any of the ones that were shared with the class.
3. Tell the students that tomorrow they will be conducting an experiment that will answer the essential question.
4. Have the students turn in their worksheets.



Denali National Park - NPS Photo

Name:

What Happened Here?

Essential Question: _____

Science is the process of gaining a better understanding of the world in which we live. The scientific method was developed so scientists could test possible explanations to questions and allow others to verify the results.

There are 5 general steps of the Scientific Method:

Observation ***Question*** ***Hypothesis*** ***Test*** ***Conclusion***

Step 1: Observation

Observing the world around you is an important first step in the scientific method. As you make observations you may begin to ask questions about those observations.

Look at the picture given to you. What do you see? What observations can you make from just looking at the picture?

Write down 5 observations about the landscape in the picture that might help you answer the essential question:

1.
2.
3.
4.
5.

Step 2: Ask a Question

The formation of a question comes from observation. However, not all questions can be answered using the scientific method. The scientific method can only be used on those questions that have testable hypotheses.

Based on your observations, write down 5 questions about the formation of the landscape.

1.
2.
3.
4.
5.

Name:

Step 3: Forming a Hypothesis

To find an answer to a question, a hypothesis is formed. A hypothesis is a possible explanation for the question. They can be proven false, but can never be proven absolutely true. This allows other people the ability to verify the results, and leaves the chance for find better explanations as our understanding grows.

To help remove any personal feelings that may be added when a hypothesis is formed, multiple hypotheses are typically proposed. This causes all the hypotheses to be tested harder in order to throw away the false explanations.

Develop 5 hypotheses that could explain each of the questions you came up with in step 2.

1.
2.
3.
4.
5.

Step 4: Testing the Hypotheses

By testing the multiple hypotheses proposed for a question, a hypothesis is either supported or proven false. The tests are repeatable, meaning other people can take the accepted hypothesis and test it again independently.

Write down a way to test each of your hypotheses:

1.
2.
3.
4.
5.

Step 5: Drawing a Conclusion

The final step of the scientific method is when hypotheses are either accepted or rejected. If a conclusion is reached that one hypothesis is rejected, then another hypothesis needs to be examined. On the other hand, if a hypothesis is accepted the concluding explanation becomes a theory. In both cases, the conclusion should state all the finding so others can verify the results or explore some more of the findings.

For this experiment, you will not be able to draw a conclusion because you were not able to test your hypotheses. However, knowing how to properly state a conclusion will be important for future experiments.

DAY 2

EDIBLE LANDSCAPES

OBJECTIVE Using common household items, students will simulate glacial movement and discover ways that landscapes are formed.

GRADES Middle or High School students

DURATION 1 50-minute class period

MATERIALS

- Chocolate chip ice cream
- Ice cream scoop
- Paper towels
- Baking sheet or pan
- Tin foil
- Graham Crackers
- Pretzel sticks
- Hard candy
- Plastic gloves

KEY CONCEPTS Glacier, glacial movement, glacial scouring, glacial till

DAY 2

EDIBLE LANDSCAPES

NATIONAL EDUCATION STANDARDS:

Science:

NS.5-8.1 Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

NS.5-8.4 Earth and Space Science

- Structure of the earth system

NS.5-8.7 History and Nature of Science

- Science as a human endeavor
- Nature of science

NS.9-12.1 Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

NS.9-12.6 Personal and Social Perspectives

- Natural resources

NS.9-12.7 History and Nature of Science

- Science as a human endeavor
- Nature of scientific knowledge

EDIBLE LANDSCAPES

DAY 2

LESSON DESCRIPTION:

Students use common household food items in an activity simulating glacial movement and landscape formation.

INSTRUCTOR NOTES:

- The teacher should model the activity for the students as they follow the *Edible Landscapes* worksheet.
- Once the students have completed up to the "Making a Connection" section of the worksheet, the teacher will go through the Edible Landscapes PowerPoint presentation with the class.

INSTRUCTIONAL LESSON PLAN:

1. Introduction to the lesson	5 minutes
2. Edible Landscapes Activity	25 minutes
3. Edible Landscapes Presentation	20 minutes
4. Clean up	5 minutes

PREPARATION AND PROCEDURE:

1. Have the materials for the experiment ready before class starts.
2. Have an "Edible Landscapes" worksheet for each student.
3. To save time, have the Edible Landscapes presentation open and ready.
    a. Once you have opened the presentation in the PowerPoint program, select "Slide Show" from the top toolbar and then select "View Show".
4. At the beginning of class, split the students up into pairs or small groups.
5. Have each group obtain the materials they will need for the activity.
6. Take the class through the worksheet, modeling each step first and then giving the students time to complete the procedure. (This should take about 25 minutes.)
7. When the students have completed the Making a Connection section at the end of page 2, take them through the PowerPoint presentation. (It should take about 20 minutes to go through the presentation, allowing them time to complete page 3 of their worksheet.)

Name:

EDIBLE LANDSCAPES

Objective: *Use common household items to discover ways that landscapes are moved and shaped.*

Materials:

- Chocolate chip ice cream
- Ice cream scoop
- Paper towels
- Baking sheet or pan
- Plastic spoons
- Graham crackers
- Pretzels sticks
- Candy pieces
- Tin foil
- Plastic gloves

Procedure:

1. Line your baking sheet or pan with tin foil and put on plastic gloves.
2. Crumble the graham crackers onto the baking sheet in a mound.

3. Sprinkle or place the candy and pretzels all around the graham cracker crumbs.
4. Place a scoop of ice cream on top of your crumb, pretzel, & candy mixture.

5. Put on plastic gloves and compact the ice cream by squeezing it.
6. Write down your observations in the Observations section below.
7. Pull the ice cream back across the crumb.

8. Write down **or** draw your observations in the Observations section below.

Name:

Observations:

As the ice cream is compacted…	*As the ice cream is dragged across the crumbs…*
1. What happens to the crumbs?	1. What happens to the crumbs?
2. What happens to the ice cream?	2. What happens to the ice cream?
3. What happens to the candy and pretzels?	3. What happens to the candy and pretzels?

Making a Connection:

1. What do you think the following materials from your experiment represent in real life?
   a. Ice cream-
   b. Graham cracker crumbs-
   c. Chocolate chips in the ice cream-
   d. Candy-
   e. Pretzels-

2. What landscape altering process in nature **do you think** this experiment is simulating?

Name:

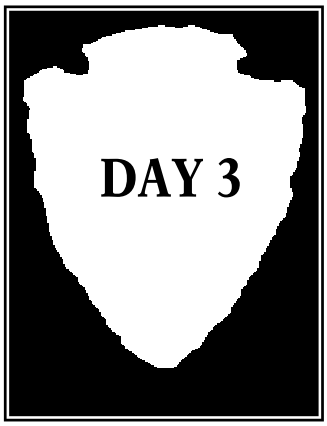
Your teacher will take you through a presentation as you answer the following questions.

1. What **do** the following materials from your experiment represent in real life?
    a. Ice cream-
    b. Graham cracker -
    c. Chocolate chips in the ice cream-
    d. Candy-
    e. Pretzels-

2. What did squeezing the ice cream with your hands represent?

3. What process what simulated by dragging the ice cream back across the crumbs?

4. Using the information you have learned in this activity, **describe how this experiment relates to the formation of landscapes**. Be sure to **use examples** from the experiment and the presentation, and **relate your answer to the photograph** at the end of the PowerPoint presentation.



GLACIERS WEBQUEST

OBJECTIVE	Students will learn key glacier concepts in a webquest using the *Views of the National Parks* multimedia education program.
GRADES	Middle or High School students
DURATION	1 50-minute class period
PROCEDURE	Student will spend an entire class period working independently or in small groups to complete the *Glaciers* webquest.
MATERIALS	▪ Copies of the *Glaciers* webquest for each student ▪ Computers for each student or pair of students
KEY CONCEPTS	What makes a glacier a glacier; where glaciers are found and why; types of glaciers; glacial movement; key glacier terms
KEY TERMS	Ablation, ablation zone, abrasion, accumulation, accumulation zone, bed, equilibrium line, firn, firn line, plucking, terminus

DAY 3

GLACIERS WEBQUEST

NATIONAL EDUCATION STANDARDS:

Science:

NS.5-8.4 Earth and Space Science

- **Structure of the earth system**

NS.5-8.6 Personal and Social Perspectives

- **Populations, resources, and environments**

NS.9-12.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.9-12.4 Earth and Space Science

- **Geochemical cycles**

NS.9-12.6 Personal and Social Perspectives

- **Natural resources**

NS.9-12.7 History and Nature of Science

- **Nature of scientific knowledge**

Technology:

NT.K-12.2 Social, Ethical and Human Issues

- **Students practice responsible use of technology systems, information, and software.**

NT.K-12.3 Technology Productivity Tools

- **Students use technology to enhance learning, increase productivity**

GLACIERS

To compliment the NPS Views Glaciers Knowledge Center

Photo By Dave Krueger

Enter the knowledge center by clicking on: **Explore Glaciers,** and then follow the directions to navigate through the **Introduction** section.

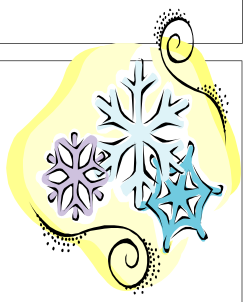
What Glaciers Are

*Click on : **What glaciers are***

What are the 3 main criteria for being a glacier?

1. _____
2. _____
3. _____

*Click on : **Made of Ice***



List the 2 features of **ice crystals** that are significant to glaciers, and then click on each topic to complete the questions below:

1. _____

   Complete the following sentence:

   Ice crystals are _____ and as a result they can _____ under their own weight.

2. _____

   Describe the density of water:

*Click on : **Form on Land***

Is the following sentence true or false? Circle one: TRUE FALSE

All glaciers must form on land, but can later move out to sea.

Click on : ***Glaciers move***

What are 2 ways that glaciers move?

1. _____

Remember: Ice crystals are weak, allowing glaciers to buckle and deform under their own weight.

2. _____

Tip: Think of a slip-n-slide!

Glossary

Select the glossary link at the bottom right portion of the screen to define the following terms.

Define: ***Plucking***

Define: ***Abrasion***

Where Glaciers Are Found

Click on : ***Precipitation***

Read the text and circle which factor is more important than the other:

Kind of precipitation vs. Total annual precipitation

Amount of snow vs. Conservation of snow

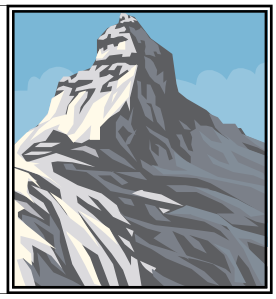
Click on : ***Temperature***

What is the most significant heat source that a glacier receives?

*Click on : **Relief***

Complete the following sentence:

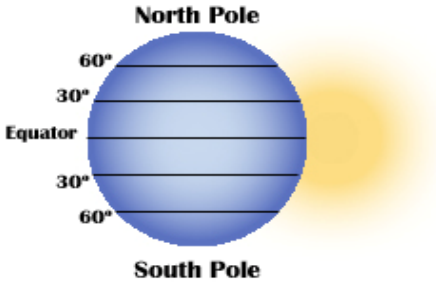
_____ *exerts a powerful influence over glaciation.*



*Click on : **Latitude***

Complete the following sentence:

High latitudes receive _____ annual solar radiation and experience prolonged _____ at sub-zero temperatures.

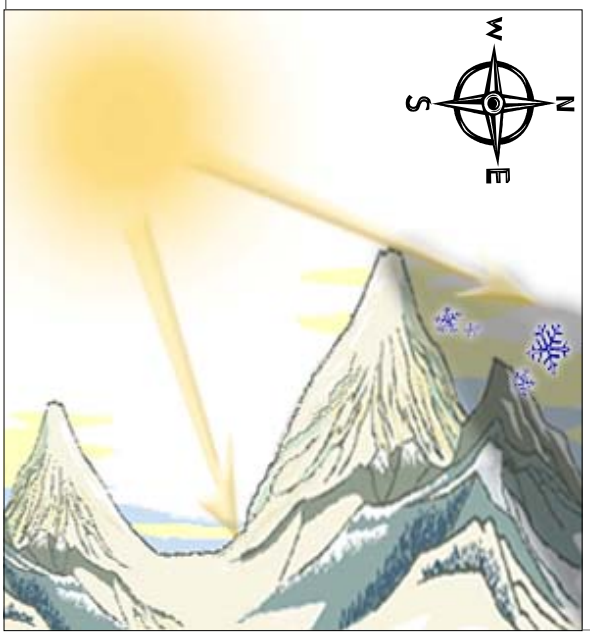


*Click on : **Altitude***

Where are glaciers found at the South Pole? _____

Where are glaciers found at mid to low latitudes? _____

*Click on : **Aspect***



The orientation of the ground surface with respect to incoming solar radiation is important to the existence of glaciers.

In the Northern Hemisphere, which slopes receive the least direct solar radiation?

Types of Glaciers

Click on : ***Types of Glaciers***

How are glaciers most easily differentiated (how best do you tell them apart)?

_____ and _____

Click on : ***Ice Sheets***

Ice sheets and ice caps fall into the same category. Which one is larger?

_____

What are the 2 main components of ice sheets and ice caps?

1.

2.

Click on : ***Ice Shelf***

Describe an ice shelf:

Is the following sentence true or false? Circle one: TRUE FALSE

If a glacier is considered to be an ice shelf then it is no longer attached to land.

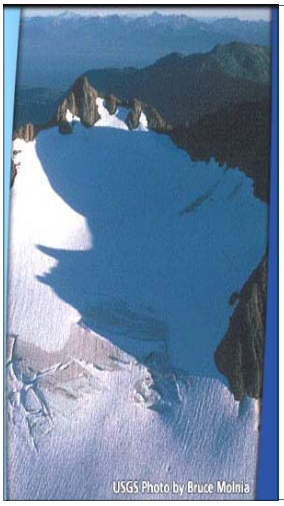
Click on : ***Icefield***

The surface of an icefield is approximately: _____

Click on : ***Valley Glacier***

Where might a valley glacier originate?

_____ or _____



Click on : ***Cirque Glacier***

Complete the following sentence describing a cirque glacier:

A small ice mass generally _____ in relation to its _____.

What characteristic shape does a cirque glacier occupy?

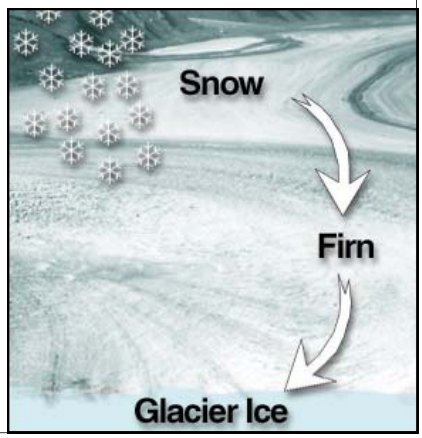
Glossary

Select the glossary link at the bottom right portion of the screen to define the following terms.

