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

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

PRINTING:

We highly suggest that the NASA Landsat Images of Bear Glacier be printed out in **color** and laminated. Color images facilitate the differentiation of glacier cover from land cover, and laminating the satellite images allows them to be used more than once.

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.

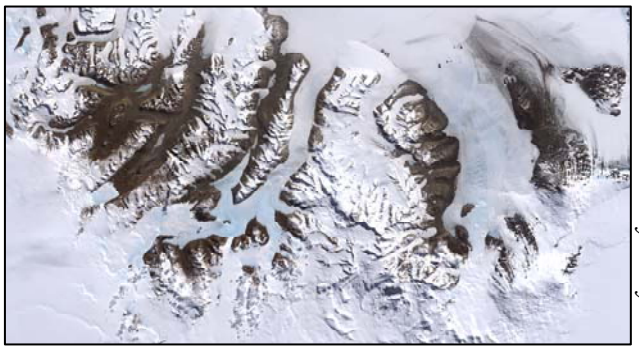
Glaciers are retreating not only along Kenai Fjord's coast, but all throughout the park. In fact, most of Alaska's estimated 10,600 glaciers are melting. Monitoring the glaciers can help determine why they are retreating.

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:

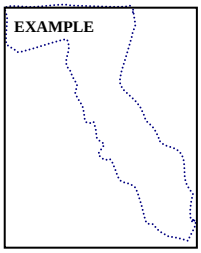
This lesson utilizes change pair images of Bear Glacier in Kenai Fjords National Park. Changes in precipitation have caused Bear Glacier to recede. As glaciers recede, they leave behind rock and debris, which is called a moraine. Bear Glacier, as it retreated, paused long enough to build up a sizeable 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 Cover Change Grid.
      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.

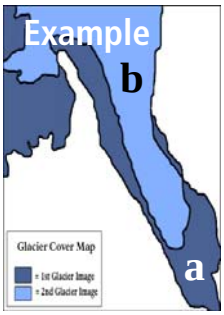
Name :

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.

$$\frac{\text{(grid squares)}}{\text{(grid squares)}} \times \frac{\text{(miles}^2\text{)}}{\text{(grid squares)}} = \text{miles}^2$$

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:

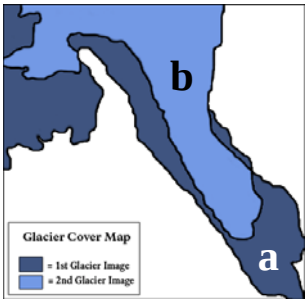
$$\frac{\text{amount of change}}{\text{original amount}} = \frac{2}{5}$$

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:

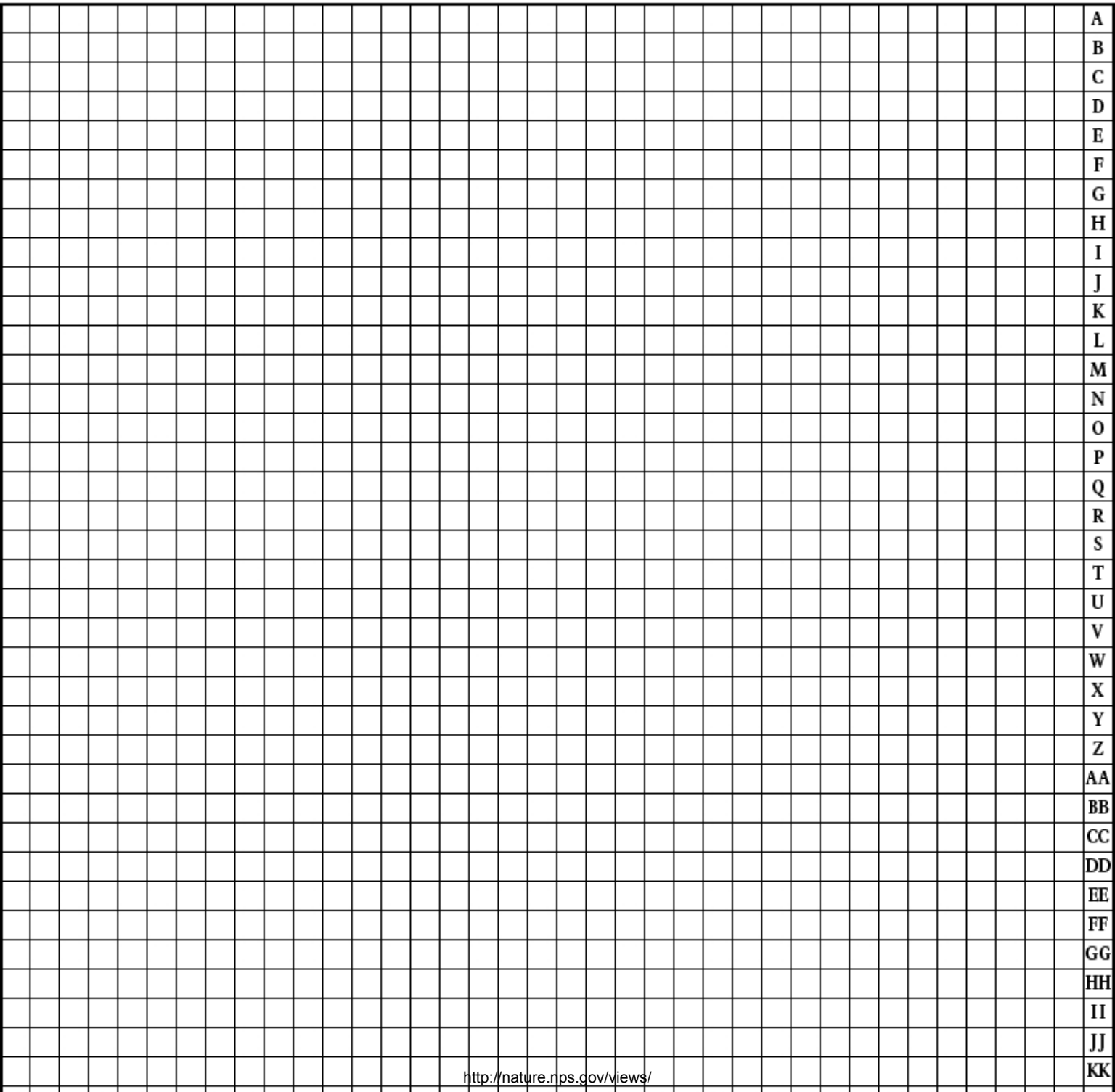
$$\frac{\text{change}}{\text{original amount}} = \frac{\text{value for c}}{\text{value for a}} = \frac{x}{100\%}$$

