

# ESSENTIAL LENS

ANALYZING PHOTOGRAPHS ACROSS THE CURRICULUM



**Earth, Climate, and Change:  
Observing Human Impact**

# Earth, Climate, and Change: Observing Human Impact

## Standards

The content is in accordance with the Next Generation Science Standards (NGSS), specifically:

### ESS2, Earth's Systems

- The Roles of Water in Earth's Surface Processes (water cycle, relationship between patterns of water movement in the atmosphere and local weather patterns)
- Weather and Climate (influence of interactions between the geosphere, hydrosphere, atmosphere, and biosphere; major influence of ocean on weather and climate)
- Biogeology (feedback between the biosphere and other Earth systems)

### ESS3, Earth and Human Activity

- Human Impacts on Earth Systems (damage or destruction of natural habitats)
- Global Climate Change (factors affecting the rise of Earth's mean surface temperature and the impact on climate)

The content also addresses climate, earth science, and atmospheric literacy principles, which are considered essential information by the Earth and Space Sciences community. (See the Framework for Science Education in "References and Further Reading.")

## Prerequisite Knowledge

Before doing these activities, especially Activity 3: Where Does the Water Go? A Global Journey, students should be familiar with the water cycle.

## Introduction

Climate change means the unusually rapid warming of the atmosphere and its scientifically documented effects around the world. The warming is measurable: although annual local weather patterns vary, the average global temperature has increased by nearly 0.8°C (1.5° F) in the last 100 years. This might not sound like much, but even small temperature changes, occurring worldwide, have a noticeable effect on the climate, which affects habitats for all organisms, including humans. In addition, the pace of change is increasing—most of the rise in average global temperature has occurred in the last few decades.

## Curriculum Snapshot

- Using photographs and satellite imagery to identify and observe changes in the Earth's features over time that indicate climate change
- Using photographs and satellite imagery to prompt discussions on the relationship between the water cycle, weather, and climate, especially the contribution of oceans

## Grade Level

Middle school and high school

## Classroom Connections

Earth and Space Science,  
Physical Science, Social Studies,  
Environmental Studies

Climate change and the human contribution to this change is sometimes denied or depicted as an uncertainty. However, according to the American Association for the Advancement of Science (see References and Further Reading), climate change is not controversial: 97 percent of climate scientists are certain that human-caused climate change is occurring. Climate research is continuing, with scientists and engineers working to predict the consequences of climate change and finding ways to overcome its negative impact.

People around the world, in cities and in rural areas, are experiencing more extreme temperatures, stronger storms, and loss of land from rising sea levels. Some of the most dramatic effects of climate change are related to water: either too much water that results in flooding or too little that results in droughts and wildfires.

For example, even slightly increased temperatures that result from climate change will melt sea ice. Both melting sea ice and higher temperatures increase the volume of the ocean. Greater ocean volume means higher levels of water along coastal areas, which adds to erosion of these areas. In addition, melting sea ice can lead to global changes in water circulation. Water from the melted ice forms a layer at the sea surface that is less dense than the underlying water because it is less salty, potentially preventing the patterns of deep ocean currents from rising to the surface. Melting sea ice also speeds up the warming of the Arctic because water absorbs 80 percent of sunlight, which is about the amount of sunlight that a cover of sea ice reflects.

In this collection, students will use photographs as data to observe and identify changes over time in water-related features such as coastlines or glaciers. They will use photographs to prompt discussions on the consequences of climate change to humans and habitats. They might even use photographs as motivation to explore how they can be citizen scientists and engineers in studying climate change and mitigating its negative effects in their own communities.

*Note: The term “weather” refers to short-term atmospheric features such as precipitation, wind, and temperature. “Climate” means the long-term weather patterns of an area; for example, average temperatures over many years.*

Older references might use the term “global warming” to refer to climate change. Global warming refers to the heating effect of greenhouse gases accumulating in the atmosphere. Scientists study more than just how temperature is affected by human activity, however. To emphasize that human activity does more than just influence temperature, the more common term for rising average global temperatures and its effect is “climate change.”

## Essential Questions

These big ideas or essential questions organize the content and topics.

- What evidence have scientists found about the impact of climate change?
- How do the movements of water affect the Earth and its systems?

## Key Learning Targets

### Students will:

- Observe how living organisms alter Earth's processes and structures over time.
- Consider how human activity changes the atmosphere, hydrosphere, and biosphere over time.
- Discuss the interactions between processes on the Earth's surface and human activities.



## ACTIVITY 1

# Activating Students' Prior Knowledge

In pairs or small groups, give students one or more of the photographs. Ask students to first talk about their overall impressions of the image, what they see, and what they think the image is of and/or trying to portray. Then have the groups write their observations about evidence they see of effects on habitats, signs of human activity, or the impact of humans. (Students might or might not see any or all of these features in their photographs. For example, although they can't see the dam in **3506**, they can figure out where it is, hypothesize that the dramatic change in the water is the result of human activity, and brainstorm about its effects on habitats. Although they can't see how climate change increases coastal erosion, they can begin to hypothesize about its impact on habitats, including for humans.) In groups or as a class, discuss how any activity or impacts they see might be affecting or have affected communities of organisms, including humans.

Emphasize that at this point, no questions or ideas are considered right or wrong.

*Note: Frequently asked questions by students about sea level are: What causes sea levels to rise? What is the impact? Some answers are that changes in sea level are caused by several factors:*

- \* Exchange of water stored on land in glaciers and ice sheets with ocean water
- \* Water expansion as the ocean warms
- \* Storm surges affected by alterations in surface and deep ocean circulation
- \* Changes in terrestrial water storage, such as extraction of groundwater, building of reservoirs, and runoff
- \* Subsidence (caving or sinking of land) in river delta regions, land movements, and tectonic displacements

Impacts of rising sea level include shoreline erosion, effects on wetlands and coral reefs, and loss of habitats and land near coasts or rising rivers and streams.