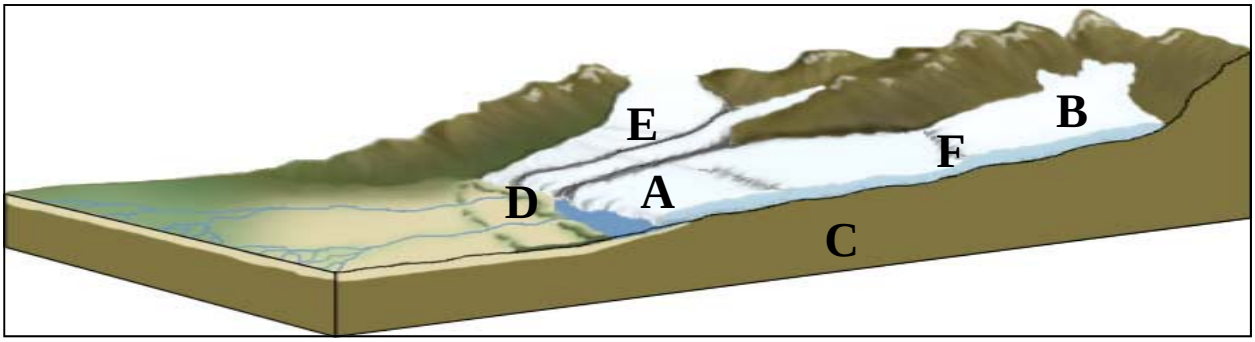
Define: ***Accumulation***

Define: ***Ablation***

Define: ***Firn***



Parts of a Glacier



Click on : ***Parts of a Glacier***

Match the following terms with their definitions below:

A. Ablation Zone
B. Accumulation Zone
C. Bed
D. Terminus
E. Firn Line
F. Equilibrium Line

__ This is not part of a glacier, but directly interacts with the glacier.

__ This is the highest level to which winter snow cover retreats on a glacier.

__ This is the part of the glacier's surface over which ablation (wastage) exceeds accumulation each year.

__ The part of a glacier's surface over which more snow is deposited than ablated each year.

__ The boundary between areas of gain and loss on a glacier's surface during one year. This is where accumulation meets ablation, and the net balance of snow is zero.

__ The end or lowest part of a glacier.

DAY 3

GLACIERS WEBQUEST

ANSWER KEY

GLACIERS—Answer Key

To compliment the NPS Views Glaciers Knowledge Center

Photo By Dave Krueger

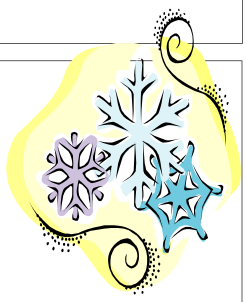
Enter the knowledge center by clicking on: **Explore Glaciers,** and then follow the directions to navigate through the **Introduction** section.

What Glaciers Are

Click on : ***What glaciers are***

What are the 3 main criteria for being a glacier?

1. ***MADE OF ICE***
2. ***FORM ON LAND***
3. ***GLACIERS MOVE***



Click on : ***Made of Ice***

List the 2 features of **ice crystals** that are significant to glaciers, and then click on each topic to complete the questions below:

1. ***STRUCTURE***

   Complete the following sentence:

   Ice crystals are ***WEAK*** and as a result they can ***DEFORM*** under their own weight.

2. ***DENSITY***

   Describe the density of water:

   WATER IS A SUBSTANCE THAT IS LESS DENSE IN ITS SOLID FORM THAN IN ITS LIQUID

Click on : ***Form on Land***

Is the following sentence true or false? Circle one: TRUE FALSE

All glaciers must form on land, but can later move out to sea.

Click on : ***Glaciers move***

What are 2 ways that glaciers move?

1. ***INTERNAL DEFORMATION***

Remember: Ice crystals are weak, allowing glaciers to buckle and deform under their own weight.

2. ***BASAL SLIDING***

Tip: Think of a slip-n-slide!

Glossary

Select the glossary link at the bottom right portion of the screen to define the following terms.

Define: **Plucking**

THE MECHANICAL REMOVAL OF PIECES OF ROCK FROM A BEDROCK FACE THAT IS IN CONTACT WITH GLACIER ICE. BLOCKS ARE QUARRIED AND PREPARED FOR REMOVAL BY THE FREEZING AND THAWING OF WATER IN CRACKS, JOINTS, AND FRACTURES. THE RESULTING PIECES ARE FROZEN INTO THE GLACIER ICE AND TRANSPORTED AWAY.

Define: **Abrasion**

ABRASION IS THE MECHANICAL WEARING, GRINDING, SCRAPING, OR RUBBING AWAY (OR DOWN) OF A ROCK SURFACE BY FRICTION AND IMPACT, IN THIS CASE BY ROCKS AND ROCK FRAGMENTS FROZEN IN A GLACIER.

Where Glaciers Are Found

Click on : ***Precipitation***

Read the text and circle which factor is more important than the other:

Kind of precipitation vs. Total annual precipitation

Amount of snow vs. Conservation of snow

Click on : ***Temperature***

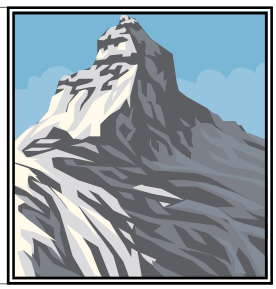
What is the most significant heat source that a glacier receives?

SOLAR RADIATION

*Click on : **Relief***

Complete the following sentence:

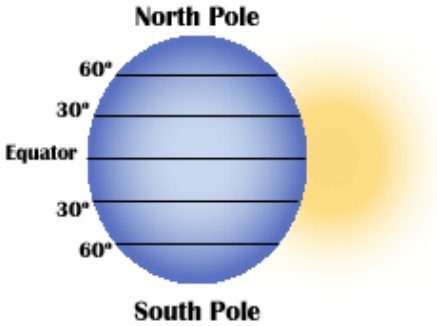
____*TOPOGRAPHY*____ exerts a powerful influence over glaciation.



*Click on : **Latitude***

Complete the following sentence:

High latitudes receive ___*LESS*___ annual solar radiation and experience prolonged ___*WINTERS*_____ at sub-zero temperatures.

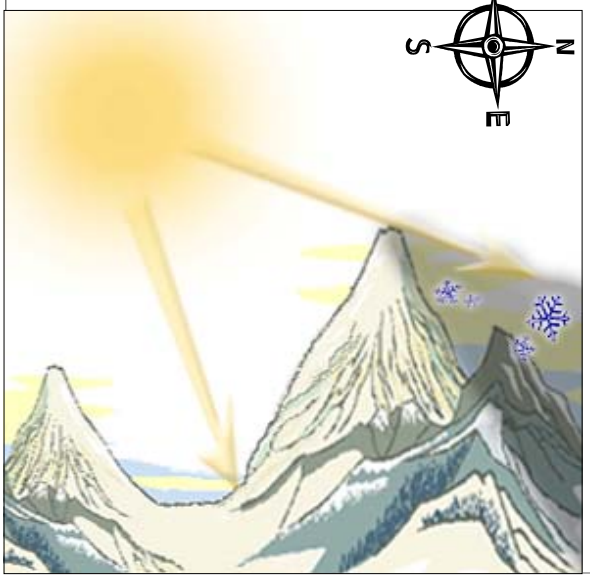


*Click on : **Altitude***

Where are glaciers found at the South Pole? *SEA LEVEL*

Where are glaciers found at mid to low latitudes? *HIGHLANDS*

*Click on : **Aspect***



The orientation of the ground surface with respect to incoming solar radiation is important to the existence of glaciers.

In the Northern Hemisphere, which slopes receive the **least** direct solar radiation?

STEEP, NORTH-FACING SLOPES

Types of Glaciers

*Click on : **Types of Glaciers***

How are glaciers most easily differentiated (how best do you tell them apart)?

TOPOGRAPHY and ***TEMPERATURE***

*Click on : **Ice Sheets***

Ice sheets and ice caps fall into the same category. Which one is larger?

ICE SHEETS

What are the 2 main components of ice sheets and ice caps?

1. ***ICE DOMES***
2. ***OUTLET GLACIERS***

*Click on : **Ice Shelf***

Describe an ice shelf:

A VERY THICK SHEET OF ICE THAT HAS BEEN PUSHED OUT OVER THE SEA FLOOR FROM A LAND-BASED GLACIER.

Is the following sentence true or false? Circle one: TRUE FALSE

If a glacier is considered to be an ice shelf than it is no longer attached to land.

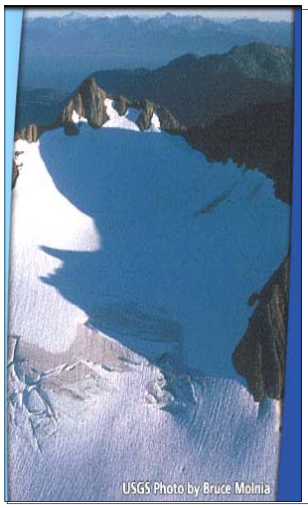
*Click on : **Icefield***

The surface of an icefield is approximately: ***LEVEL***

*Click on : **Valley Glacier***

Where might a valley glacier originate?

ICEFIELD or ***CIRQUE***



*Click on : **Cirque Glacier***

Complete the following sentence describing a cirque glacier:

A small ice mass generally ___***WIDE***___ in relation to its ___***LENGTH***___.

What characteristic shape does a cirque glacier occupy?

ARMCHAIR-SHAPED BEDROCK HOLLOW

Glossary

Select the glossary link at the bottom right portion of the screen to define the following terms.

Define: **Accumulation**

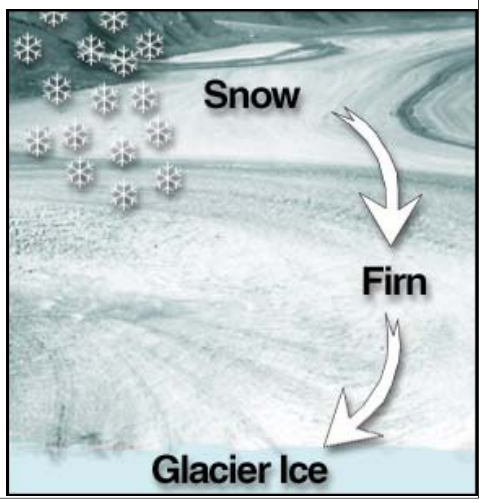
ACCUMULATION IS THE ADDITION OF ICE AND SNOW TO A GLACIER. THIS OCCURS THROUGH A VARIETY OF PROCESSES INCLUDING PRECIPITATION AND WIND DEPOSITION.

Define: **Ablation**

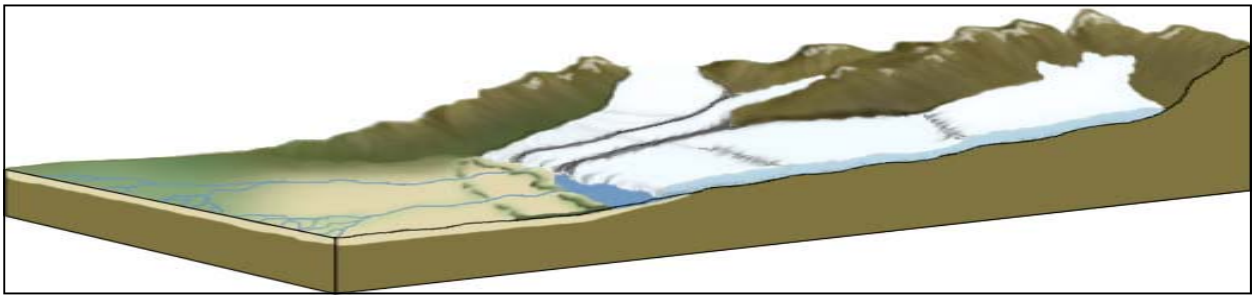
THE LOSSES IN GLACIAL BALANCE ARE PRODUCTS OF ABLATION. IN MOST GLACIERS, MELTING CONSTITUTES THE MAJORITY OF ABLATION, BUT EVAPORATION, SUBLIMATION , WIND EROSION, AND CALVING ALSO CONTRIBUTE TO NET LOSS.

Define: **Firn**

FIRN IS AN INTERMEDIATE STAGE IN THE TRANSFORMATION OF SNOW TO GLACIER ICE. SNOW BECOMES FIRN WHEN IT HAS BEEN COMPRESSED SO THAT NO SPACES REMAIN BETWEEN FLAKES OR CRYSTALS, A PROCESS THAT TAKES LESS THAN A YEAR.



Parts of a Glacier



Click on : ***Parts of a Glacier***

Match the following terms with their definitions below:

A. Ablation Zone
B. Accumulation Zone
C. Bed
D. Terminus
E. Firn Line
F. Equilibrium Line

C This is not part of a glacier, per se, but the direct interaction between a glacier and this part warrants mention.

E This is the highest level to which winter snow cover retreats on a glacier.

A This is the part of the glacier's surface over which ablation (wastage) exceeds accumulation each year.

B The part of a glacier's surface over which more snow is deposited than ablated each year.

F The boundary between areas of gain and loss on a glacier's surface during one year. This is where accumulation meets ablation, and the net balance of snow is zero.

D The end or lowest part of a glacier.

DAY 4
Activity #1

FEATURES OF EROSION

OBJECTIVE	Students will learn 11 key features of glacial erosion.
GRADES	Middle or High School students
DURATION	25 minutes
MATERIALS	▪ Copies of the *Features of Erosion* worksheet for each student ▪ *Features of Erosion* PowerPoint presentation ▪ Computer connected to a large classroom screen
KEY TERMS	Arête, cirque, fjord, glacial basin, hanging valley, horn, roche mountonnée, tarn, truncated spur, u-shaped (glacial) valley, whaleback

DAY 4
Activity #1

FEATURES OF EROSION

NATIONAL EDUCATION STANDARDS:

Science:

NS.5-8.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.5-8.4 Earth and Space Science

- **Structure of the earth system**

NS.5-8.6 Personal and Social Perspectives

- **Populations, resources, and environments.**

NS.5-8.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of science**

NS.9-12.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.9-12.6 Personal and Social Perspectives

- **Natural resources**

NS.9-12.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of scientific knowledge**

Name:

FEATURES OF EROSION

DAY 4
Activity #1

FEATURES OF EROSION

ANSWER KEY

FEATURES OF EROSION

Arête	*SHARP ROCK RIDGES BETWEEN TWO STEEP, GLACIALLY SCULPTED SLOPES*
Cirque	*STEEP-WALLED, GENTLE-FLOORED SEMICIRCULAR HOLLOWS FOUND HIGH IN MOUNTAINOUS AREAS.*
Fjord	*LONG, NARROW, DEEP ARM OF THE SEA FILLING A GLACIATED COASTAL MOUNTAIN VALLEY.*
Glacial Basin	*CLOSED BEDROCK BASIN CREATED BY LOCALIZED GLACIAL EXCAVATION. MANY OF THESE BASINS HARBOR LAKES.*
Tarn	*A SINGLE GLACIAL BASIN LAKE.*
Hanging Valley	*A GLACIER VALLEY THAT ENDS WHERE IT MEETS A DEEPER GLACIER VALLEY AND FORMS A CLIFF.*
Horn	*HIGH, SHARP, STEEP-SIDED PYRAMIDAL PEAK.*
Roche Mountonnée	*A GLACIAL LANDFORM THAT SHOWS BOTH ABRASION AND PLUCKING.*
Truncated Spur	*THE TOE OF A MOUNTAIN OR HILL THAT HAS BEEN ERODED AWAY BY A GLACIER.*
U-Shaped (Glacial) Valley	*A "U"-SHAPED VALLEY IS FORMED WHEN A GLACIER IS ABLE TO SCOUR ITS SIDES AS WELL AS ITS BASE. (THIS DIFFERS FROM RIVER VALLEYS WHICH HAVE A MORE CHARACTERISTIC "V" SHAPE.)*
Whaleback	*SMOOTH, GLACIALLY-SCULPTED BEDROCK KNOB OF MODEST SIZE RESEMBLING THE BACK OF A WHALE.*

DAY 4
Activity #2

NATURAL ARCHITECTS

PROCEDURE: Students work in pairs or small groups to set up a lab activity that will be completed the following school day.

The teacher should model the lab set-up procedure as the students follow the directions on the lab preparation sheet.

GRADES: Middle to high school students

DURATION: 20 minutes

MATERIALS:

- Paper plate
- Paper cups
- Tap water
- Gravel or course sand
- Plastic wrap
- Tape
- Copies of the *Natural Architects* lab activity preparation sheet for each pair or small group of students.