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

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

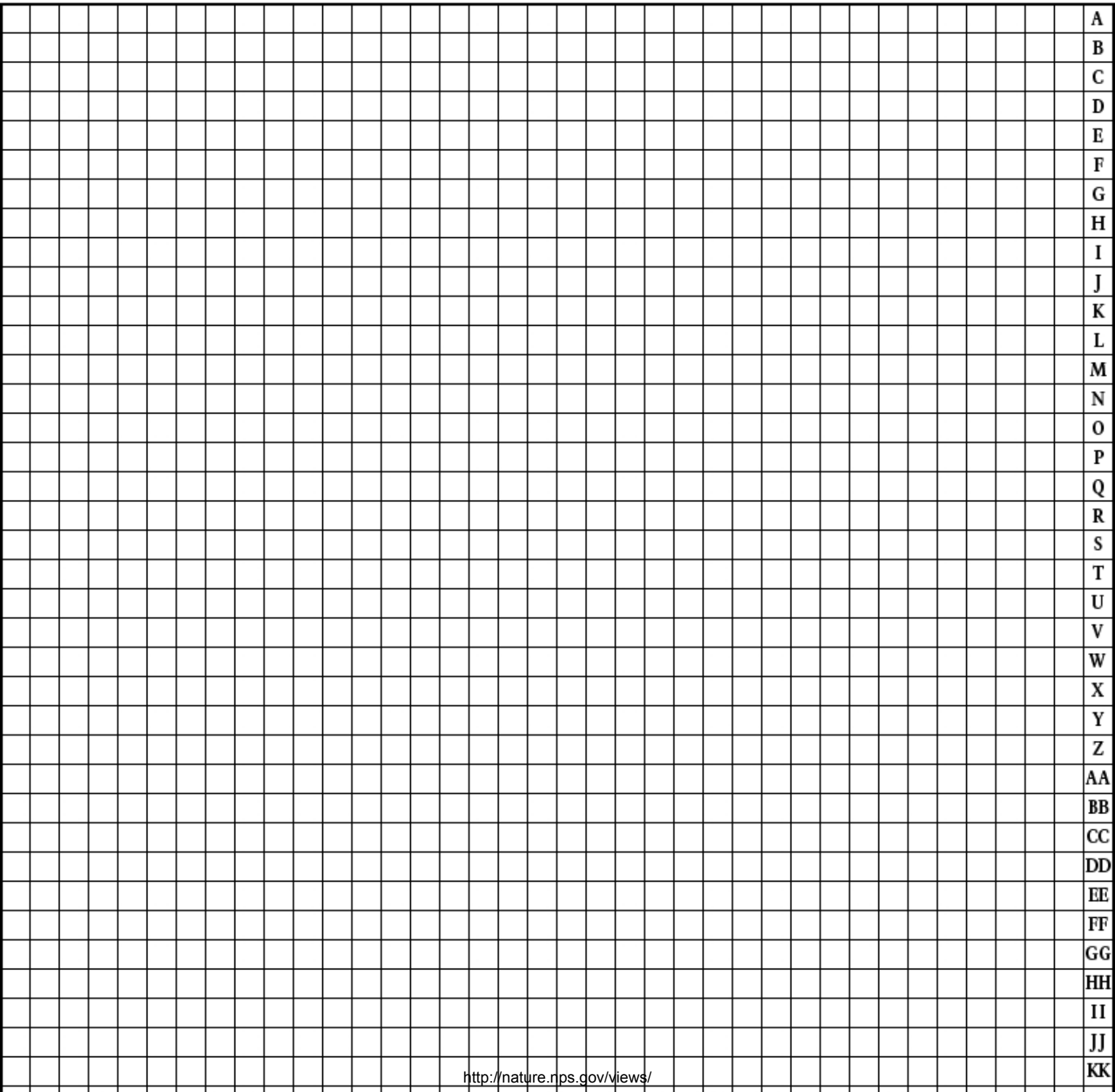
Cover Change Grid

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.