## Photographs for This Activity (Appendix, pgs. 18-33)

3500, 3505, 3506, 3507,  
3509, 3513, 3515, 3520,  
3521, 3522, 3551, 3558, 3561,  
3563, 3564, 3565

*Notes: Students might ask about permafrost. Permafrost is soil that is permanently frozen. When the permafrost melts, the soil is more susceptible to erosion. (In addition, permafrost stores carbon. When the ice melts, the stored carbon is released as greenhouse gases such as carbon dioxide, which further contributes to climate change.)*

The term hurricane is used for high wind, cyclonic storms in the Atlantic and Northeast Pacific. The same storm is a typhoon in the Northwest (Asian) Pacific, and a cyclone in the South Pacific and Indian Ocean. Monsoon is the term for a seasonal wind in Southeast Asia. Some monsoons bring heavy rain.

Also, see the Habitable Planet resources (see “References and Further Reading”), which have potential discussion topics and common student misconceptions, such as the possibility of a technological fix or the impossibility of human extinction.

## ACTIVITY 2

### What Is the Evidence?

#### Learning Targets:

- I can use photographs to observe changes over time and make inferences on the effects of these changes.
- I can ask questions about the evidence of change that is altering the global climate.

#### Background

Weather changes and overall climate can vary between warm and cool periods; however, average global temperatures have unquestionably risen in the last 100 years. Photographs can record how the effects of small changes in temperature will, over time, result in dramatic changes in oceans, coastlines, and other habitats. Photographs are essential for recording these changes because they might occur slowly, with variation over months or years that obscures a definite overall trend. For example, because coral reefs grow slowly, changes to their structure or composition are difficult to observe day to day. The same slow alterations occur to polar caps, glaciers, and sea level. Over time, however, these small changes add up to a noticeable difference. In this activity, students will use photos taken of a single location at different times to look for evidence of climate change.

Climate scientists have overwhelming evidence that human activities are affecting our climate, mainly through increased production of greenhouse gases such as methane and carbon dioxide (CH<sub>4</sub> and CO<sub>2</sub>). Many sources generate these gases, including normal metabolism. Humans exhale CO<sub>2</sub> and several types of bacteria generate CH<sub>4</sub>. Burning fossil fuels also generates greenhouse gases, however, and our use of petroleum-based fuels and the amount of greenhouse gases in the atmosphere have increased dramatically since the nineteenth century. Greenhouse gases re-radiate heat, raising atmospheric temperatures. Higher temperatures increase the amount of water that evaporates from oceans into the air. This affects land conditions as precipitation patterns change, potentially leading to floods or droughts.

Although we sometimes think of climate change as affecting only summer temperatures, in many ecosystems, warming winters also severely affect plants, animals, and humans. For example, increased atmospheric moisture makes snowstorms more severe. A lack of freezing days can cause infestations of insects that would normally be killed by freezing temperatures.

#### Photographs for This Activity (Appendix, pgs. 34-42)

3503, 3504, 3516, 3518,  
3554, 3555, 3560, 3572,  
3573

Another consequence of climate change is rising sea levels because of several factors, including higher water temperatures, and increased volume as water that is trapped as ice sheets and glaciers melts. When sea levels are higher, islands and coastal regions are more seriously affected by storm surges and, on an everyday basis, by encroaching salt water that changes habitats. Plants, animals, and microorganisms that are adapted to particular environmental conditions must adapt or change habitats to survive. Changing habitats affect conditions for humans, such as our supply of food and water.

## Begin the Activity

In pairs or small groups, give students a series of photographs of the same location taken at different times. Have students observe, and then list and describe all the features in each photograph. Have them pay particular attention to anything that changed or anything that is exactly the same in the photos.

Once they have generated a list, have the students mark the list for items that changed and items that did not change in the photo series. Have the students use the list to draw a Venn diagram. One circle will list items in the earlier photo, with their descriptions, that look different from items in the later photo. The other circle will list items in the later photo, with descriptions, that look different from the earlier photo. The intersection will list items that appear the same in both photos. (So the nonintersecting parts might list the same items—such as a mountain or a rock—but will have different descriptions for those items, such as snow-covered or bare. The intersecting part will have items that have the same descriptions for both photos, such as a rocky ridge with a little snow.)

*Optional, advanced, or group discussion example: Photo 3516 show photos before and after Hurricane Sandy, a particularly strong hurricane in 2012. Although an individual hurricane might seem like an isolated event, increased atmospheric moisture can make storms more severe.*

Students' answers will vary depending on the set of photos they received. Their answers should reflect the changes they have already noticed and what will happen if those changes continue.

For example, if they noticed that the amount of water in an area has increased over time, they might say that the area is likely to continue flooding, and people who live in the area will have to move.

They might note that coral reef death affects species that depend on coral habitats. (Coral bleaching, which is loss of the algae that live in coral tissues, occurs when water is too warm and can lead to death of the coral.)

## Materials:

- Paper, pencils or pens

## Questions to Consider

- What might be the impact of these changes beyond what is in the photo?
- What changes might be disruptive for wildlife habitats, vegetation, or human communities?
- What ways can you think of to reduce the disruptive effects of the changes you observed?
  - \* Suggested activity for this question: Have students make a two-column table with pros and cons of trying to reduce a disruptive effect of climate change. For example, if students think of building a dam to prevent floods, a good exercise might be writing down the upstream effects of a dam.
- Optional question if your class has covered material on Earth's Systems (ES22): What might be the scientific basis for any changes your team noted in the earlier and later photographs?