NATURAL ARCHITECTS

◆ HOW GLACIERS SHAPE THE LAND ◆

LAB ACTIVITY PREPARATION

Materials:

1. Paper cup
2. Tap water
3. Gravel or course sand (enough to fill about ½ of your cup)
4. Plastic wrap
5. Tape
6. Paper plate

Procedure:

1. For this activity you will need to work with a partner or in a small group.
2. Fill ½ your cup with gravel or sand.
3. Fill the cup with water until there is about an inch of water over the rocks.
4. Securely tape plastic wrap over the top of the cup.
5. Flip the cup onto the paper plate.
6. Write your group's name on the paper plate.
7. Leave the inverted cup (on the plate) in a freezer overnight.

DAY 5

NATURAL ARCHITECTS

HOW GLACIERS SHAPE THE LAND

OBJECTIVE Students will be able to demonstrate and understand the processes associated with glaciation in a hands-on glacier activity.

GRADES Middle or High school students

DURATION 1 50-minute class period

MATERIALS

- Pre-made "glacier"
- Paper towels
- Unglazed brick or flat paving brick
- Flat limestone rock
- Smooth piece of wood
- Protective or plastic gloves

KEY CONCEPT Glacial scouring

DAY 5

NATURAL ARCHITECTS

HOW GLACIERS SHAPE THE LAND

NATIONAL EDUCATION STANDARDS

Science:

NS.5-8.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.5-8.4 Earth and Space Science

- **Structure of the earth system**

NS.5-8.6 Personal and Social Perspectives

- **Populations, resources, and environments.**

NS.5-8.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of science**

NS.9-12.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.9-12.6 Personal and Social Perspectives

- **Natural resources**

NS.9-12.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of scientific knowledge**

Name:

NATURAL ARCHITECTS

◆ HOW GLACIERS SHAPE THE LAND ◆

Purpose: This activity will demonstrate the processes associated with glaciation.

Materials:

1. Your group's "glacier"
2. Paper towels
3. Unglazed brick or flat paving brick
4. A flat limestone rock (optional)
5. Smooth piece of wood
6. Protective or plastic gloves

Procedure:

1. Get the glacier that your group made.
2. Un-wrap the plastic wrap and peel off the paper cup.
3. Once you have put your gloves on, perform the following steps for the brick, the wood, and the rock (if you have one).
   a. With the gravel side down, scrape your glacier across your object.
      i. To simulate the movement of a glacier, you should only scrape in one direction.
      ii. It may be necessary to scrape, in the same direction, a number of times before you get any results.
   b. Draw any patterns you see in the table below.

Patterns		
Wood	**Brick**	**Rock**

   c. Record your observations in the Observations table on the following page.
      i. Was the surface of your object or glacier scratched?
      ii. Was any material removed from your object or glacier?

Name:

Observations		
Wood	**Brick**	**Rock**

Results:

1. What happened when you scraped the glacier against the wood?

2. What happened when you scraped the glacier against the rock?

3. What happened when you scraped the glacier against the brick?

Making a Connection:

1. What can you infer about the way that real glaciers affect the landforms over which they move?

2. If evidence of glacial scouring is found in an area that is too warm for glaciers to exist, what can you infer about the past climate of that area?

DAY 6
Activity #1

HOW GLACIERS MOVE

OBJECTIVE After going through 3 mock glacier experiments, students will understand the various processes involved with glacial movement and flow.

GRADES Middle or High School students

DURATION 25 minutes

MATERIALS

- Copies of the *How Glaciers Move* worksheet for each student
- *Glaciers Experiments* PowerPoint presentation
- Computer connected to a large classroom screen

KEY CONCEPTS Glacial movement: basal slip, internal flow

KEY TERMS Zone of accumulation, zone of ablation, extending flow, extreme extending flow, compressive flow

DAY 6
Activity #1

HOW GLACIERS MOVE

NATIONAL EDUCATION STANDARDS

Science:

NS.5-8.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.5-8.4 Earth and Space Science

- **Structure of the earth system**

NS.5-8.6 Personal and Social Perspectives

- **Populations, resources, and environments.**

NS.5-8.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of science**

NS.9-12.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.9-12.6 Personal and Social Perspectives

- **Natural resources**

NS.9-12.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of scientific knowledge**

Name:

HOW GLACIERS MOVE

EXPERIMENT #1: A VIEW FROM ABOVE

Background:

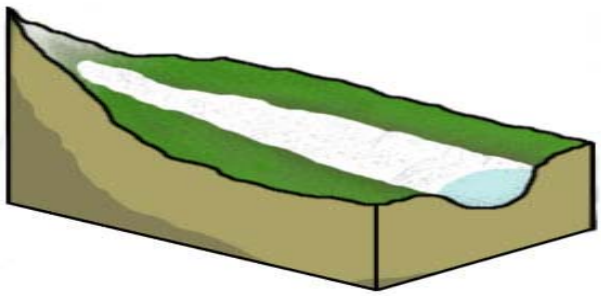
One of the main criteria for being a glacier is that it must move or flow. Glaciers internally flow as a result of the snow inside buckling and deforming under its own weight. At the center of a glacier, where the ice is thickest, the deformation is greatest. Therefore, the glacier flows more rapidly at the center than at the edges where the glacier isn't as thick.

Experiment:

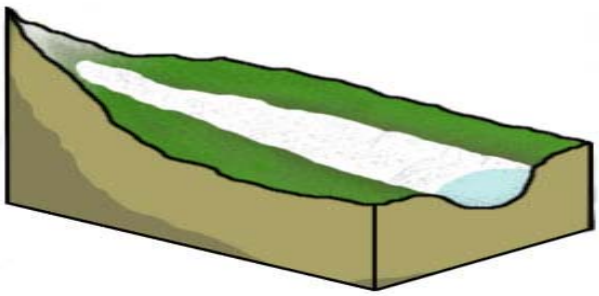
Suppose stones are placed in a straight line across the surface of a valley glacier. After a year or two, the line of rocks would no longer be straight. Where do you think the rocks would be after 1, 2 or 3 years?

1. ***Draw where the stones would be at the start and during the first, second, and third year.***

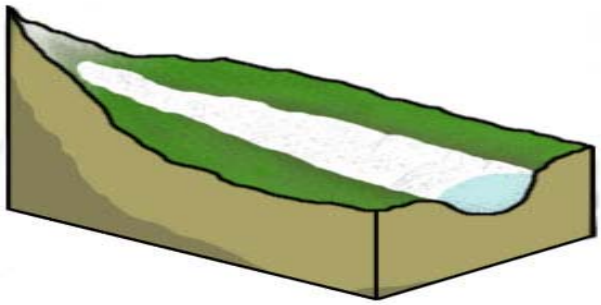
Start



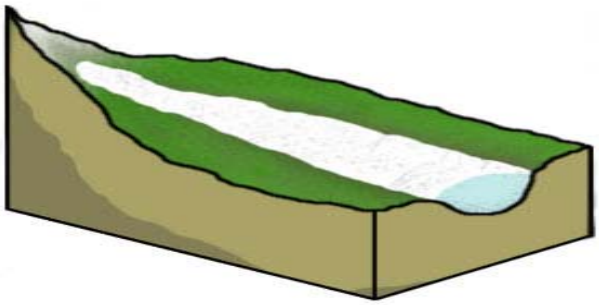
Year 1



Year 2



Year 3



Name:

EXPERIMENT #2: A SLICED VIEW

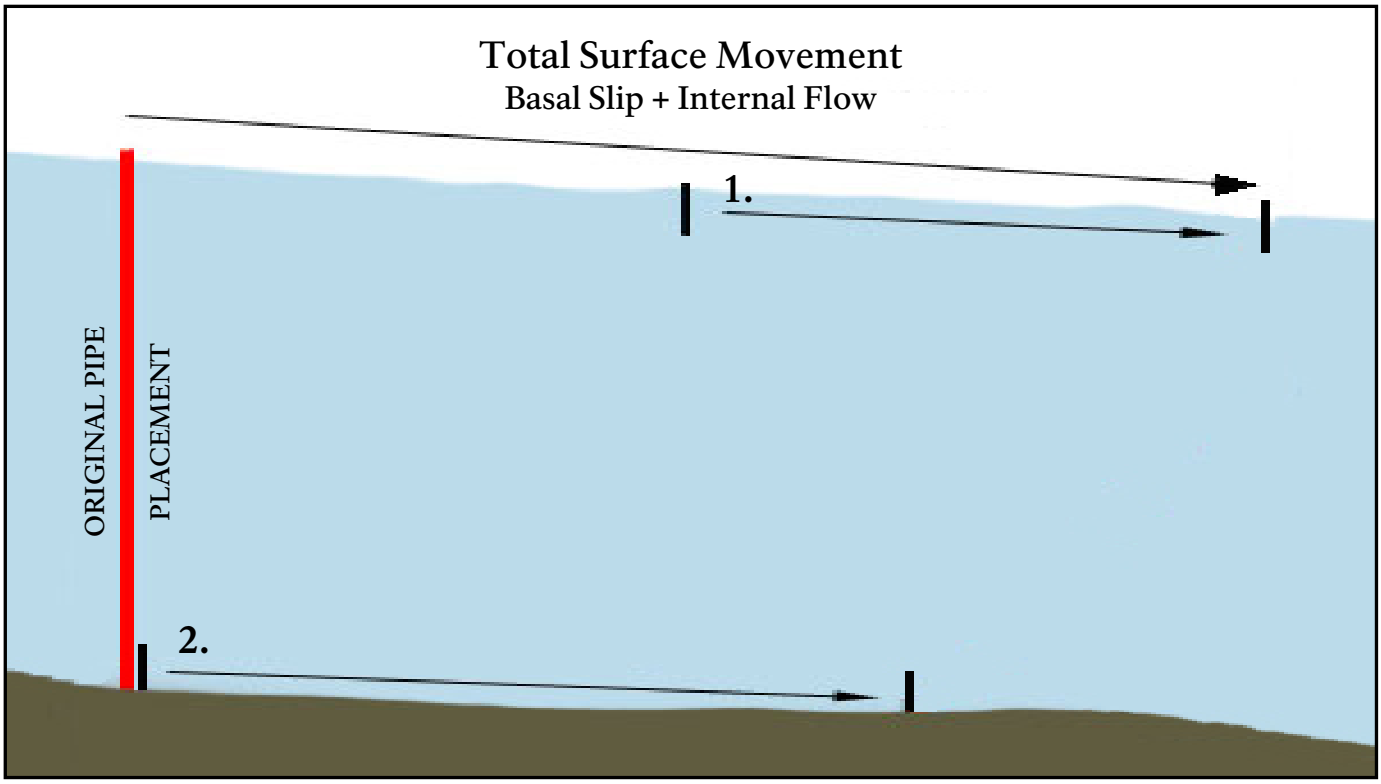
Background:

Most glaciers move too slowly for us to see. However, as a glacier slips and slides on its bed a number of mechanisms and processes are at work. One process, called **basal sliding**, occurs when a thin layer of water forms at the base of a glacier and significantly reduces the friction between the glacier and its bed. In certain situations, this may cause a glacier to float across the landscape. How does this happen? Think back to what you know about the density of water: Water is a substance that is less dense in its solid form than in its liquid form, and this property is what makes basal sliding possible.

Experiment:

Suppose a bendable pipe is inserted into a deep, narrow hole that was drilled vertically through a glacier from top to bottom. In a year or two, the inclination (slant) and position of the pipe would change. The pipe would be bent into a curve by the internal flow at the top of the glacier. In addition to the pipe bending, it would also have moved down-valley, revealing that the glacier slipped over its bed.

1. ***Label the: <u>Basal Slip</u> and <u>Internal Flow</u>***
2. ***Draw where you think the pipe will be after a couple years.***



http://www.nature.nps.gov/views/

Name:

EXPERIMENT #3: MYSTERIOUS MOVEMENT

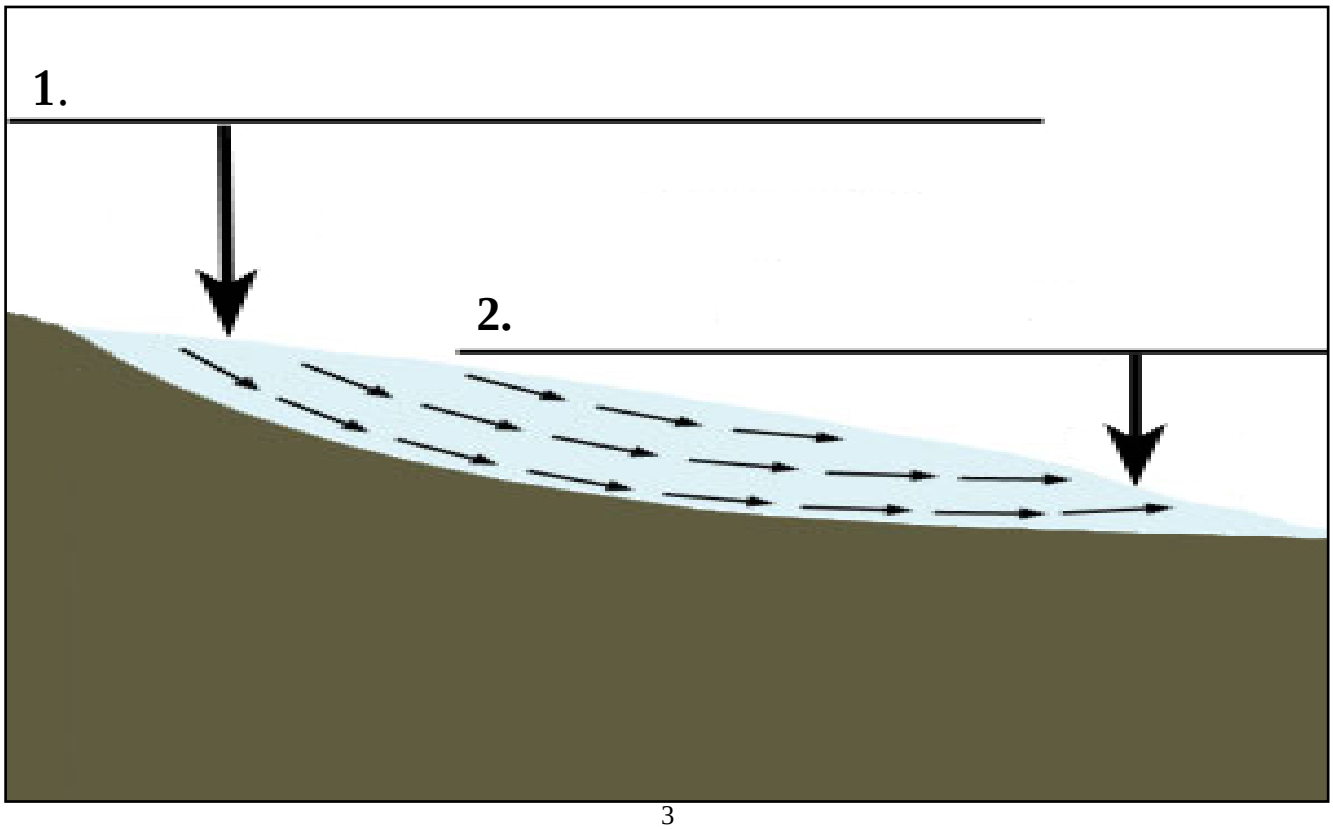
Background:

For this experiment you need to understand the difference between the ablation zone and the accumulation zone of a glacier. Glacial ablation refers to the reduction of a glacier due to melting or evaporation. Therefore, the ablation zone refers to the part of a glacier's surface over which ablation (wastage) exceeds accumulation each year. The accumulation zone is the part of a glacier's surface over which more snow is deposited than is ablated (wasted away) each year. The basic pattern of flow in the accumulation zone is downward, but it changes to upward in the ablation zone. This is due to variations in ice movement, which we will learn about next.

Experiment:

Suppose a child broke their mother's favorite vase while playing baseball indoors and foolishly wished to dispose of the pieces in a glacier. The child would eventually realize the error of not taking into consideration the vertical component of glacial movement. If the vase is buried in the accumulation zone, it will ultimately emerge in the ablation zone and the mother would find it.