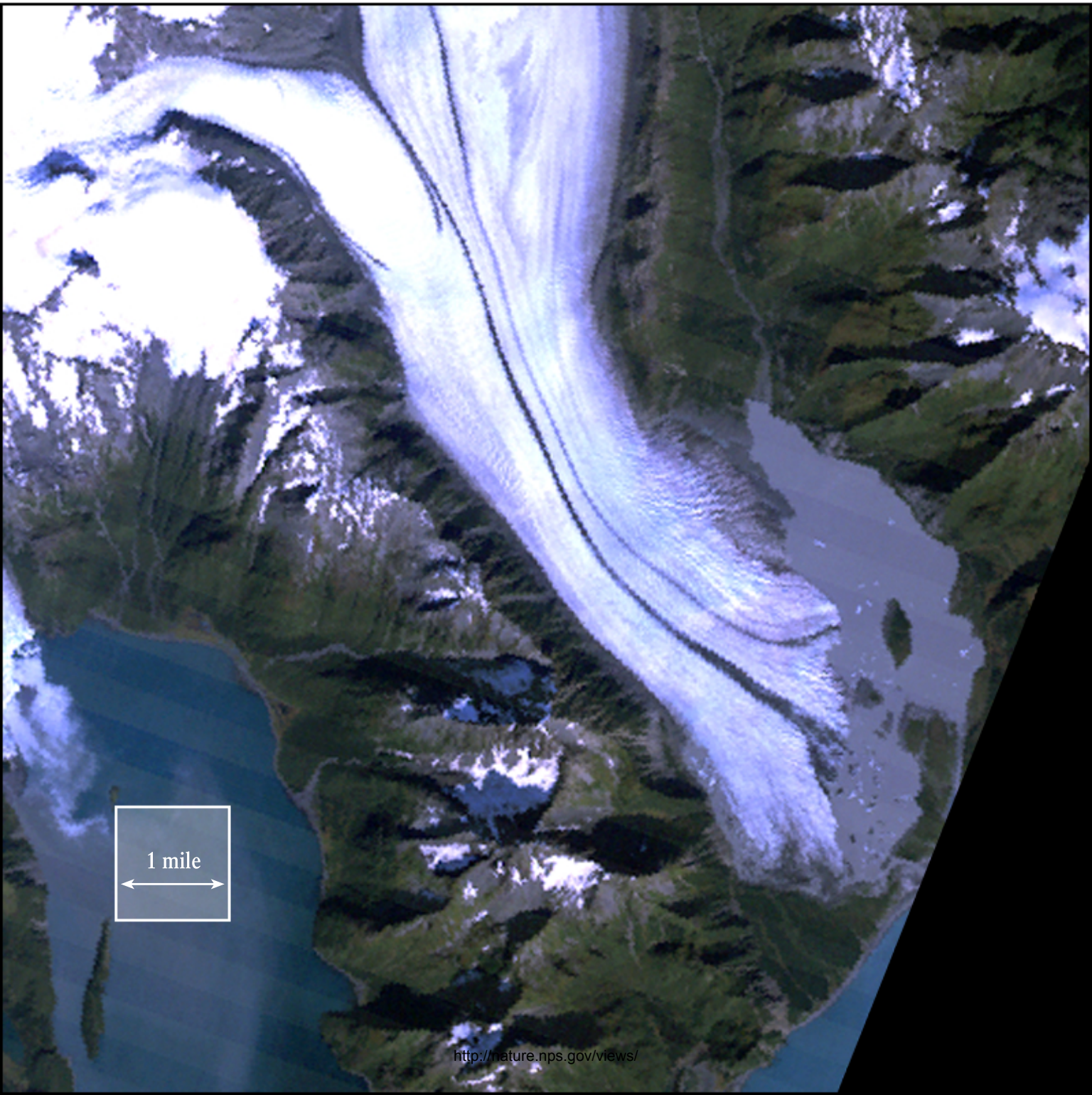
Cover Change Grid

Transparency



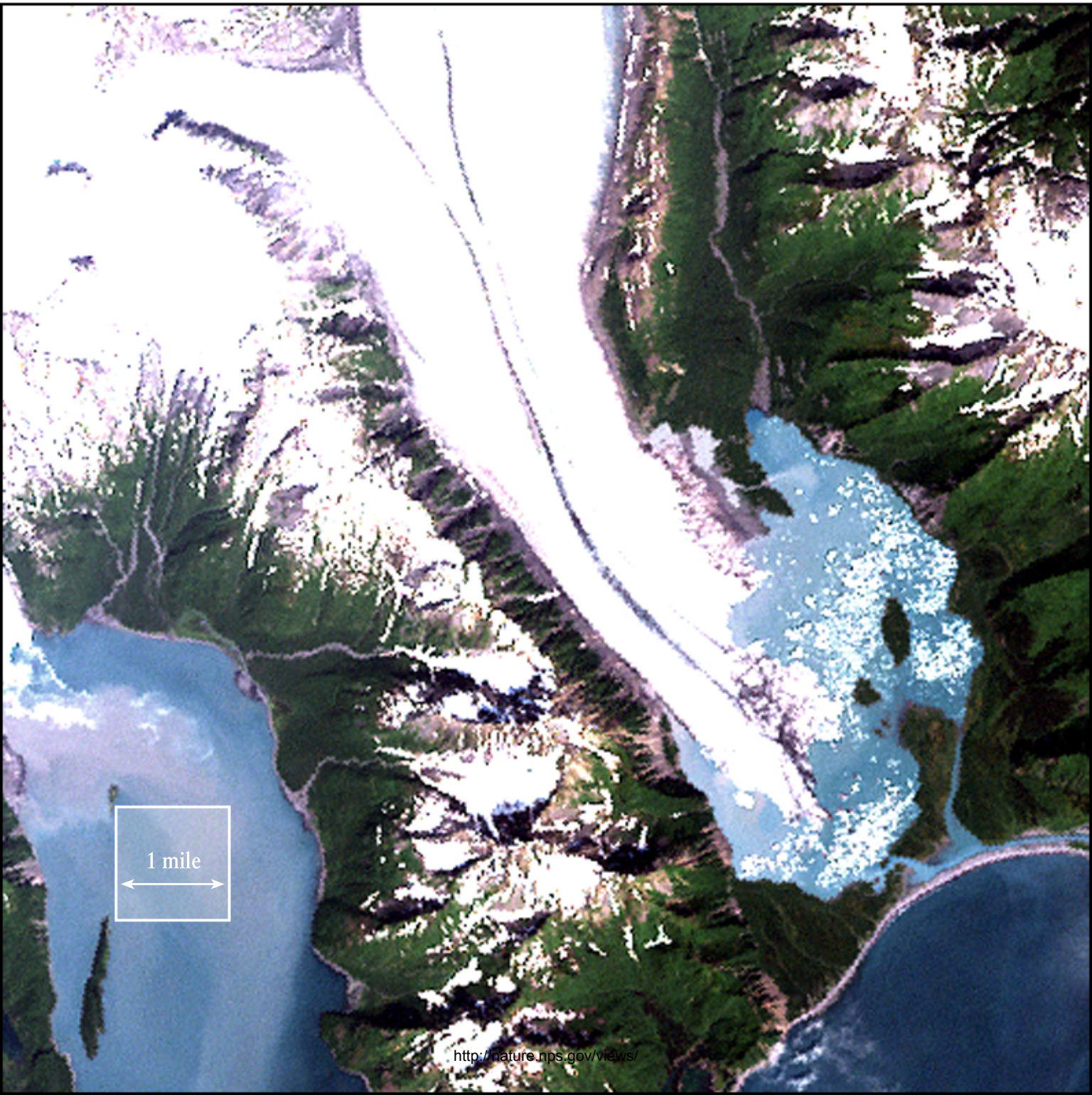
Bear Glacier - September 12, 1986

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



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