They might note that flooding could continue if warmer temperatures result in increased water evaporation, leading to the heavy rainfall that causes flooding. In contrast, increased evaporation in places that are normally dry results in droughts. Other impacts include heat waves; warmer winters; changing ecosystems; a possible loss, decrease, or increase in species; and effects on agriculture from drought, heat, and floods.

Anything that causes changes in the ecosystem is likely to be disruptive to wildlife. For example, flooding will disrupt a habitat for any wildlife living in the flooded area. Students might note that, although humans often have the technology to help them live in changing conditions, severe changes, such as extreme flooding or drought, might cause people to move from a community.

## ACTIVITY 3

# Where Does the Water Go? A Global Journey

### Learning Targets

- I can describe the cycling of water through Earth's systems.
- I can interpret and explain how the complex interactions of air and water movements results in changes in local weather.

### Background

This activity should be done after the class has learned about the water cycle. Consider reviewing the essential features of the cycle before starting this activity.

Water is three-fourths of the Earth's surface. Most of that water (97%) is in oceans, so changes in our oceans also have profound effects on the atmosphere and conditions on land. As students learned in the class, water is solid (ice), liquid (water), or gas (vapor), moving between these states and around the planet. Sunlight melts ice and evaporates water, creating atmospheric water vapor, which condenses into rain or snow. Gravity causes the water to fall to Earth, where it returns to oceans, lakes, and rivers.

### Photographs for This Activity (Appendix, pgs. 43-54)

3526, 3528, 3531, 3532,  
3536, 3537, 3538, 3544,  
3545, 3546, 3549, 3552

### Materials

- Sticky notes



## Begin the Activity

Students might have noticed that many of the consequences of climate change that they have been observing in the photo collection are related to water. Increased atmospheric moisture leads to stronger storms and flooding, for example. Ask students what percent of the Earth's water they think is in oceans (97%). Ask them to identify other locations of water (including ice) on Earth and in the Earth's atmosphere.

After reviewing the locations of water, have students work in small groups or pairs to re-create the water cycle by using the provided photos. As they arrange photos on their desks, have them explain the different water states (ice, liquid, and vapor), how water might travel between locations while in the different states, and the factors—such as sunlight or air temperature—that might cause water to be converted to one state or another. (Optional: have them refer to a diagram of the water cycle from their textbook or other source.)

Ask students to reflect and comment on connections between the states of water and its global locations. Have them discuss the likely consequences of climate change on each step, each component, and the entire system. To keep track of their ideas, they might add sticky notes to each picture, predicting the effects of climate change on this part of the water cycle.

Students might predict acceleration or intensification of parts of the cycle; for example, they might predict increased evaporation with increased temperature. They might predict stronger rain and snowstorms after the increased evaporation.

## Questions to Consider

- What ideas did your group come up with about the possible effects of climate change on the water cycle? Share your results with other groups. How do your ideas compare to the ideas of other groups?
- Overall, how would you describe the effects that climate change might have on the water cycle, especially if current trends continue?
- What are the impacts that water and changes in water level can have on the surface of the earth?
- How did photographs help organize ideas about climate change and the water cycle?
- Optional/advanced: If you have studied other cycles that occur on the earth, do you think that they would also be affected by climate change? If climate change continues with recent trends, what might happen on the surface of the Earth?

## ACTIVITY 4

### Citizen Science

#### Learning Targets:

- I can apply scientific principles to evaluating methods for monitoring and minimizing human impact on my local environment.

#### Background

Scientists and the public are noticing more extreme weather of all types, such as stronger winter storms, earlier springs, and warmer summers. These observations give students opportunities to design or contribute to public science projects. For example, temperatures, storm frequencies, and rain and snowfall can all be measured. Your school might even be involved in recording local meteorological data. Long-term weather data for your area might be available at local or national websites. Climate change affects habitats, which influences the plants and animals in an area and the timing of their seasonal appearances. Conservation societies often organize volunteers to keep records of local flora and fauna; for example in annual bird and fish counts or plant surveys. Teachers, students at your school, or their families might be involved in these efforts. Other examples of ways that students might participate in public science projects are in the photos.

In this activity, students will use photographs as prompts to discuss what they are or could be doing to apply what they have learned in this collection to observe or address climate change in their community.

#### Begin the Activity

Give students photos of climate scientists and student-citizen scientists at work. Use the photos as prompts for discussions about what problems climate change is creating around the world, either issues students have heard of or effects they would predict based on what they have learned about climate change, the water cycle, weather, and climate. Have students discuss possible studies and research projects they might conduct locally.

#### Photographs for This Activity (Appendix, pgs. 55-59)

3556, 3557, 3569, 3570,  
3571

#### Question to Consider

- What are some actions an ordinary citizen scientist can take to counteract the negative impact of climate-change-related local weather patterns? Choose a possible action and discuss whether a community affected by climate change should take this action. If so, what might some consequences be? If not, why not?

## Extension Activities

1. Explore current extreme weather events around the globe. Check news sources to find examples of extreme weather events. Find news stories with photos and examine the photos, using the questions from the activities in this collection. An additional option is to write an essay in a style your class has been learning (such as persuasive) based on one or more news stories and the accompanying photos.
2. Join the U.S. Geological Survey's iCoast project, and analyze coastline photographs before and after a major storm. Human eyes are better than computers at noting changes in complex coastline features, so the U.S. Geological Survey needs your help.  
<http://coastal.er.usgs.gov/icoast/index.php>

## Essential Lens Video Connections

- Watch *A Closer Look* to learn more about analyzing photographs

## Reference Materials & Further Reading

Framework for Science Education

*A Framework for K-12 Science Education. Practices, Crosscutting Concepts, and Core Ideas.*

[http://www.nap.edu/catalog.php?record\\_id=13165](http://www.nap.edu/catalog.php?record_id=13165)

Graph from the California Department of Water Resources

<http://cdec.water.ca.gov/cdecapp/resapp/getResGraphsMain.action>

The Habitable Planet

<http://www.learner.org/courses/envsci/unit/text.php?unit=12&secNum=0>

“Water: Our Thirsty World.” *National Geographic Magazine*.