Label the: ***<u>Zone of Accumulation</u>*** ***and*** ***<u>Zone of Ablation</u>***

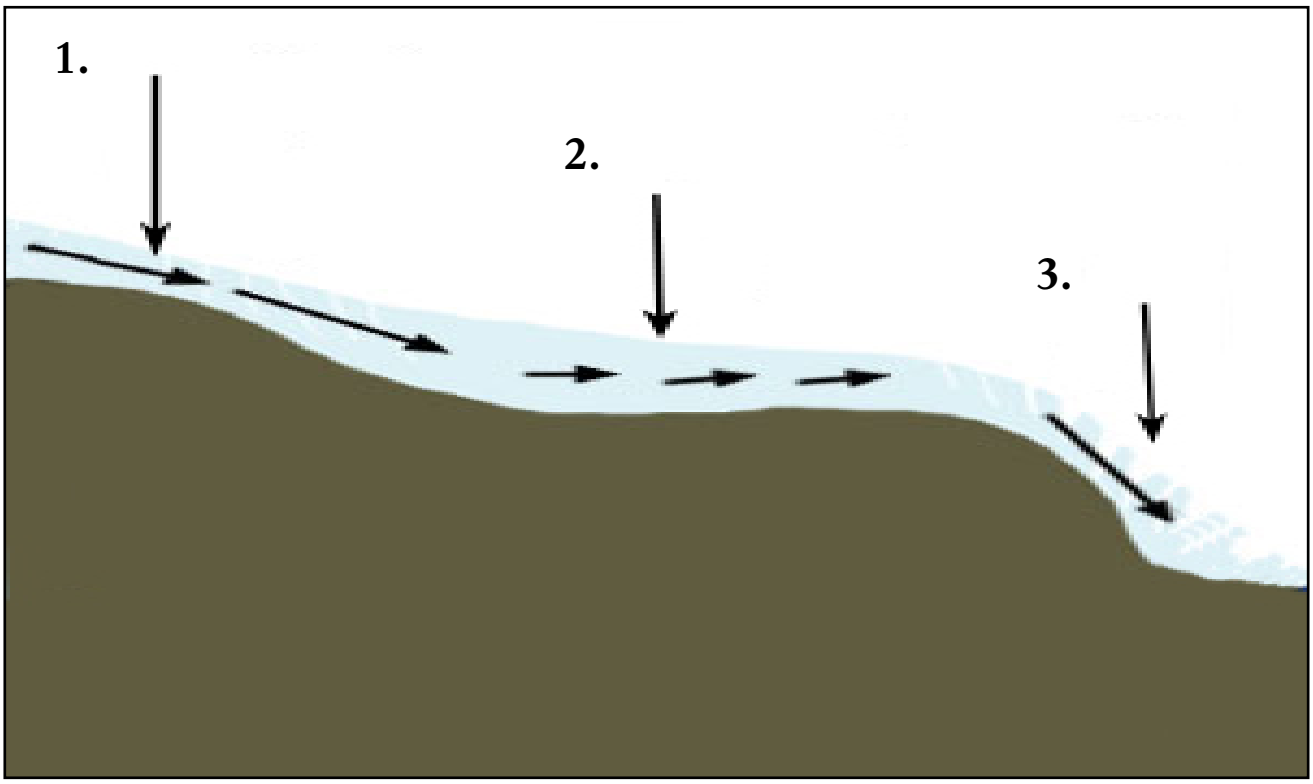


Name:

Background:

Variations in ice movement are associated with two different types of flow within a glacier: extending flow and compressive flow. In extending flow, a glacier is spread out and thinned because it is accelerating and does not have an opportunity to build up. When the flow is greatly accelerated, like in an icefall, the glacier is even more extended and thinned. This is called an extreme extending flow. The opposite occurs when the flow is decreasing. Slower flows allow the glacier to build up, in turn causing the glacier to compress under its own weight. This is called a compressive flow.

1. ***Label the:***
    a. ***<u>Extending Flow</u>***
    b. ***<u>Extreme Extending Flow</u> (Icefall)***
    c. ***<u>Compressive Flow</u>***



Name:

Questions:

1. **Where is ice thickest in a glacier?**

2. **Does ice move faster in the center of a glacier or at its edges?**

3. **What are the 2 main types of glacial movement?**

4. **What is the basic pattern of flow in the accumulation zone?**

5. **What is the basic pattern of flow in the ablation zone?**

6. **What is the name for an extreme extending flow?**

DAY 6
Activity #1

HOW GLACIERS MOVE

ANSWER KEY

Questions: Answer Key

1. Where is ice thickest in a glacier?

   Ice is thickest at the center of the glacier.

2. Does ice move faster in the center of a glacier or at its edges?

   Ice moves the fastest at the center of the glacier.

3. What are the 2 main types of glacial movement?

   Basil Slip and Internal Flow

4. What is the basic pattern of flow in the accumulation zone?

   Downward

5. What is the basic pattern of flow in the ablation zone?

   Upward

6. What is the name for an extreme extending flow?

   Icefall

DAY 6
Activity #2

FEATURES OF DEPOSITION

OBJECTIVE

Students will learn the key features of glacial deposition via a presentation of glacier images and corresponding text.

GRADES

Middle or High School students

DURATION

20 minutes

MATERIALS

- Copies of the *Features of Deposition* worksheet for each student
- *Features of Deposition* PowerPoint presentation
- Computer connected to a large classroom screen

KEY TERMS

Braided streams, drumlin, erratics, esker, kame, kettle, moraines, till

DAY 6
Activity #2

FEATURES OF DEPOSITION

NATIONAL EDUCATION STANDARDS

Science:

NS.5-8.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.5-8.4 Earth and Space Science

- **Structure of the earth system**

NS.5-8.6 Personal and Social Perspectives

- **Populations, resources, and environments.**

NS.5-8.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of science**

NS.9-12.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.9-12.6 Personal and Social Perspectives

- **Natural resources**

NS.9-12.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of scientific knowledge**

Name:

FEATURES OF DEPOSITION

DAY 6
Activity #2

FEATURES OF DEPOSITION

ANSWER KEY

Name:

FEATURES OF DEPOSITION

Braided Stream	*A network of intertwining stream channels resembling the strands of a complex braid.*
Drumlin	*A low, streamlined mound of glacial till shaped by an overriding glacier.*
Erratics	*Large boulders that end up stranded when glaciers recede.*
Esker	*A long, low ridge of sand and gravel that was deposited by meltwater.*
Kame	*Sand and gravel deposits formed by running water on stagnant or moving glacier ice.*
Kettle	*Depressions that form when a block of ice becomes buried in sediment and then melts, leaving a pit behind.*
Moraines	*Accumulations of till and other sediments.*
Till	*A poorly-sorted mixture of fine and coarse rock debris deposited directly from glacial ice.*

GLACIAL RETREAT

QUANTIFYING CHANGES IN GLACIER COVER OVER TIME

PURPOSE To enable students to analyze changes in glacier cover over time using satellite images.

GRADES Middle or High School Students

DURATION 1 50-minute class period

MATERIALS *The following materials are available to download and print:*

- *Glacier Retreat* worksheet for each student
- Cover change grid for each pair of students - **You will need to transfer the ready-made grid to a transparency sheet.**
- NASA Landsat images for each pair of students

The following materials need to be acquired:

- Transparency sheets
- Markers with fine points for writing on transparencies

KEY CONCEPTS Glacial retreat and cover change; analyzing land change over time; using technology to introduce students to the perspective of space-based observations

CREDIT Team members from the Views of the National Parks and the NASA Landsat Program worked to adapt this activity from a lesson plan created and produced by the NASA Landsat Education Team:

http://landsat.gsfc.nasa.gov/education/resources/Landsat_QuantifyChanges.pdf

DAY 7

GLACIAL RETREAT

NATIONAL EDUCATION STANDARDS

Science:

NS.5-8.1 Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

NS.5-8.4 Earth and Space Science

- Structure of the earth system

NS.5-8.6 Personal and Social Perspectives

- Populations, resources, and environments

NS.9-12.1 Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

NS.9-12.4 Earth and Space Science

- Geochemical cycles

NS.9-12.6 Personal and Social Perspectives

- Natural resources

NS.9-12.7 History and Nature of Science

- Nature of scientific knowledge

Technology:

NT.K-12.2 Social, Ethical and Human Issues

- Students practice responsible use of technology systems, information, and software.

NT.K-12.3 Technology Productivity Tools

- Students use technology to enhance learning, increase productivity

Math:

NM.ALG.6-8.3

- Use mathematical models to represent and understand quantitative relationships.

NM.ALG.9-12.3

- Use mathematical models to represent and understand quantitative relationships.

GLACIAL RETREAT

DAY 7

LESSON DESCRIPTION:

Students will work in pairs using NASA Landsat satellite images to analyze changes in glacier cover over time of Bear Glacier, Kenai Fjords National Park.

SUGGESTED INSTRUCTIONAL LESSON PLAN:

1. Introduction to the lesson	----------	2 minutes
2. Read through **Glacial Retreat** introduction section	----------	8 minutes
3. Ask questions concerning the introduction	----------	1 minute
4. Grid Counting demonstration by teacher	----------	2 minutes
5. Students complete up to Procedure #7	----------	20 minutes
6. Teacher writes student results on the board	----------	5 minutes
7. Students calculate class average & finish worksheet	----------	10 minutes
8. Wrap-Up and Question Answering	----------	2 minutes

ADDITIONAL RESOURCES:

1. The *Views of the National Parks* (*Views*) multimedia education program has developed a comprehensive module on Glacier information. To access this module, and to see what other resources the *Views* program can offer your classroom, go to: http://www.nature.nps.gov/views/
   a. Once you are inside the *Views* program, select the Visitor Center, then the Knowledge Centers, and then the Glaciers module.
2. For more information about the Landsat program, including where to find more images, data, and education resources for both formal and informal settings, go to: http://landsat.gsfc.nasa.gov
3. The following documents are included for the purpose of being additional classroom resources:
   a. National Park Service bulletin on climate change in national parks.
   b. National Park Service bulletin on climate change and melting glaciers.
   c. National Park Service bulletin on climate change and biotic patterns in Glacier National Park.

GLACIAL RETREAT

KENAI FJORDS NATIONAL PARK:

K.F.N.P is located on the southeastern portion of Alaska's Kenai (pronounced: Key-nigh) Peninsula, bordering the Gulf of Alaska. Along the coastline of the park, glaciers have cut deep valleys into the mountains. As the glaciers retreat, these coastal valleys are filled with seawater, creating fjords.

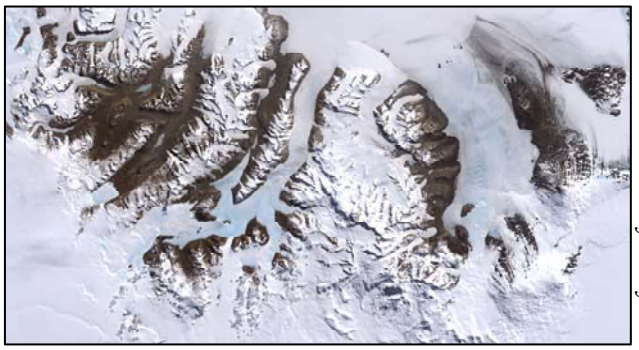
Glaciers are retreating not only along Kenai Fjord's coast, but all throughout the park. In fact, most of Alaska's estimated 10,600 glaciers are melting. Monitoring the glaciers can help determine why they are retreating.

MONITORING GLACIERS:

Glacier-monitoring efforts in national parks provide valuable information to park managers, as well as to the scientific community at large, about the effects of regional and global climate change. However, direct observations of glaciers are often difficult because they exist in cold, Polar Regions or high mountain areas that are inaccessible or inhospitable to humans. Furthermore, ice sheets and ice caps are so huge and change so slowly that repeated measurements are needed over large areas and long periods of time. Until recently, glaciologists had no accurate means of seeing the aerial extent of glacier ice on Earth.

IMAGES FROM SPACE:

Satellite images provide scientists aerial views of glaciers, and a major source of these images has been provided by the Landsat Program. The Landsat Program is a series of Earth-observing satellite missions jointly managed by NASA and



Landsat Photo - Dry Valley

the U.S. Geological Survey. Since 1972, Landsat satellites have collected information about Earth from space by taking specialized digital photographs of Earth's continents and surrounding coastal regions. The Landsat program has been collecting images for over three decades, enabling people to see and study the dynamic changes caused by both natural processes and human practices.

One way to evaluate these changes is to compare images of a single area over an extended period of time. Two satellite images taken at different times of the same location are called *change pairs* and are frequently used by glaciologists to evaluate changes in a glacier.

BEAR GLACIER:

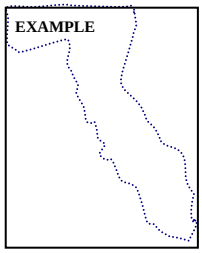
This lesson utilizes change pair images of Bear Glacier in Kenai Fjords National Park. Changes in precipitation have caused Bear Glacier to recede. As glaciers recede, they leave behind rock and debris, which is called a moraine. Bear Glacier, as it retreated, paused long enough to build up a sizeable moraine. In fact, the beach in front of Bear Glacier is an old recessional moraine that has cut off Bear Glacier's access to the tidewater's edge. As a result, Bear Glacier, once classified as a tidewater glacier, is now a terrestrial glacier.

LESSON DESCRIPTION:

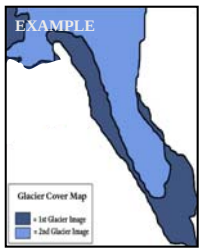
In this activity, you will use satellite images from the NASA Landsat team to quantify changes in glacier cover over time. The first image was taken on September 12, 1986, and the second was taken on July 30, 2002.

PROCEDURE:

1. Together with your partner, visually identify the areas in each image that are covered by Bear glacier.
   a. Be careful not to include the icebergs floating in the lake or snow that has collected in the mountains that is not part of the glacier itself.
2. Place the transparency with the cover change grid over the image from 1986, and tape the corners of the transparency to the image.
3. One partner will hold the image while the other partner outlines the glacier cover on to the transparency with a colored marker.
   a. It is very important to distinguish between the glacier and the clouds, therefore, an option for this activity is to trace around only the long extension of the glacier (see outline example on the right).



4. Make a legend for your transparency cover change grid, which is now becoming a glacier cover map (see example map and legend to the right).
5. Place the transparent glacier cover map you just made over the 2002 image of Bear Glacier and tape the corners to hold it in place.
6. Using a different color of marker than you used in step 3, trace the outline of the 2002 glacier on the transparency grid.



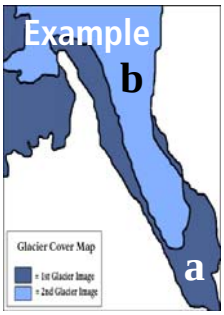
7. Count and record the number of grid squares representing a change in glacier cover. It will take both partners to do this:
   a. One partner will compare the transparency map to the 2002 satellite image and identify the grid squares that show glacier change.
      i. You may notice that some squares contain land that is only partially covered by the glacier. In this case, the most dominant cover type should be used.
   b. The other partner will mark the equivalent changed squares using the <u>Cover Change Grid</u>.
      i. Work from the upper left to the upper right across each row, putting a dot in each square that represents a change in glacier cover.
8. Once you have determined how many grid squares represent a change in glacier cover, you will use this information to calculate the percent cover change in the satellite images provided of Bear Glacier.
9. Your teacher will ask for everyone's results and then list them on the board. Write them down and then use them to calculate the class average.

Name :

A. RESULTS

1. What is Bear Glacier's coverage in the 1986 image? _____ grid squares (a)
2. What is Bear Glacier's coverage in the 2002 image? _____ grid squares (b)
3. What is the difference in coverage between 1986 and 2002? _____ grid squares (c)

B. CALCULATING PERCENT COVER CHANGE IN BEAR GLACIER



To calculate the percent change in glacier cover, you are looking for the change (x) that occurred in the original amount (a).