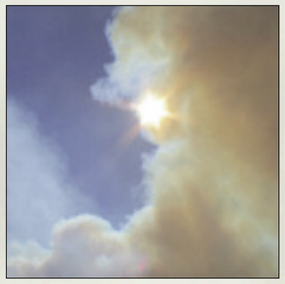
ADDITIONAL RESOURCES

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/

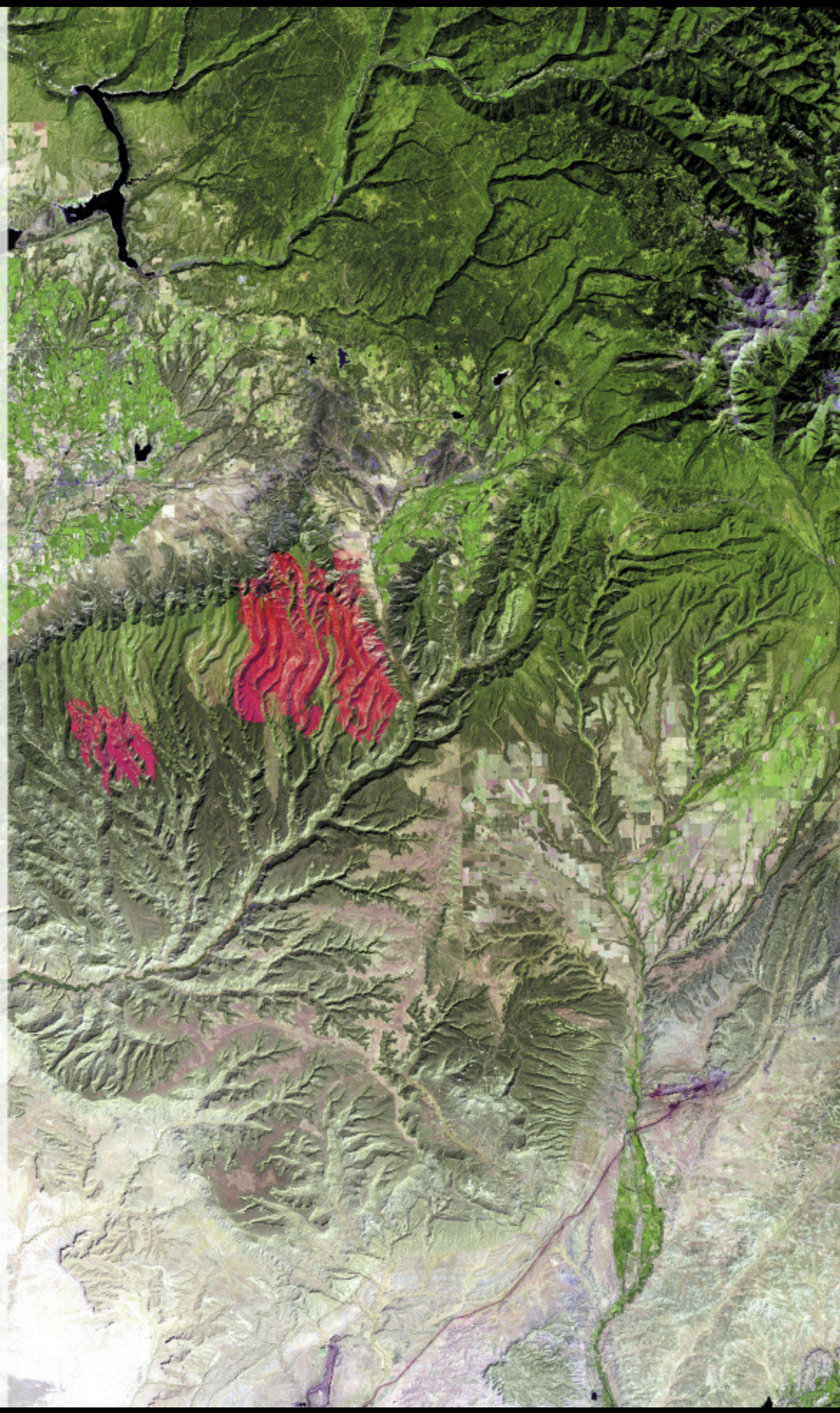
The Arctic Climate Impact Assessment
http://amap.no/acia/ACIAContent.html