<http://ngm.nationalgeographic.com/2010/04/table-of-contents/>

Gary Braasch website

<http://www.worldviewofglobalwarming.org>

Facing the Future

<https://www.facingthefuture.org>

American Association for the Advancement of Science (AAAS)

<http://whatweknow.aaas.org/>

NASA maps and climate change

<http://earthobservatory.nasa.gov/Features/WorldOfChange/decadaltemp.php>

[http://www.nasa.gov/mission\\_pages/noaa-n/climate/climate\\_weather.html](http://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html)

USGS Image gallery

[http://gallery.usgs.gov/collections/Climate\\_Change](http://gallery.usgs.gov/collections/Climate_Change)

Erosion in Alaska

<http://www.usgs.gov/newsroom/article.asp?ID=2141#.U5zXh41dVe5>

Journey North

<https://www.learner.org/jnorth/>

GLOBE

[www.globe.gov](http://www.globe.gov)

Project Budburst  
<http://budburst.org>

Cornell Laboratory of Ornithology  
<http://www.birds.cornell.edu>

University Corporation for Atmospheric Research (UCAR) LEARN Project  
<http://www.ucar.edu/learn>

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

United Nations Educational, Scientific and Cultural Organization (UNESCO)  
<http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/education-for-sustainable-development>

Education for Sustainable Development Toolkit  
<http://www.esdtoolkit.org>

National Oceanic and Atmospheric Administration Climate Literacy  
<http://cpo.noaa.gov/OutreachandEducation/ClimateLiteracy.aspx>

Loren Eiseley, anthropologist and author  
<http://www.eiseley.org>

American Geophysical Union  
<http://virtualoptions.agu.org>

Permafrost  
[http://www.wunderground.com/resources/climate/melting\\_permafrost.asp](http://www.wunderground.com/resources/climate/melting_permafrost.asp)

California Drought Article  
<http://www.nbclosangeles.com/news/local/Water-CA-California-Drought-Friant-Dam-San-Joaquin-Delta-259219481.html>

## Books

Braasch, Gary. *Earth under Fire: How Global Warming Is Changing the World*. Berkeley and Los Angeles: University of California Press, 2007.  
<http://www.earthunderfire.com>

Cherry, Lynne and Gary Braasch. *How We Know What We Know About Our Changing Climate: Scientists and Kids Explore Global Warming*. Nevada City, CA: Dawn Publications, 2008.

[http://www.lynncherry.com/how\\_we\\_know\\_what\\_we\\_know\\_about\\_our\\_changing\\_climate\\_\\_scientists\\_and\\_kids\\_explore\\_67915.htm](http://www.lynncherry.com/how_we_know_what_we_know_about_our_changing_climate__scientists_and_kids_explore_67915.htm)

National Science Teachers Association Press. *Global Climate Change: Resources for Environmental Literacy*. NSTA Press Book. 2007.

[http://www.nsta.org/store/product\\_detail.aspx?id=10.2505/9781933531182](http://www.nsta.org/store/product_detail.aspx?id=10.2505/9781933531182)

Fleck, John. *The Tree Rings' Tale: Understanding Our Changing Climate*.

Albuquerque, NM: University of New Mexico Press, 2009.

<http://www.unmpress.com/books.php?ID=11781365963614>

## Film and Video

*Chasing Ice*

<http://www.chasingice.com>

"California's Extreme Drought, Explained." *New York Times* video. July 5, 2004.

<http://www.nytimes.com/video/us/100000002980095/californias-extreme-drought-explained.html?action=click&pgtype=Homepage&module=video-player-region&region=video-player-region&WT.nav=video-player-region>

## Additional Photographic Collections to Support this Topic

NASA: Images of Change

[http://climate.nasa.gov/state\\_of\\_flux#Drought\\_California\\_930x308.jpg](http://climate.nasa.gov/state_of_flux#Drought_California_930x308.jpg)

Thomas Lovejoy

<http://www.nationalgeographic.com/explorers/bios/thomas-lovejoy/>

The Shrinking Aral Sea and related student activities

<http://www.columbia.edu/~tmt2120/introduction.htm>

Annenburg Learner: Teaching Geography

<http://www.learner.org/workshops/geography/pdf/1aralsea.pdf>

NASA: Earth Observatory

<http://earthobservatory.nasa.gov/IOTD/view.php?id=4463>



# APPENDIX

## Activity 1

### pgs. 18-33

3500, 3505, 3506, 3507,  
3509, 3513, 3515, 3520,  
3521, 3522, 3551, 3558,  
3561, 3563, 3564, 3565

## Activity 2

### pgs. 34-42

3503, 3504, 3516, 3518,  
3554, 3555, 3560, 3572,  
3573

## Activity 3

### pgs. 43-54

3526, 3528, 3531, 3532,  
3536, 3537, 3538, 3544,  
3545, 3546, 3549, 3552

## Activity 4

### pgs. 55-59

3556, 3557, 3569, 3570,  
3571

## Activity 1 3500

Permafrost

Erosion

Measurement

USGS

researcher

Benjamin

Jones measures

erosion near a

collapsed block

of ice-rich

permafrost

along Alaska's

Arctic coast.

August 2008.