This proportion can be represented mathematically as $^{x}/_{100}$.

Set up the proportion for the percent of change equal to the values that represent the 1986 and 2002 glacier cover: $\frac{x}{100} = \frac{c}{a}$

Plug in your values for (a) and (c) and then solve for (x).

C. GO THE EXTRA MILE

1. Using the scale from the original satellite images, convert your cover change value from grid squares to miles^2.

   Hint: look at how many grid squares equals 1 square mile and plug that into the formula below.

_____ (grid squares) X _____ (miles^2) / (grid squares) = _____ miles^2

C. COMPARING RESULTS

1. Calculate the class average for the percent glacier cover change using miles.

Record the class percent cover change values here.

Total = _____

1. What is the class average for the percent cover change in Bear Glacier? _____
2. What was the value you calculated in section B for the percent cover change? _____
3. What is the difference between your answer and the class average? _____

E. EVALUATION

1. How might you improve the accuracy of your map and your calculations? For example, did you trace your cover outline carefully? How accurately did you count the grid squares?

2. What effects do you think your method of data collection had on your results?

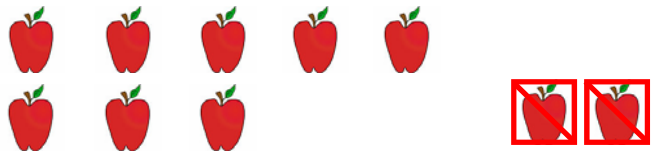
3. If the glacial retreat captured in the satellite images of Bear Glacier is typical of most glaciers, what do you think will happen to the glaciers worldwide in the next 50 years?

Math help for calculating the percent of cover change:

Example Problem:

If you have 5 apples….

and you take 2 away…



then you have 3 of the 5 original apples.

Remember…You are looking for the amount of **CHANGE**.

Change = (original - amount at the end) = (5 - 3) = 2

The **ratio** of the **amount changed** to the **original amount** would be expressed as:

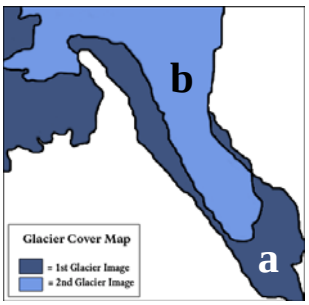
$$\frac{\text{amount of change}}{\text{original amount}} = \frac{2}{5}$$

To calculate the **percent change** in apples, you are looking for **change** (x) of the **original** amount you have, which would be (x) of 100%, or x / 100%.

Set up the proportion to solve for x:

$$\frac{2}{5} = \frac{x}{100\%} \xrightarrow{\text{solve for x}} \begin{aligned} 5 * (x) &= 2 * 100\% \\ 5x &= 200\% \\ x &= 40\% \end{aligned}$$

Calculating glacier cover:



This can also be applied to calculating the percent cover change in glacier cover using what you already know about the images:

Original amount of cover = **a**

Amount of cover that is left after the glacier retreats= **b**

Change in cover = (original cover - cover at the end) = **c**

Set up the proportion using the values above:

$$\frac{\text{change}}{\text{original amount}} = \frac{\text{value for c}}{\text{value for a}} = \frac{x}{100\%}$$

Now **solve for x**, which is the percent of cover change:

$$a * x = c * 100\%$$

http://www.nature.nps.gov/views/

Cover Change Grid

Use this worksheet to indicate grid squares representing changes in cover.

Draw a dot in each grid square that shows change, and if no change has occured, leave that square blank.

																																					A
																																					B
																																					C
																																					D
																																					E
																																					F
																																					G
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1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	

Cover Change Grid

Transparency

																																					A
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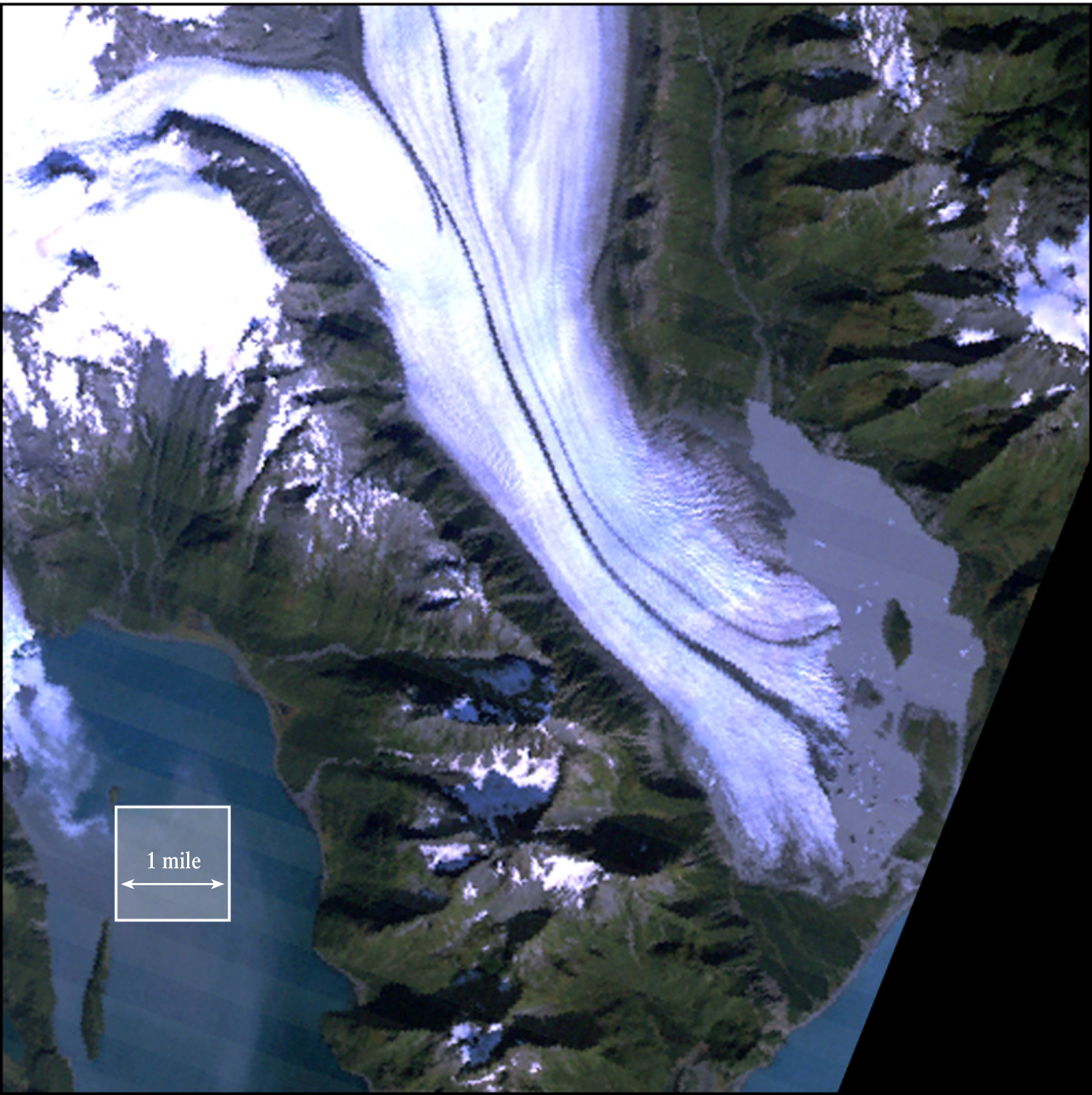
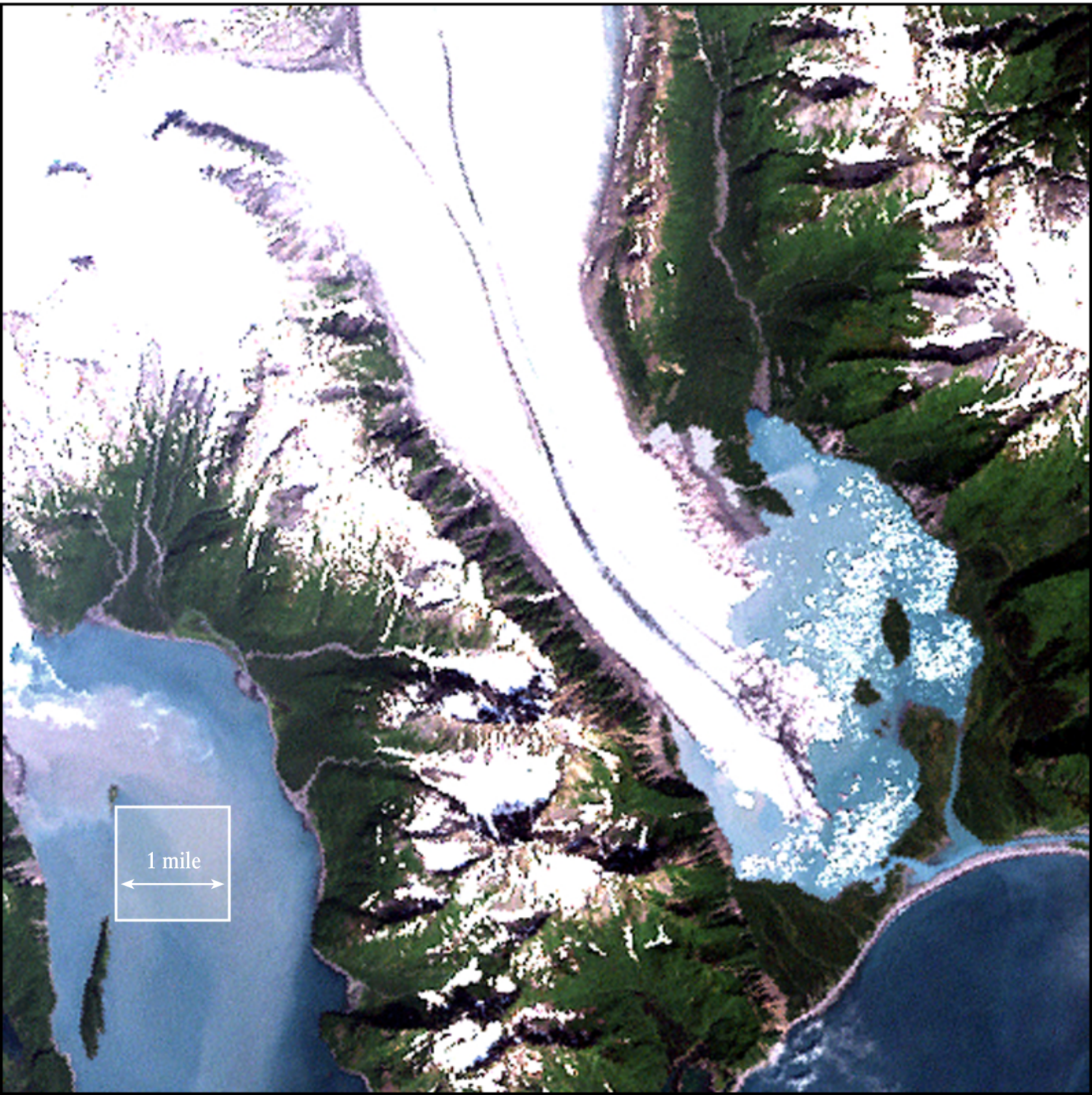
Bear Glacier - September 12, 1986

Landsat 5 Image courtesy NASA and USGS
http://landsat.gsfc.nasa.gov



Bear Glacier - July 30, 2002

Landsat 7 Image courtesy NASA and USGS
http://landsat.gsfc.nasa.gov



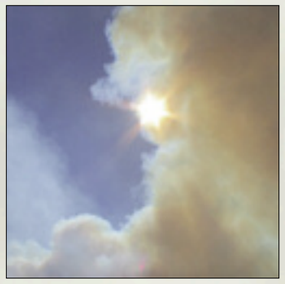
DAY 7

GLACIAL RETREAT

ADDITIONAL RESOURCES

Climate Change in National Parks

National Park Service
U.S. Department of the Interior



"Earth's climate is changing, with global temperature now rising at a rate unprecedented in the experience of modern human society."

–Arctic Climate Impact Assessment, 2004

Change has always been a powerful force of nature. National parks and the stories they represent help us understand and appreciate how much our lives are influenced by change. They illustrate for us how interconnected we are with our environment whenever change occurs.

Today, we hear more and more about the effects of "climate change." Scientists tell us there is little doubt that human activities are having a major impact on the atmosphere and ecosystems of our planet.

Glaciers and snow packs are melting, stream temperatures are going up, coastal erosion is increasing, and changes in weather patterns are leading to drought and heat waves both locally and regionally. According to researchers, the magnitude and pace of these changes, as well as additional ones that climatologists believe to be probable, are unprecedented in human history. Many of them have consequences that will affect the resources and influence the experiences for which the national parks were established. Regardless of their causes, we must do what we can to manage these impacts and adapt to the new circumstances they bring. Perhaps the same wisdom that has preserved our heritage in the past can guide us in making choices for the future.

Local "weather" is often confused with global "climate." Specific park records may reflect periods of warming or cooling depending on regional circumstances. Global mean temperature, on the other hand, is based on surface and atmospheric temperatures from thousands of locations, and from satellites worldwide. Global mean temperature has risen 0.8 degrees C, since 1880.

Climate Change is Happening

Warmer winters and longer, more intense melt seasons have increased the rate of glacial retreat in Alaska's Glacier Bay and Kenai Fjords National Parks. It is estimated by scientists with the U.S. Geological Survey that by 2030, many of the glaciers in Montana's Glacier National Park will be completely gone.

Muir Glacier, 1941 (left) and 2004 (right)
Glacier Bay National Park and Preserve

At parks like Bandelier National Monument, higher temperatures and drought have brought high mortality to the pinon pines as infestations of bark beetles have expanded to higher elevations and new ranges. At Everglades National Park, increasing sea level may overwhelm the mangrove communities that filter out saltwater and maintain the freshwater wetlands. At Canyon de Chelly National Monument, Mesa Verde and Rocky Mountain National Parks, floods and fires have damaged historic structures and are threatening the loss of archeological sites.

Changes have Consequences

Many climate change consequences make it difficult for park managers to preserve the resources unimpaired. Higher temperatures in spring and summer and earlier melting of the snow pack in recent years have contributed to an increase in the frequency and duration of wildland fires. Recent studies have concluded that a changing climate, not previous fire-suppression policies or land-use changes, is the major cause. The 2006 wildfire season has set a 45-year-high in the number of acres burned. Particularly at risk are plant and animal species that are more restricted in their needs for habitat, have limited ability to relocate, or have surrounding development that leaves them few options.

In Yosemite, the pika population is in danger of extinction as warming temperatures occur higher and higher on the mountainsides. With each season, the cool habitat in which they make their homes shifts further upslope. Eventually, if this continues, they may have nowhere higher to go.

Nutrient-rich whitebark pine seeds are a critical food source for the grizzly bears of Yellowstone. Warmer winters have enabled bark beetles to significantly increase mortality of whitebark pines over their entire American range with little sign of relief. Not only does this lower the grizzlies' survival rates, they are now more likely to experience human conflicts in their search for alternate foods.

Another dilemma for managers is occurring at Joshua Tree National Park. Joshua trees require cool winters and freezing temperatures in order to flower and set their seeds. Researchers have documented substantial mortality of Joshua trees and predict that because of climate warming, the trees will be unable to persist much longer within the park. Soon, Joshua trees may no longer be found in the park bearing their name.

Arrange for Change

We Must Do What We Can

While many changes to park resources are inevitable, they can still influence the ways in which visitors use and enjoy the parks. Closures are resulting from increased wildfires. Reduced winter snow pack and, in some cases, more rain, have changed the timing of surface runoff each year which often makes spring and summer water activities difficult or impossible. Salmon and trout populations, popular for fishing, are showing high mortality rates due to warming water and flooding. Indigenous users of these fisheries, especially in Alaska, are at risk to lose not only a food source, but a way of life. And winter seasons are opening later and closing earlier. Although this extends the season for activities like hiking and camping, it reduces opportunities for recreational skiing and other winter sports due to inadequate snow cover. Many of these impacts have economic implications.