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.

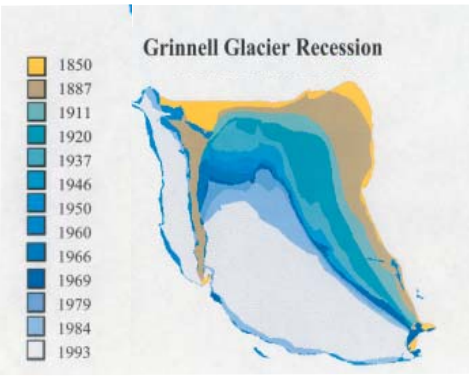
Grinnell Glacier, shown in the middle foreground, has retreated dramatically in recent years and has split off from Salamander Glacier, on the upper right. The smaller Gem Glacier on the upper left is also still visible.

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



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.

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.

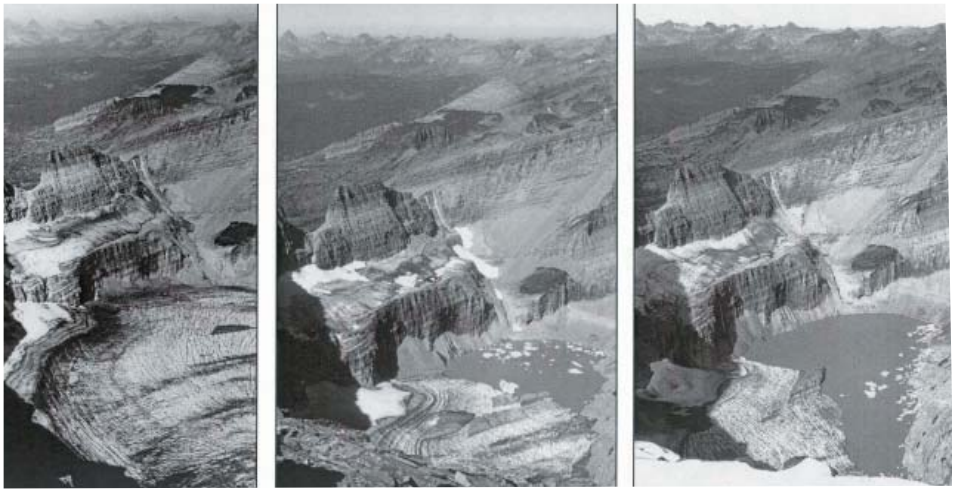
Glacier's Management Strategy

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.



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.

Crown of the Continent Research Learning Center
PO Box 128
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Resources for More Information

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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.

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

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.

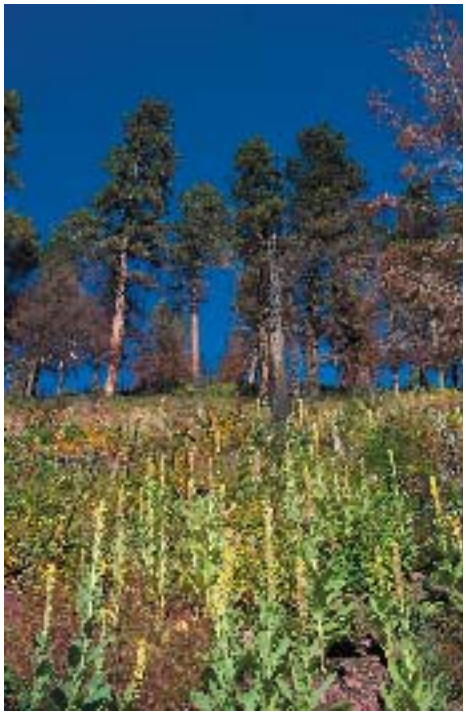
An Altered Landscape

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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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. Research 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.