Alaska.

(Christopher

Arp/U.S.

Geological

Survey)





## Activity 1 3505

Coastal  
erosion on the  
North Slope  
of Alaska.  
July 8, 2012.  
Alaska. (John  
Pearce/U.S.  
Geological  
Survey)

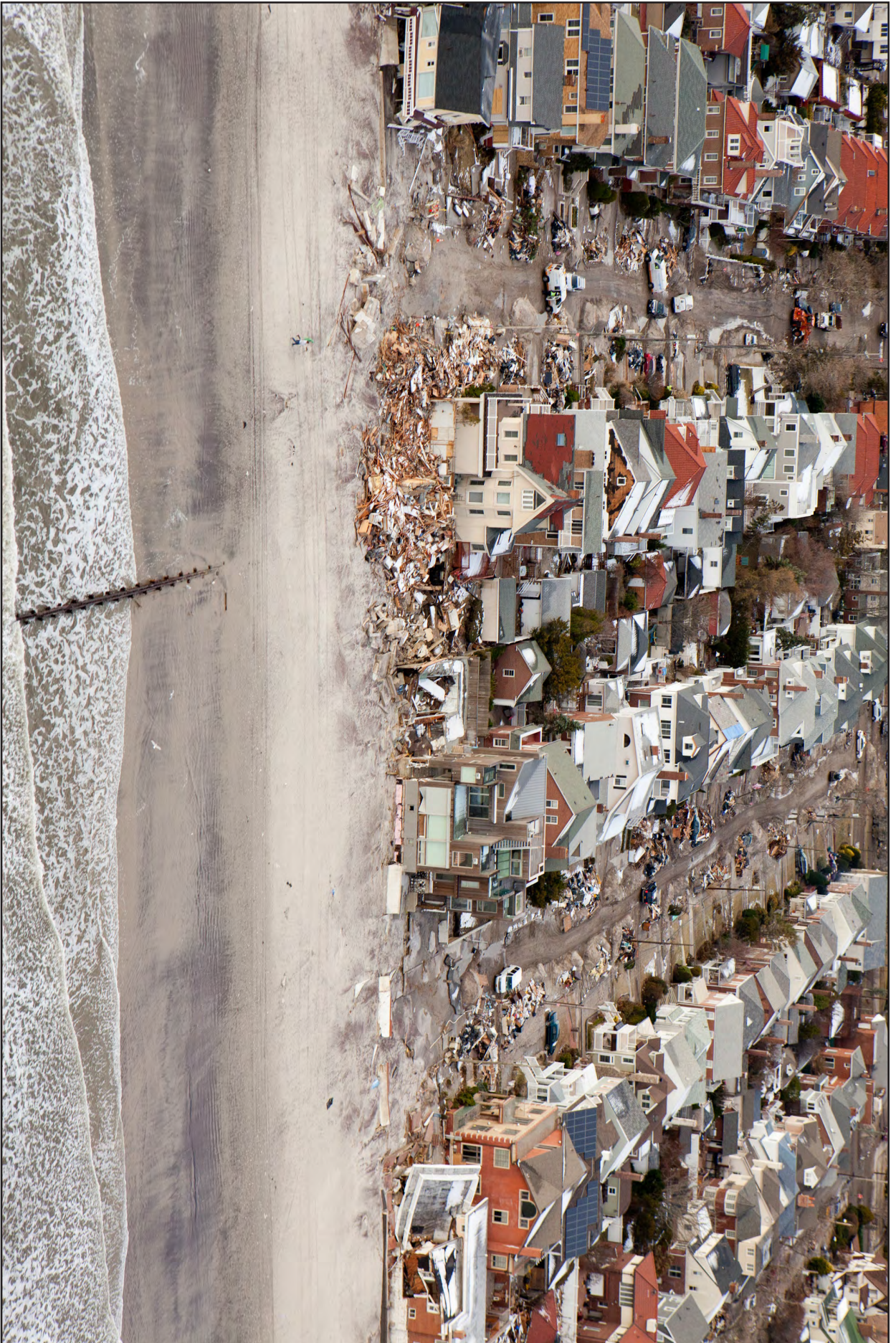






**Activity 1 - 3506** - The Mirani Dam on the Dasht River in southern Pakistan was completed in 2006. The resulting reservoir provides water for drinking, irrigation, and hydroelectric power. Though the dam also helps to control flooding, heavy rains in 2007 increased the reservoir depth from 244 to 271 feet (74 to 82 meters) with attendant flooding that displaced more than 15,000 people. The left image shows the region before the dam was built. The image on right image shows the dam in 2011 with the expanded agriculture that the dam's water supports. August 2, 1999 (left) and June 8, 2011 (right). Pakistan. (U.S. Geological Survey Landsat Missions Gallery "Mirani Dam," U.S. Department of the Interior/USGS and NASA)





**Activity 1 - 3507** - Aerial views of damage to Long Beach due to Hurricane Sandy. Following the hurricane, a nor'easter struck the area, causing more power outages and additional flooding.  
November 8, 2012. Long Beach, New York. (Andrea Booher/FEMA News Photo)



**Activity 1**  
**3509**

A cabin  
along the  
Arctic Alaska  
coastline  
was recently  
washed into  
the ocean  
because the  
bluff it was  
sitting on top  
of was eroded  
away. August  
2005. Alaska.  
(Benjamin  
Jones/U.S.  
Geological  
Survey)





## Activity 1 3513

How people  
are adapting to  
climate change  
and fighting food  
insecurity

For people who  
live in areas  
covered by  
water during  
the monsoon  
season, such as  
the riverine areas  
of Bangladesh,  
it is impossible  
to grow crops.  
Practical Action  
has developed  
a technology to  
allow farmers  
to grow food on  
flooded land.