Scientists who study climate change agree that human activities are a big part of the current warming trend. As stated in the 2001 report of the Intergovernmental Panel on Climate Change, "there is new and stronger evidence that most of the warming observed over the past 50 years is attributable to human activities." At Mauna Loa in Hawaii and around the world, specific evidence has been gathered of an increase in greenhouse gases in the atmosphere, predominantly carbon dioxide, which are contributing to the warming of the planet. Carbon dioxide levels in the atmosphere today are higher than they've been in over 650,000 years.

For our national parks to thrive and for us to continue enjoying them, it seems appropriate now to do what we can to reduce climate change impacts and adapt to their consequences. Fortunately, we have the tools, knowledge, and ingenuity to better understand these changes and make informed choices for coping with them. Prominent scientists are saying that our own survival may be at stake.

"What is the use of a house, if you haven't got a tolerable planet to put it on?"

-Henry David Thoreau

Parks and Scientists Provide Hope for the Future

National parks are helping us figure out how to respond to these changes. Parks across the nation are conducting "Climate Friendly Parks" workshops, co-sponsored by the Environmental Protection Agency, to evaluate energy usage and identify efficiencies that improve park operations. Many are developing alternate energy strategies to reduce their emissions of greenhouse gases. Use of solar and wind energy, fuel cells, electric and hybrid forms of transportation, and mass transportation where high visitation exists, are being developed. Vulnerable resources are being monitored in most parks, and several have researchers who are specifically addressing climate change impacts. And rangers in many parks are being trained and provided the latest reports about climate science in order to answer questions and assist visitors in understanding climate change and its implications.

Many times during our nation's history, citizens have confronted difficult circumstances and found creative solutions. Our parks tell compelling stories about the American Revolution, the abolition of slavery, the fight for civil rights, and about countless inspirational personalities who have made a difference for our nation. Many parks convey stories about people's responses over thousands of years to shifting climate patterns. These stories are now part of a call to action for all visitors in the stewardship of our resources for future generations. It is important that all of us participate in answering that call.

Scientists tell us we already possess the technologies needed to reduce the abundance of CO_2. They've also created strategies to do so within 50 years. Many of these actions involve choices that individuals can make to conserve and reduce energy use. One of the best strategies for coping with climate change on a personal level is to become "carbon neutral." Because we exhale carbon dioxide and need energy for our daily activities, we're unlikely to eliminate all impacts. However, if we reduce our energy use to a basic level, and offset the emissions we do generate by investing in clean alternatives, we may achieve balance and not further compromise global resources. Changing to energy efficient light bulbs and appliances, unplugging computers and electronic devices when they're not in use, and using public transportation whenever and as often as we can are good examples of conservation practices. There are many more. To find out more about becoming carbon neutral and to become better informed about climate science, here are some helpful references:

The Intergovernmental Panel on Climate Change
http://www.ipcc.ch/

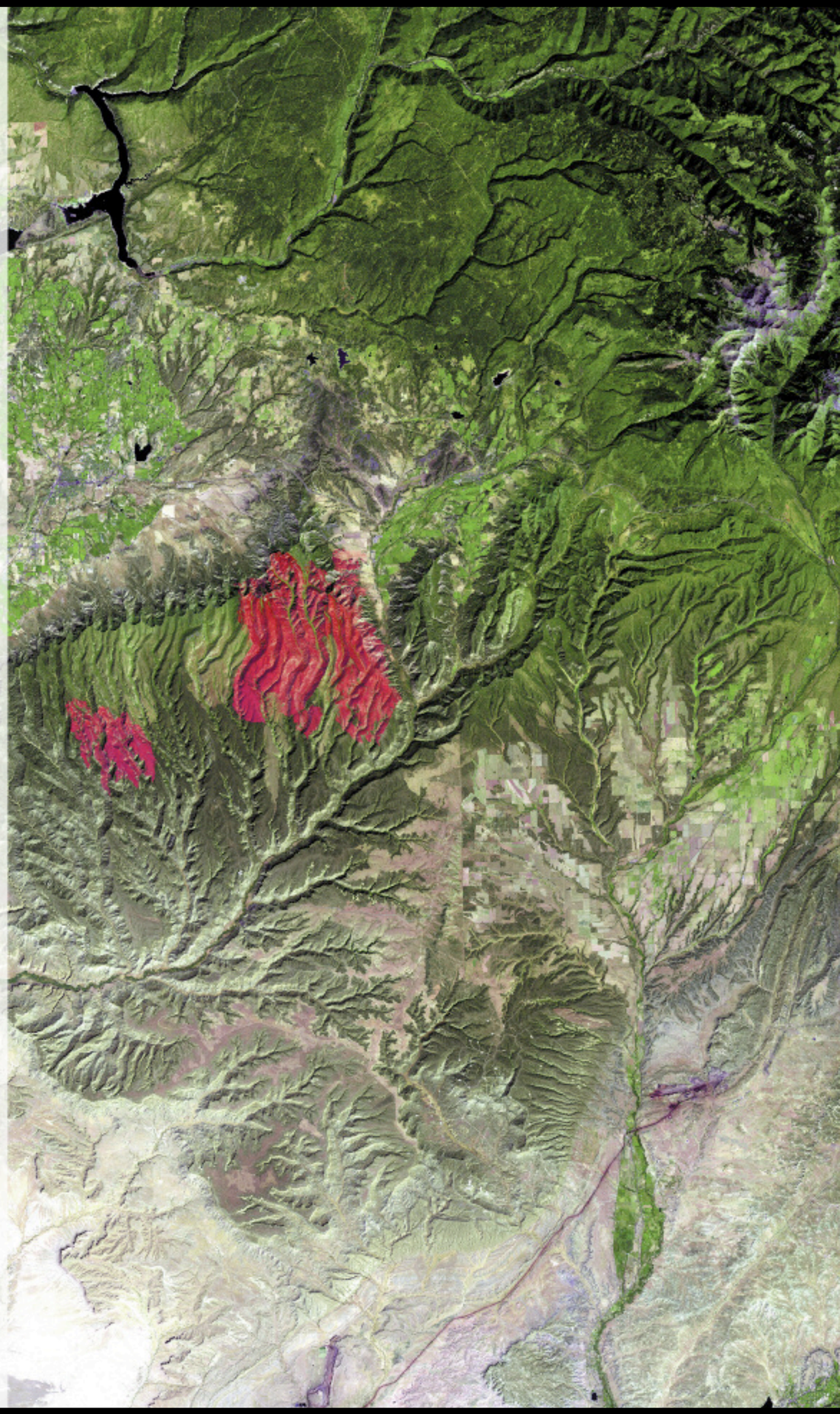
The Arctic Climate Impact Assessment
http://amap.no/acia/ACIAContent.html

Understanding and Responding to Climate Change
http://dels.nas.edu/basc/Climate-HIGH.pdf

EPA's Global Warming – Actions
http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsIndividualMakeaDifference.html

NPS/NASA Earth-to-Sky Interpretive Training tool
http://www.earthtosky.org

Regardless of the causes, taking action to manage the impacts of changing climate will have positive benefits for our resources. In the future, national parks may tell the story of our collective success in dealing with climate change, moving to a way of life in greater harmony with the natural processes that operate on our planet. After all, Earth is the only planet we can call home.



A false-color Landsat 7 satellite image of the Mesa Verde fire scars (in red). The large burn scar on the right is from the 2000 Bircher fire that burned 19,709 acres of NPS land.

Resource Bulletin

Global Climate Change and Melting Glaciers

Global Warming

Global warming is one of the most pressing environmental issues of the 21st century. For many years, scientists have been studying this phenomenon and the evidence is now clear. Earth's climate is warming and mountain ecosystems like those found in Glacier National Park are seeing some of the most dramatic changes.

In the last 100 years, global average temperature increased by 1.6 degrees Fahrenheit with accelerated warming over the last two to three decades. The 1990s were the hottest decade, not just of the last century, but of the last millennium! The 5 hottest years of record since the 1890s, in rank order, were 2005, 1998, 2002, 2003, and 2004. Scientists predict that by the end of the 21st century Earth will experience a warming trend of 2-10 degrees. While this may not seem like much, it could bring major changes to Earth's ecosystems, especially those at high altitudes and latitudes like Glacier National Park.

While Earth's climate is known to have changed in the past due to natural causes, the warming trend over the last few decades is primarily the result of human activities. Of major concern is the buildup of carbon dioxide and other "greenhouse gases" in the atmosphere.

Greenhouse gases hold heat in the atmosphere that would otherwise radiate back out into space. While the greenhouse effect is what has made life on Earth possible, these gases are now increasing at an alarming rate. Since the beginning of the industrial revolution, the carbon dioxide concentration in the atmophere has increased by 30%. Human activities that release carbon dioxide are burning of fossil fuels, harvesting and burning trees, and land conversion to cities and agriculture.

Grinnell Glacier, shown in the middle foreground, has retreated dramatically in recent years and has split off from Salamander Glacier, on the upper right. The smaller Gem Glacier on the upper left is also still visible.

Melting Mountain Glaciers

Glaciers are formed when more snow falls in winter than melts in summer. As snow accumulates over many seasons it becomes ice. The weight from snow and ice causes the bottom layers to move, fashioning a frozen river of snow and ice that slowly flows across the landscape, eroding and shaping it into unique landforms. When this process is reversed, the glaciers retreat back up the mountain. The advance and retreat of glaciers is strongly tied to temperature and precipitation and is a simple, but effective, way to monitor climate change.

The amazing mountains and valleys of Glacier National Park were sculpted by the action of glaciers over hundreds of thousands of years of glacial advance and retreat. In 1850, at the end of the Little Ice Age, there were an estimated 150 glaciers in the park. By 1968, these had been reduced to around 50, 37 of which had been named. Today the number of glaciers in the park is 27, many of which are mere remnants of what they once were.

Rapid retreat of mountain glaciers is not just happening in Glacier National Park, but is occuring worldwide. While Earth's climate has undergone cooling and warming cycles in the past, the rate and magnitude of change we

are witnessing today has not occurred since human civilization began. If the current rate of warming persists, scientists predict the glaciers in Glacier National Park will be completely gone by the year 2030.

The total loss of glaciers will certainly be a major change for Glacier National Park. For many people, the glaciers are one of the reasons the park holds special significance and are a feature they expect to see when they visit. Glaciers are also an important natural resource, providing vital functions for the ecosystem.

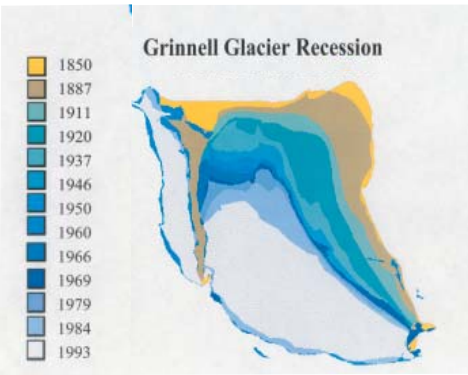
Glacier's Management Strategy

Now that the impacts of global warming are beginning to be understood, managers are taking the issue very seriously. Ultimately, greenhouse gas emissions, especially carbon dioxide, must be reduced. The National Park Service, in partnership with the Environmental Protection Agency, held a workshop in Whitefish, MT for park personnel in December 2003 to discuss the issues relating to climate change in the park and what steps the park can take to respond to this threat.

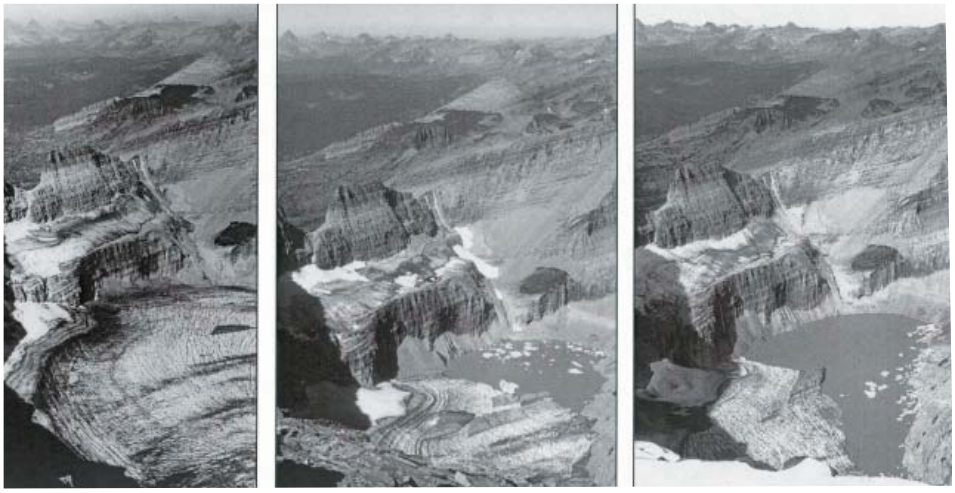
The two-day workshop, Climate Friendly Parks: Moving From Knowledge to Action, was aimed at park staff, concessioners, and park partners. An assessment of greenhouse gas emissions from Glacier was conducted prior to the workshop to provide background on what the primary activities are that can be targeted for emissions reduction. The single greatest contributor to carbon dioxide emissions in the park is transportation. Other significant sources are energy use in buildings and solid waste disposal.

An important outcome of the workshop included organization of the Glacier Green Team. The Team meets quarterly to discuss issues relating to sustainable environmental practices in the park. Another outcome of the workshop was development of an action plan that outlines steps we can take toward sound environmental mamangent of our operations.

Many of the ideas from the action plan have recently been integrated into Glacier's Environmental Management Plan, which was completed in May 2006. A number of the actions from the plan have already been taken to reduce greenhouse gas emissions and raise awareness of the issues. These include employee transportation alternatives like the Red Bike Program and bus and carpooling initiatives, as well as a recycling plan, and monitoring energy use in buildings. Visitor transportation options are also being planned in conjunction with the Going-to-the-Sun Road rehabilitation project.



The size of Grinnell Glacier has receded dramatically over the last hundred and forty years. The white area shows the extent of the glacier in 1993; the colored areas show the glacier's extent for years prior to that.



Repeat photographs of Grinnell Glacier taken from Mt. Gould show the rapid retreat of the glacier and the formation of a glacial lake; dates from left to right are 1938, 1981, 1998.

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Resources for More Information

Glacier National Park staff:

Leigh Welling, Director, Crown of the Continent Research Learning Center
Dan Fagre, Ecologist, USGS Glacier Field Station

Documents and web sites:

Glacier National Park Global Climate Change
http://www.nps.gov/glac/resources/bio7.htm#Global

Ecological Significance of Long-term Climate Changes in Montane Ecosystems, and Global Climate Change
http://nrmsc.usgs.gov/research/climate_changes.htm

Glacier National Park Green Team: http://www.glac.nps.gov/glac/office/greenteam.cfm

Resource Bulletin

Climate Change and Biotic Patterns

A Biologically Diverse Ecosystem

Glacier National Park is a highly heterogeneous landscape that is home to a rich diversity of plants and animals. One reason for this is the steepness of the terrain. With high mountains and low valleys, dense forests and open meadows, and numerous wetland habitats, Glacier can provide a home to an amazing array of species. But as climate changes, ecosystems will change too. Exactly how our current warming climate will affect Glacier's biotic communities is an active area of scientific research.

Climate helps determine what flora and fauna exist in a habitat. Every species has temperature and moisture ranges within which they can survive and thrive. Glacier's weather and climate can be highly variable from high to low elevations and also between the east and west sides of the Continental Divide. The cool, harsh high alpine environments support very different species than the milder conditions usually found at lower elevations. East of the divide tends to be colder and drier than west because the Pacific maritime climate delivers moisture and heat from west to east.

The temperature range, amount of rain, wind, and other climatic conditions that each part of the park receives helps to define the kinds of organisms found there. While not static, these microclimates create diversified and distinct communities within the landscape.

Glacier National Park is renowned for its spectacular biological diversity, such as this Indian Paintbrush meadow along the Garden Wall.

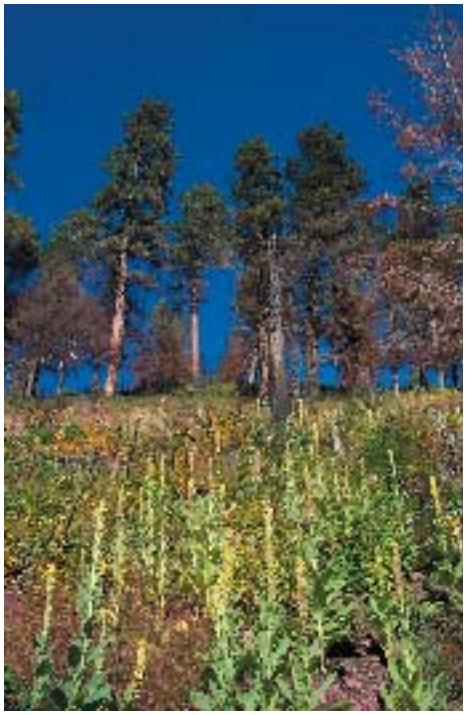
An Altered Landscape

As climate changes, plants and animals adapted to current conditions and locations will either need to adapt to survive in different conditions or "follow" the temperature range in which they can survive. The ability of populations to adapt or move when climate changes depends on many factors, one which is the rate of change. The current warming climate is accelerated by human activities and it is unclear how, or even if, most modern species can adapt well enough to survive.

In a warming climate, vegetation zones will tend to migrate northward and/or upslope to higher elevations. Alpine treeline studies help scientists understand how this process takes place. Studies from Glacier suggest forest patches at high elevations are getting denser and are beginning to invade alpine meadows.

Of major concern is the potential loss of alpine and subalpine environments that provide prime habitat for plants such as Jones Columbine and White Mountain Avens, animals like bighorn sheep and mountain goats, and winter hibernation space for bears. Species living here cannot migrate to higher ground.

While some species may be able to move and adapt to climate change, the current rapid rate of warming may present significant difficulties for others. Some vegetative communities, such as old growth forests, are not capable of migrating quickly. In other cases, migration may not occur due to lack of suitable corridors that connect current locations to higher or more northern territories where the plants can become established and thrive. Roads,



Common mullein, a non-native invasive species, spreads quickly in a burn area of the North Fork region in Glacier National Park.

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http://nrmsc.usgs.gov/research/climate_changes.htm

The Millenium Ecosystem Assessment
http://www.millenniumassessment.org/en/index.aspx

US National Assessment on the Impacts of Climate Variability and Change
http://www.usgcrp.gov/usgcrp/nacc/forests/default.htm

Bibliography: Climate Change and its Impact on Species/Ecosystems
http://eelink.net/~asilwildlife/CCWildlife.html

urban and industrial areas, and agricultural fields all present obstacles to the migration potential of plants and animals. Species that cannot adapt or move, will not survive.

Changes In Disturbance Regimes

Climate change will affect not only the types of plants and animals that can survive in certain areas, it will also impact processes that shape the landscape such as fire. For example, changes to temperature and precipitation patterns will affect soil moisture as well as the frequency of storms (which bring lightening that start fires). In general, under warming conditions, scientists expect there to be a greater potential for more frequent, larger, more severe, and more intense wildland fires.

While fire is an important shaper of Glacier's landscape, too intense or too frequent fires may make it more difficult for native species to return. Disturbance by fire may create an ideal environment for non-native invasive species to thrive.

Glacier's Management Strategy

Climate change, especially the rapid change we are currently experiencing, is a serious issue. As scientists work to understand how Glacier's ecosystems will be impacted, managers struggle to understand what kinds of decisions can and should be made in the face of these changes to protect park resources. It is unlikely that any management actions would be sufficient to preserve Glacier National Park in its current state. Some level of change is inevitable and may even be desirable. Unfortunately, there is no simple solution.

In some cases, managers may be forced to choose when and where to invest limited time and energy for resource protection and restoration. For example, areas such as old growth cedar-hemlock forests, that evolved in a much colder climate, may simply have to be understood as remnants of another time. In other cases, park managers may need to work with other agencies and land managers to identify and protect corridors that connect important wildlife habitats to allow species to migrate.

Management strategies for disturbances such as fire and invasive plants will need to adapt to the context of climate change pressures. Resarch and internal education efforts can help park staff become aware of the issues and can encourage discussions that may provide new ideas and approaches. Engaging the support of our neighbors and partners will be critical as we seek solutions to these complex issues.

A warmer climate may allow forests to survive at higher elevations. If treeline migrates upward, the high elevation habitats of alpine and subalpine meadows will be reduced.

DAY 8

BENEFITS & HAZARDS OF GLACIERS

WEBQUEST

OBJECTIVE Students will learn about the benefits and hazards associated with glaciers in a webquest using the *Views of the National Parks* multimedia education program.

GRADES Middle or High School students

DURATION 1 50-minute class period

PROCEDURE Students will work independently or in small groups to complete the *Benefits and Hazards of Glaciers* webquest.

MATERIALS

- Copies of the webquest for each student
- Computers for each student or pair of students
- Access to the *Views of the National Parks* program (Internet or DVD)

KEY CONCEPTS Reservoirs of water, commercial and tourism value, electric power generation, habitat, icebergs, surging, outbursts, ice avalanches, rising sea levels

DAY 8

BENEFITS & HAZARDS OF GLACIERS: WEBQUEST

NATIONAL EDUCATION STANDARDS:

Science:

NS.5-8.4 Earth and Space Science

- Structure of the earth system

NS.5-8.6 Personal and Social Perspectives

- Populations, resources, and environments
- Natural hazards
- Risks and benefits

NS.9-12.1 Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

NS.9-12.4 Earth and Space Science

- Geochemical cycles

NS.9-12.6 Personal and Social Perspectives

- Natural resources
- Natural hazards
- Risks and benefits

NS.9-12.7 History and Nature of Science

- Nature of scientific knowledge

Technology:

NT.K-12.2 Social, Ethical and Human Issues

- Students practice responsible use of technology systems, information, and software.

NT.K-12.3 Technology Productivity Tools

- Students use technology to enhance learning, increase productivity

Name: _____

DIRECTIONS

1. Access **Views of the National Parks** via a DVD or the internet, and choose the "**Multimedia Version**".
2. Click on the **Knowledge Centers**, and choose the **Glaciers** knowledge center.
3. Enter the site by clicking on "**Explore Glaciers**".
4. Click on the "**Monitoring**" option on the top toolbar.
5. Choose either the "**Benefits of Glaciers**" or "**Hazards of Glaciers**" side bar on the left side of the screen, depending on which section of questions you are answering.
6. After opening either the benefits or hazards section, you will see **5 buttons** on the bottom right. Click on the buttons to access information related to each set of questions.

BENEFITS OF GLACIERS

Reservoirs of Water:

1. From what source do a number of the world's desert regions receive water?

2. Glacial runoff, the term used to describe the melted water that flows down off a glacier, contributes water to desert regions in times when they need it the most. When are these times?

3. Glacial deposits also act as reservoirs for _____.

Commercial Value of Glacier Ice:

1. List 4 ways that people all over the world have used glacier ice:
   -
   -
   -
   -

Electric Power Generation:

1. Electric power generation is enhanced from _____ .

2. During the winter, how much of Switzerland's energy production is generated by water released from glacier reservoirs?

Tourism:

1. List 5 ways that tourists can enjoy glaciers as recreational resources:
   -
   -
   -
   -
   -

Habitats:

1. The increase or decrease in glacier area significantly impacts what 2 ecosystems?

2. Describe what happens in wetland communities as a glacier retreats and how this is beneficial to the species living in the area.

HAZARDS OF GLACIERS

Icebergs:

1. List 3 things that are put in danger by icebergs:
   -
   -
   -

Surging:

1. Describe the surging and advancing of glaciers.

Outbursts:

1. Catastrophic outburst floods result from the failure of _____ .
2. Draining of glacier-damned lakes occurs either _____ or _____ a glacier dam.
3. Describe the resulting destruction of an outburst flood and the major hazards.

Ice Avalanches:

1. Where is the threat from ice avalanches most apparent?
2. Which is more common: an ice avalanche or a snow avalanche?
3. Why is it difficult to monitor the development of ice avalanches?
4. List 2 reasons for continuing to research ice avalanches:
   -
   -

Sea Level Rise:

1. Where is most of the world's glacier ice held?
2. How much of the planet's freshwater supply is held in these places?
3. Describe, in detail, the 3 major consequences of rising sea levels.
   -
   -
   -

ANSWER KEY

DIRECTIONS

1. Access **Views of the National Parks** via a CD or the internet, and choose the "**Multimedia Version**".
2. Click on the **Knowledge Centers**, and choose the **Glaciers** knowledge center.
3. Enter the site by clicking on "**Explore Glaciers**".
4. Click on the "**Monitoring**" option on the top toolbar.
5. Choose either the "**Benefits of Glaciers**" or "**Hazards of Glaciers**" side bar on the left side of the screen, depending on which section of question you are answering.
6. After opening either the benefits or hazards section, you will see **5 buttons** on the bottom right. Click on the buttons to access information related to each set of questions.

BENEFITS OF GLACIERS

Reservoirs of Water:

1. From what source do a number of the world's desert regions receive water?
   FROM ADJACENT MOUNTAIN RANGES

2. Glacial runoff, the term used to describe the melted water that flows down off a glacier, contributes water to desert regions in times when they need it the most. When are these times?
   DURING HOT, DRY SEASONS AND YEARS

3. Glacial deposits also act as reservoirs for _____*GROUNDWATER*_____.

Commercial Value of Glacier Ice:

1. List 4 ways that people all over the world have used glacier ice:
   - *USED FOR REFRIGERATION*
   - *USED AS AN EXPENSIVE WAY TO COOL DRINKS*
   - *SOLD AS PURE MINERAL WATER*
   - *SOLD AS LOCAL SNOW CONES*

Electric Power Generation:

1. Electric power generation is enhanced from ***MELTWATER FROM GLACIERS***.

2. During the winter, how much of Switzerland's energy production is generated by water released from glacier reservoirs? *HALF*

ANSWER KEY

Tourism:

1. List 5 ways that tourists can enjoy glaciers as recreational resources:
   - *SKIING*
   - *MOUNTAINEERING*
   - *SCENIC TOURS IN LARGE VEHICLES*
   - *SCENIC OVERFLIGHTS*
   - *BOAT EXCURSIONS*

Habitats:

1. The increase or decrease in glacier area significantly impacts what 2 ecosystems?

   HIGH-MOUNTAIN and HIGH-LATTITUDE ECOSYSTEMS

2. Describe what happens in wetland communities as a glacier retreats and how this is beneficial to the species living in the area.

   AS A GLACIER RETREATS, AN INCREASED AMOUNT OF SEDIMENT IS PROVIDED TO THE WETLANDS. THIS MAY CAUSE THE DEVELOPMENT OF SMALL LAKES, WHICH IN TURN PROVIDES ADDITIONAL HABITAT FOR THE SPECIES LIVING IN THE AREA.

HAZARDS OF GLACIERS

Icebergs:

1. List 3 things that are put in danger by icebergs:
   - *OCEAN TRANSPORTATION*
   - *OCEAN SHIPPING*
   - *OFFSHORE OIL INSTALLATIONS*

Surging:

1. Describe the surging and advancing of glaciers.

   SURGING GLACIERS SUDDENLY AND DRAMATICALLY ACCELERATE, ADVANCING SEVERAL MILES IN A FEW MONTHS AND TRAVELING MANY TIMES THEIR NORMAL SPEEDS.

ANSWER KEY

Outbursts:

1. Catastrophic outburst floods result from the failure of *ICE-DAMNED LAKES*.
2. Draining of glacier-damned lakes occurs either ___*THROUGH*____ or __*OVER*___ a glacier dam.
3. Describe the resulting destruction of an outburst flood and the major hazards.

   OURBURST FLOODS CAN RESULT IN DENSE, VISCOUS DEBRIS FLOWS. THE MAJOR HAZARD OF DEBRIS FLOWS IS FROM BURIAL OR IMPACT.

Ice Avalanches:

1. Where is the threat from ice avalanches most apparent?

   IN DENSELY POPULATED MOUNTAIN RANGES WITH GLACIERS

2. Which is more common: an ice avalanche or a snow avalanche?

   A SNOW AVALANCHE

3. Why is it difficult to monitor the development of ice avalanches?

   BECAUSE THEY OCCUR MOST FREQUENTLY AT HIGH ALTITUDES

4. List 2 reasons for continuing to research ice avalanches:
   - *MOUNTAIN RANGES ARE INCREASINGLY BEING USED FOR RECREATION*
   - *THE GENERATION OF HYDRO-ELECTRIC POWER*

Sea Level Rise:

1. Where is most of the world's glacier ice held?

   IN TWO LARGE ICE SHEETS: ANTARCTICA AND GREENLAND

2. How much of the planet's freshwater supply is held in these places? *77%*
3. Describe, in detail, the 3 major consequences of rising sea levels.
   - *A RISE IN SEA LEVEL WOULD ALTER THE POSITION AND MORPHOLOGY OF COASTLINES;*
   - *CREATE OR DESTROY COASTAL WETLANDS AND SALT MARSHES AND INDUCE SALT-WATER INTRUSION INTO ACQUIFERS;*
   - *COASTAL EROSION.*

DAY 9
Activity #1

GLACIER ARTISTS

DESCRIPTION Students will work together in small teams, and then as a class, to draw key glacial features.

PURPOSE This activity serves as a review activity.

GRADES Middle or High school students

DURATION 30 minutes

MATERIALS

- Large white sheets of paper for every small group
- Markers, crayons, and/or colored pencils
- Chalk or dry erase markers for use on a classroom board

DAY 9
Activity #1

GLACIER ARTISTS

NATIONAL EDUCATION STANDARDS

Science:

NS.5-8.4 Earth and Space Science

- **Structure of the earth system**

NS.5-8.6 Personal and Social Perspectives

- **Populations, resources, and environments**

NS.9-12.1 Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

NS.9-12.4 Earth and Space Science

- **Geochemical cycles**

NS.9-12.6 Personal and Social Perspectives

- **Natural resources**

NS.9-12.7 History and Nature of Science

- **Nature of scientific knowledge**

Fine Arts

NA-VA.5-8.1 **Understanding and applying media, techniques and processes.**

NA-VA.9-12.6 **Making connections between visual arts and other disciplines.**

GLACIER ARTISTS

DAY 9

LESSON DESCRIPTION:

- This review activity has students work together as a team to draw key glacier features.

PROCEDURE:

1. Divide the class into small groups.
2. Give each group a large piece of white paper and a variety of markers, colored pencils, and/or crayons.
3. Explain that they will have 10 minutes to draw as many glacier features as they can, WITHOUT using their notes.
   a. Each student will take turns drawing until they cannot think of anymore features or time runs out. This will ensure that each student participates in the activity.
   b. The teacher should walk around the room to ensure that students are passing around the paper and each group member is taking a turn at drawing.
4. When it looks like the students cannot add any more glacier information to their drawings, have the groups switch papers with another group.
5. Allow the students approximately 5 minutes to add or correct any information on the other group's drawings.
6. Hang all the drawings on the board and give the students time to look at them.
7. When the students are back at their seats, lead them in a discussion about what they were able to remember about glaciers, and what things they noticed other groups had on their drawings that they didn't. (This is a great way for students to realize what they need to study if the teacher is going to be giving them an exam).