The floating  
garden is a clever  
solution that  
employs the use  
of water hyacinth,  
which is collected  
to construct a  
raft. This is then  
covered with soil  
and cow dung, in  
which vegetables  
can be planted.  
A new raft needs  
to be built every  
year, but the old  
one can be used  
as fertilizer during  
the dry season.  
October 3, 2006.  
Bangladesh.  
(Practical Action)





## Activity 1 3515

How people are adapting to climate change and fighting food insecurity

For people who live in areas covered by water during the monsoon season, such as the riverine areas of Bangladesh, it is impossible to grow crops.

Practical Action has developed a technology to allow farmers to grow food on flooded land.

The floating garden is a clever solution that employs the use of water hyacinth, which is collected to construct a raft. This is then covered with soil and cow dung, in which vegetables can be planted. A new raft needs to be built every year, but the old one can be used as fertilizer during the dry season. Date unknown. Bangladesh. (Practical Action)





## Activity 1 3520

Near Drew Point, Alaska, along the northern coast. The photo shows what often follows such undercutting: chunks of coastline tumbling into the sea. June 20, 2008. Alaska. (Stratus Consulting/ University of Colorado)







**Activity 1 - 3521** - Near Drew Point, Alaska, along the northern coast. The photo shows how ocean waves have undercut the land nearest the shore. Grassy turf extends out over a wave-cut notch.

Ocean waves slowly eat away coastal cliffs the world over, but in parts of Alaska, these processes have accelerated due to changing climate. There, coastal erosion owes its accelerated pace to two climate-driven phenomena: declining sea ice and thawing permafrost. August 9, 2007. Alaska. (Stratus Consulting/University of Colorado)





**Activity 1 - 3522** - Large parts of New Orleans remain flooded two weeks after several levees failed in the wake of Hurricane Katrina. September 14, 2005. New Orleans. (Bob McMillan/FEMA News Photo)





**Activity 1 - 3551** - Many parts of New Orleans remain underwater with rescue operations ongoing over two weeks after Hurricane Katrina made landfall. September 16, 2005. New Orleans. (Bob McMillan/FEMA News Photo)





**Activity 1 - 3558** - Augusta city crew cleans up fallen trees off Broad Street in downtown Augusta. Throughout the east Georgia region, the grand total was 36,000 outages. Georgia Power set up a massive staging area for utility trucks – many of them supplied by out-of-state contractors – in the parking lot of the defunct Regency Mall south of downtown Augusta. February 13, 2014. Augusta, Georgia. (Hyosub Shin/Atlanta Journal-Constitution/AP Photo)





**Activity 1 - 3561** - Hurricane Sandy created widespread flooding, power outages, and devastation on Long Island, New York. November 7, 2012. Long Island, New York. (Andrea Booher/FEMA News Photo)





**Activity 1 - 3563** - A view of a residential area flooded by heavy rains, with some areas receiving as much as 18 inches in a 24-hour period in Boulder, Colo., Sept. 14, 2013. U.S. Soldiers with the 2nd General Support Aviation Battalion, 4th Combat Aviation Brigade, 4th Infantry Division, assisted state and local emergency response efforts under the Immediate Response Authority. Colorado and Wyoming National Guard units were activated to provide assistance to people affected by massive flooding along Colorado's Front Range. September 14, 2013. Boulder, Colorado. (Staff Sgt. Wallace Bonner/U.S. Army)





**Activity 1 - 3564** - A view of state infrastructure destroyed by heavy rains, with some areas receiving as much as 18 inches in a 24-hour period in Boulder, Colo., Sept. 14, 2013. U.S. Soldiers with the 2nd General Support Aviation Battalion, 4th Combat Aviation Brigade, 4th Infantry Division, assisted state and local emergency response efforts under the Immediate Response Authority. Colorado and Wyoming National Guard units were activated to provide assistance to people affected by massive flooding along Colorado's Front Range. September 14, 2013. Boulder, Colorado. (Staff Sgt. Wallace Bonner/U.S. Army)





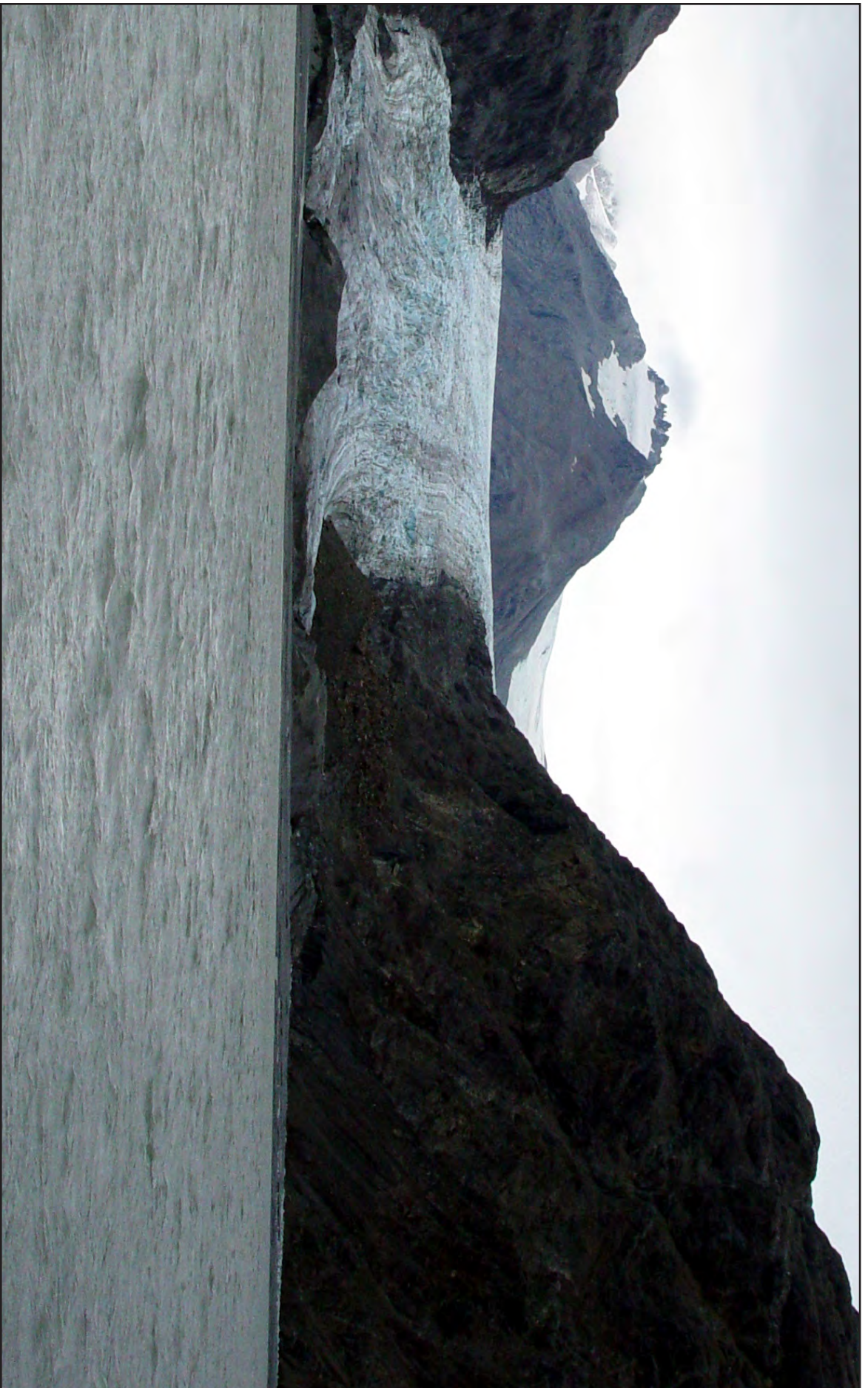
**Activity 1 - 3565** - An extended area of Longmont, Colo., is mostly submerged as flooding continues to devastate the Front Range, Friday, Sept. 13, 2013. The flooding has affected parts of a 4,500-square-mile area, almost the size of Connecticut. September 13, 2013. Longmont, Colorado. (John Wark/AP Photo)





**Activity 2 - 3503 - Muir Glacier and Muir Inlet, 1980** This ship-deck-based August 1980 photograph of Muir Glacier and Muir Inlet, Glacier Bay National Park and Preserve, St. Elias Mountains, Alaska, shows the nearly 200-ft-high retreating tidewater end of Muir Glacier with part of its face capped by a few angular pinnacles of ice, called séracs. Note the icebergs in the ship's wake in the lower-right side of the photograph. The location of Muir's terminus is less than a mile from the landward end of Muir Inlet. August 1, 1980. Alaska. (Bruce Molnia/U.S. Geological Survey)





**Activity 2 - 3504 - Muir Glacier and Muir Inlet, 2003** This photo was taken in September 2003. In the 23 years between photographs (see image **3503**), Muir Glacier has retreated more than a mile and ceased to have a tidewater terminus. Since 1980, Muir Glacier has thinned by more than 600 ft, permitting a view of a mountain with a summit elevation of greater than 4000 ft, located in the center of the photograph. A re-examination of the 1980 photograph shows that the summit of this mountain was visible but that it blended in with adjacent clouds. September 1, 2003. Alaska. (Bruce Molnia/U.S. Geological Survey)