INSTRUCTIONAL LESSON PLAN:

1. Introduction to the lesson and set-up	5 minutes
2. Glacier Artists Group Drawing	10 minutes
3. Switching Drawings	10 minutes
4. Clean-Up and Wrap-Up	5 minutes

DAY 9
Activity #2

GLACIER REVIEW SHEET

PURPOSE

This worksheet will help to prepare students for a final assessment covering glacier concepts. An assessment that uses PowerPoint in a game-like fashion has been developed to compliment the material in this 2-week unit.

GRADES

Middle or High school students

DURATION

- This review sheet is intended to be started on Day 9 of the 2-week glacier unit, and then finished as homework. *However*, it can also be given out as homework on Day 8, and then finished on Day 9 after the Glacier Artists activity.

MATERIALS

- Glacier Review worksheet
- Work completed during the glacier unit will assist the students in answering the questions on the review sheet.

DAY 9
Activity #2

GLACIER REVIEW SHEET

NATIONAL EDUCATION STANDARDS

Science:

NS.5-8.4 Earth and Space Science

- **Structure of the earth system**

NS.5-8.6 Personal and Social Perspectives

- **Populations, resources, and environments**

NS.5-8.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of science**

NS.9-12.4 Earth and Space Science

- **Geochemical cycles**

NS.9-12.5 Science and Technology

- **Understandings about science and technology**

NS.9-12.6 Personal and Social Perspectives

- **Natural resources**

NS.9-12.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of scientific knowledge**

◆ Glaciers Unit Review Sheet ◆

1. What are the 3 criteria for being a glacier?
    a.
    b.
    c.
2. What are the 2 features of ice crystals that are significant to glaciers?
    a.
    b.
3. What are 2 ways that glaciers move?
    a.
    b.
4. Describe how basal sliding is directly influenced by the density of water.

5. What is the most significant heat source that a glacier receives?

6. Describe how latitude affects where glaciers are found.

7. Describe how altitude affects where glaciers are found.

8. How is aspect important to the existence of glaciers?

9. What are the 2 best ways for differentiating glaciers (how best do you tell them apart?)
    a.
    b.
10. What is the difference between ice sheets and ice caps?

11. What are the 2 main components of ice sheets and ice caps?

    a.

    b.

12. What is an ice shelf?

13. Describe the surface of an icefield.

14. Where are 2 places that a valley glacier might come from?

    a.

    b.

15. Describe a cirque glacier.

16. Where is ice thickest in a glacier?

17. Describe the movement of the ice flow within a glacier at the center and at the edges.

18. What is the difference between the pattern of flow in the accumulation zone and the ablation zone?

19. What is the difference between an extended flow and a compressive flow?

20. What is an icefall?

21. Describe glacial scouring:

22. List 4 commercial uses for glacier ice:

    a.

    b.

    c.

    d.

23. How does meltwater from glaciers affect electric power generation?

24. List 5 recreational uses for glaciers:

    a.

    b.

    c.

    d.

25. How can a retreating glacier benefit wildlife species living in the area?

26. Describe a glacier that is surging and advancing.

27. What is a major hazard from a glacier-caused outburst flood?

28. Where is the threat from an ice avalanche most apparent?

29. Where is most of the world's glacier ice held **and** how much of the planet's freshwater is held in these places?

30. What are 3 main consequences of rising sea levels?

    a.

    b.

    c.

31. Define the following glacier terms:

a. Accumulation

b. Accumulation Zone

c. Ablation

d. Ablation Zone

e. Abrasion

f. Arête

g. Cirque

h. Equilibrium Line

i. Firn

j. Firn Line

k. Fjord

l. Glacial Basin

m. Glacial Runoff

n. Hanging Valley

o. Horn

p. Plucking

q. Roche Mountonnée

r. Tarn

s. Terminus

t. Truncated Spur

u. U-shaped (or Glacial) Valley

v. Whaleback

◆ Glaciers Unit Review Sheet ◆

ANSWER KEY

1. What are the 3 criteria for being a glacier?
   a. *MADE OF ICE*
   b. *FORM ON LAND*
   c. *GLACIERS MOVE*
2. What are the 2 feature of ice crystals that are significant to glaciers?
   a. *STRUCTURE*
   b. *DENSITY*
3. What are 2 ways that glaciers move?
   a. *INTERNAL DEFORMATION*
   b. *BASAL SLIDING*
4. Describe how basal sliding is directly influenced by the density of water.

   WATER IS LESS DENSE AS A SOLID THAN AS A LIQUID, SO THIS ALLOWS A GLACIER TO SLIDE OR FLOAT ON TOP OF MELTED WATER THAT HAS FORMED AT ITS BASE.
5. What is the most significant heat source that a glacier receives?

   SOLAR RADIATION
6. Describe how latitude affects where glaciers are found.

   HIGHER LATITUDES RECEIVE LESS ANNUAL SOLAR RADIATION AND EXPERIENCE PROLONGED WINTERS, AND AS A RESULT, ARE ABLE TO SUSTAIN GLACIERS.
7. Describe how altitude affects where glaciers are found.

   GLACIERS ARE FOUND AT SEA LEVEL AT THE SOUTH POLE BECAUSE IT IS COLD ENOUGH AT THE LOWER ALTITUDES TO SUSTAIN GLACIERS. CONVERSELY, GLACIERS ARE FOUND IN THE HIGHLANDS AT MID TO LOW LATITUDES BECAUSE LOWER ELEVATIONS ARE TOO WARM TO SUSTAIN GLACIERS.
8. How is aspect important to the existence of glaciers?

   THE ORIENTATION OF THE GROUND SURFACE WITH RESPECT TO SOLAR RADIATION AFFECTS THE EXISTENCE OF GLACIERS BECAUSE THE SLOPES WITH THE LEAST SOLAR RADIATION WILL MORE EASILY SUSTAIN GLACIERS: STEEP, NORTH-FACING SLOPES IN THE NORTHERN HEMISPHERE RECEIVE THE LEAST DIRECT SOLAR RADIATION.
9. What are the 2 best ways for differentiating glaciers (how best do you tell them apart?)
   a. *TOPOGRAPHY*
   b. *TEMPERATURE*
10. What is the difference between ice sheets and ice caps?

    ICESHEETS ARE LARGER THAN ICE CAPS

11. What are the 2 main components of ice sheets and ice caps?

    a. *ICE DOMES*

    b. *OUTLET GLACIERS*

12. What is an ice shelf?

    A VERY THICK SHEET OF ICE THAT HAS BEEN SHOVED OUT OVER THE SEA FLOOR FROM A LAND BASED GLACIER.

13. Describe the surface of an icefield.

    THE SURFACE IS APPROXIMATELY LEVEL

14. Where are 2 places that a valley glacier might come from?

    a. *ICEFIELD*

    b. *CIRQUE*

15. Describe a cirque glacier.

    A SMALL ICE MASS GENERALLY WIDE IN RELATION TO ITS LENGTH THAT OCCUPIES CHARACTERISTIC ARMCHAIR-SHAPED BEDROCK HOLLOW.

16. Where is ice thickest in a glacier?

    AT THE CENTER

17. Describe the movement of the ice flow within a glacier at the center and at the edges.

    ICE FLOWS FASTER IN THE CENTER OF THE GLACIER THAN AT ITS EDGES.

18. What is the difference between the pattern of flow in the accumulation zone and the ablation zone?

    THE BASIC PATTERN OF FLOW IN THE ACCUMULATION ZONE IS DOWNWARD.

    THE BASIC PATTERN OF FLOW IN THE ABLATION ZONE IS UPWARD.

19. What is the difference between an extended flow and a compressive flow?

    IN AN EXTENDED FLOW, A GLACIER IS EXTENDED AND THINNED BECAUSE IT IS ACCELERATING AND DOES NOT HAVE THE OPPORTUNITY TO BUILD UP.

    IN A COMPRESSIVE FLOW, THE FLOW IS SLOWER AND THE GLACIER HAS THE OPPORTUNITY TO BUILD UP, GET THICK, AND THEN COMPRESS UNDER ITS OWN WEIGHT.

20. What is an icefall?

    AN EXTREME EXTENDING FLOW

21. Describe glacial scouring:

    GLACIAL SCOURING OCCURS WHEN MOVING GLACIERS CARVE OUT LARGE CHUNKS OF LAND AND ACT LIKE SANDPAPER AS THEY WEAR DOWN AND ERODE THE LANDSCAPE.

22. List 4 commercial uses for glacier ice:

    a. *USED FOR REFRIGERATION*
    b. *USED AS AN EXPENSIVE WAY TO COOL DRINKS*
    c. *SOLD AS PURE MINERAL WATER*
    d. *SOLD AS LOCAL SNOW CONES*

23. How does meltwater from glaciers affect electric power generation?

    MELTWATER FROM GLACIERS ENHANCES ELECTRIC POWER GENERATION

24. List 5 recreations uses for glaciers:

    a. *SKIING*
    b. *MOUNTAINEERING*
    c. *SCENIC TOURS IN LARGE VEHICLES*
    d. *BOAT EXCURSIONS*

25. How can a retreating glacier benefit wildlife species living in the area?

    AS A GLACIER RETREATS, AN INCREASED AMOUNT OF SEDIMENT IS PROVIDED TO THE WETLANDS. THIS MAY CAUSE THE DEVELOPMENT OF SMALL LAKES, WHICH IN TURN PROVIDES ADDITIONAL HABITAT FOR WILDLIFE SPECIES LIVING IN THE AREA.

26. Describe a glacier that is surging and advancing.

    SURGING GLACIERS SUDDENLY AND DRAMATICALLY ACCELERATE, ADVANCING SEVERAL MILES IN A FEW MONTHS AND TRAVELING MANY TIMES THEIR NORMAL SPEEDS.

27. What is a major hazard from a glacier-caused outburst flood?

    OUTBURST FLOODS CAN RESULT IN DENSE, VISCOUS DEBRIS FLOWS. THE MAJOR HAZARD OF DEBRID FLOWS IS FROM BURIAL OR IMPACT.

28. Where is the threat from an ice avalanche the most apparent?

    THE THREAT FROM ICE AVALANCHES IS THE MOST APPARENT IN DENSELY POPULATED MOUNTAIN RANGES WITH GLACIERS.

29. Where is most of the world's glacier ice held **and** how much of the planet's freshwater is held in these places?

    77% OF THE WORLD'S GLACIER ICE IS HELD IN TWO LARGE SHEETS: ANTARTICA AND GREENLAND

30. What are 3 main consequences of rising sea levels?

    a. *A RISE IN SEA LEVEL WOULD ALTER THE POSITION AND MORPHOLOGY OF COASTLINES*
    b. *CREATE OR DESTROY COASTAL WETLANDS AND SALT MARSHES AND INDUCE SALT-WATER INTRUSION INTO ACQUIFERS.*
    c. *COASTAL EROSION*

31. Define the following glacier terms:

a. Accumulation.....*THE ADDITION OF ICE AND SNOW TO A GLACIER.*

b. Accumulation Zone.....*THE PART OF A GLACIER'S SURFACE WHERE MORE SNOW IS GAINED THAN LOST (MORE SNOW IS DEPOSITED THAN ABLATED).*

c. Ablation..... *DECREASING A GLACIER THROUGH MELTING, EVAPORTATION, SUBLIMATION, WIND EROSION, AND/OR CALVING.*

d. Ablation Zone..... *THE PART OF A GLACIER WHERE ABLATION (LOSS) EXCEEDS ACCUMULATION OVER A YEAR.*

e. Abrasion..... *THE MECHANICAL WEARING, GRINDING, SCRAPING, OR RUBBING AWAY (OR DOWN) OF A ROCK SURFACE BY FRICTION AND IMPACT FROM ROCKS OR ROCK FRAGMENTS FROZEN IN A GLACIER.*

f. Arête..... *SHARP, ROCK RIDGES, BETWEEN TWO STEEP, GLACIALLY SCULPTED SLOPES.*

g. Cirque..... *STEEP WALLED, GENTLE-FLOORED SEMICIRCULAR HOLLOWS FOUND HIGH IN MOUNTAINOUS AREAS.*

h. Equilibrium Line..... *THE BOUNDARY BETWEEN AREAS OF GAIN AND LOSS ON A GLACIER'S SURFACE DURING ONE YEAR. THIS IS WHERE ACCUMULATION MEETS ABLATION AND THE NET BALANCE OF SNOW IS ZERO.*

i. Firn.....*AN INTERMEDIATE STAGE IN THE TRANSFORMATION OF SNOW TO GLACIER ICE. SNOW BECOMES FIRN WHEN IT HAS BEEN COMPRESSED SO THAT NO PORE SPACES REMAIN BETWEEN FLAKES OR CRYSTALS, A PROCESS THAT TAKES LESS THAN A YEAR.*

j. Firn Line..... *THIS IS THE HIGHEST LEVEL TO WHICH WINTER SNOW COVER RETREATS ON A GLACIER.*

k. Fjord..... *LONG, NARROW, DEEP ARM OF THE SEA FILLING A GLACIATED COASTAL VALLEY.*

l. Glacial Basin..... *CLOSED BEDROCK BASIN CREATED BY LOCALIZED GLACIAL EXCAVATION.*

m. Glacial Runoff.....*THE TERM USED TO DESCRIBE THE MELTED WATER THAT FLOWS DOWN OFF A GLACIER.*

n. Hanging Valley..... *A GLACIER VALLEY THAT ENDS WHERE IT MEETS A DEEPER GLACIER VALLEY AND FORMS A CLIFF.*

o. Horn.....*HIGH, SHARP, STEEP-SIDED PYRAMIDAL PEAK.*

p. Plucking.....*THE MECHANICAL REMOVAL OF PIECES OF ROCK FROM A BEDROCK FACE THAT IS IN CONTACT WITH GLACIER ICE.*

q. Roche Mountonnée.....*A GLACIAL LANDFORM THAT SHOWS BOTH ABRASION AND PLUCKING.*

r. Tarn..... *A SINGLE GLACIAL BASIN LAKE.*

s. Terminus.....*THE END OR LOWEST PART OF A GLACIER.*

t. Truncated Spur.....*THE TOE OF A MOUNTAIN OR HILL THAT HAS BEEN ERODED AWAY BY A GLACIER.*

u. U-shaped (or Glacial) Valley.....*A "U"-SHAPED VALLEY IS FORMED WHEN A GLACIER IS ABLE TO SCOUR ON ITS SIDES AS WELL AS ITS BASE. THIS VARIES FROM RIVER VALLEYS WHICH HAVE A MORE CHARACTERISTIC "V" SHAPE.*

v. Whaleback.....*SMOOTH, GLACIALLY SCULPTED BEDROCK KNOB OF MODEST SIZE RESEMBLING THE BACK OF A WHALE.*

DAY 10

GLACIER QUIZ GAME

AN INFORMAL ASSESMENT OF ACQUIRED GLACIER KNOWLEDGE

OBJECTIVE Students will work together in pairs or small teams to answer glacier related trivia questions.

GRADES Middle or High school students

DURATION 1 55-minute class period

MATERIALS *Glacier Review Game* PowerPoint presentation

PROCEDURE

- Divide the class into pairs or small groups.
- Open the *Glacier Review Game* using the PowerPoint program.
- Select Slide Show from the top menu bar and then select "View Show."
- Run through the game having each group write their answers on a separate sheet of paper.

DAY 10

GLACIER QUIZ GAME

NATIONAL EDUCATION STANDARDS

Science:

NS.5-8.4 Earth and Space Science

- **Structure of the earth system**

NS.5-8.6 Personal and Social Perspectives

- **Populations, resources, and environments**

NS.5-8.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of science**

NS.9-12.4 Earth and Space Science

- **Geochemical cycles**

NS.9-12.5 Science and Technology

- **Understandings about science and technology**

NS.9-12.6 Personal and Social Perspectives

- **Natural resources**

NS.9-12.7 History and Nature of Science

- **Science as a human endeavor**
- **Nature of scientific knowledge**

Technology:

NT.K-12.3 Technology Productivity Tools

- **Students use technology to enhance learning, increase productivity**