## Activity 2

3516

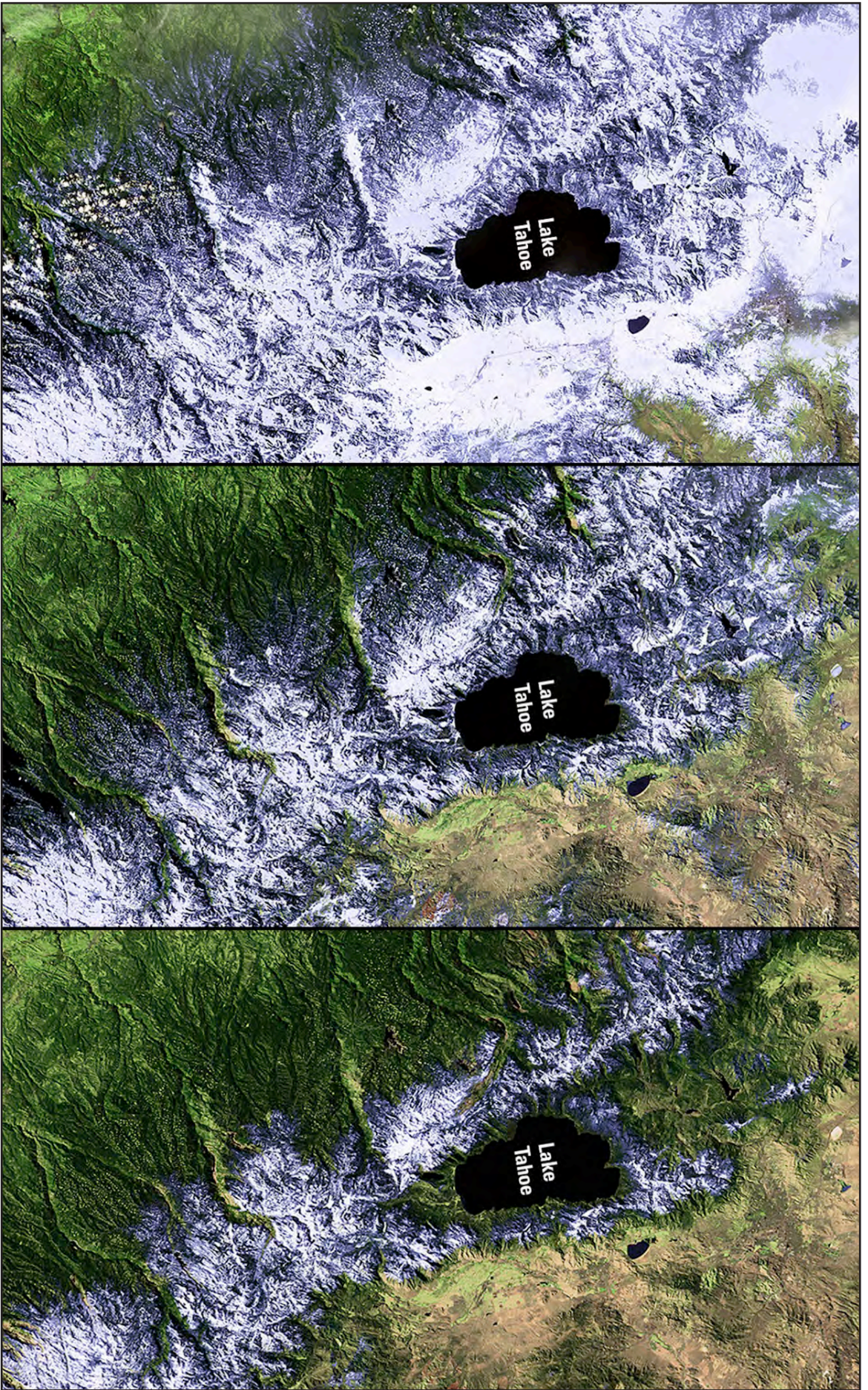
The two aerial photographs show a portion of the New Jersey coastal town of Mantoloking, just north of where Hurricane Sandy made landfall. The photograph on the right is by the Remote Sensing Division of the National Oceanic and Atmospheric Administration (NOAA) on October 31, 2012; the image on the left was acquired by the same group on March 18, 2007. The images were acquired from an altitude of roughly 7,500 feet, using a Trimble Digital Sensor System.

The Mantoloking Bridge cost roughly \$25 million when it was opened in 2005 to replace a bridge built in 1938. After Sandy passed through on October 29, 2012, the bridge was covered in water, sand, and debris from houses; county officials closed it because they considered it unstable.

On the barrier island, entire blocks of houses along Route 35 (also called Ocean Boulevard) were damaged or completely washed away by the storm surge and wind. Fires raged in the town from natural gas lines that had ruptured and ignited. A new inlet was cut across the island, connecting the Atlantic Ocean and the Jones Tide Pond. March 18, 2007 (left) & October 31, 2012 (right). Mantoloking, New Jersey. (Aerial photography courtesy of the NOAA Remote Sensing Division. Caption by Mike Carlowicz.)







**Activity 2 - 3518 - Drought Conditions in California** California is undergoing its most severe drought in decades, due in part to decreased rainfall and reduced winter snowpack in the Sierra Nevada mountain range, as seen in these images. In 2013, California received less precipitation than in any other year since it became a state in 1850. Water conservation efforts are already in place for many locations, and the potential for wildfire and major agricultural impact is high. February 2011, 2013, and 2014. Lake Tahoe, California. (U.S. Geological Survey Landsat Missions Gallery "Drought Conditions in California, USA," U.S. Department of the Interior/USGS and NASA)





**Activity 2 - 3554** - Mendenhall Glacier. This archival photo from the National Snow and Ice Data Center/NOAA archives was made in 1894 by William Ogilvie during a geologic survey, 1894. Juneau, Alaska. (William Ogilvie/NSIDC/NOAA)





**Activity 2 - 3555** - Mendenhall Glacier has retreated 2800 meters since 1910, and 580 meters since 1948. The trimline on the north side of the glacier is evident. In this part of Alaska, vegetation grows rapidly and bare, deglaciated terrain usually develops substantial vegetation within 50 years. The lake began to form in 1910 as the glacier retreat reached the southern margin of the lake. 2008. Juneau, Alaska. (Gary Braasch Photography)





**Activity 2 - 3560** - Comparison photos showing the historic Millerton Courthouse as it sits atop a bluff overlooking Millerton Lake in Friant, Calif. in 2009, top, with the water at a high point; and on Aug. 5, 2014, where the water isn't visible at the same angle. Currently, the level of water is at 270,284 acre feet or 51.9 percent of capacity. 2009 (top) and 2014 (bottom). Friant, California. [Darrell Wong (top) and Craig Kohlruess (bottom)/Fresno Bee/AP Photo]









**Activity 2 - 3573** - A dying Buck Island Barrier Reef, caused by a myriad of reasons, including bleaching caused by warmer ocean waters. 2011. St. Croix, U.S. Virgin Islands. (David Arnold/doublexposure.net/Marine Photobank)





**Activity 3 - 3526** - Denali Wilderness, Denali National Park and Preserve. December 16, 2011. Alaska. (Tim Rains/U.S. National Park Service)





**Activity 3 - 3528** - Reflection on Lake McDonald in Glacier National Park. May 14, 2012. Montana. (David Restivo/U.S. National Park Service)



### Activity 3

3531

Rain

over the

Absarokas,

Yellowstone

National

Park. June

24, 2014.

Wyoming.

(Neal

Herbert/

U.S.

National

Park

(Service)







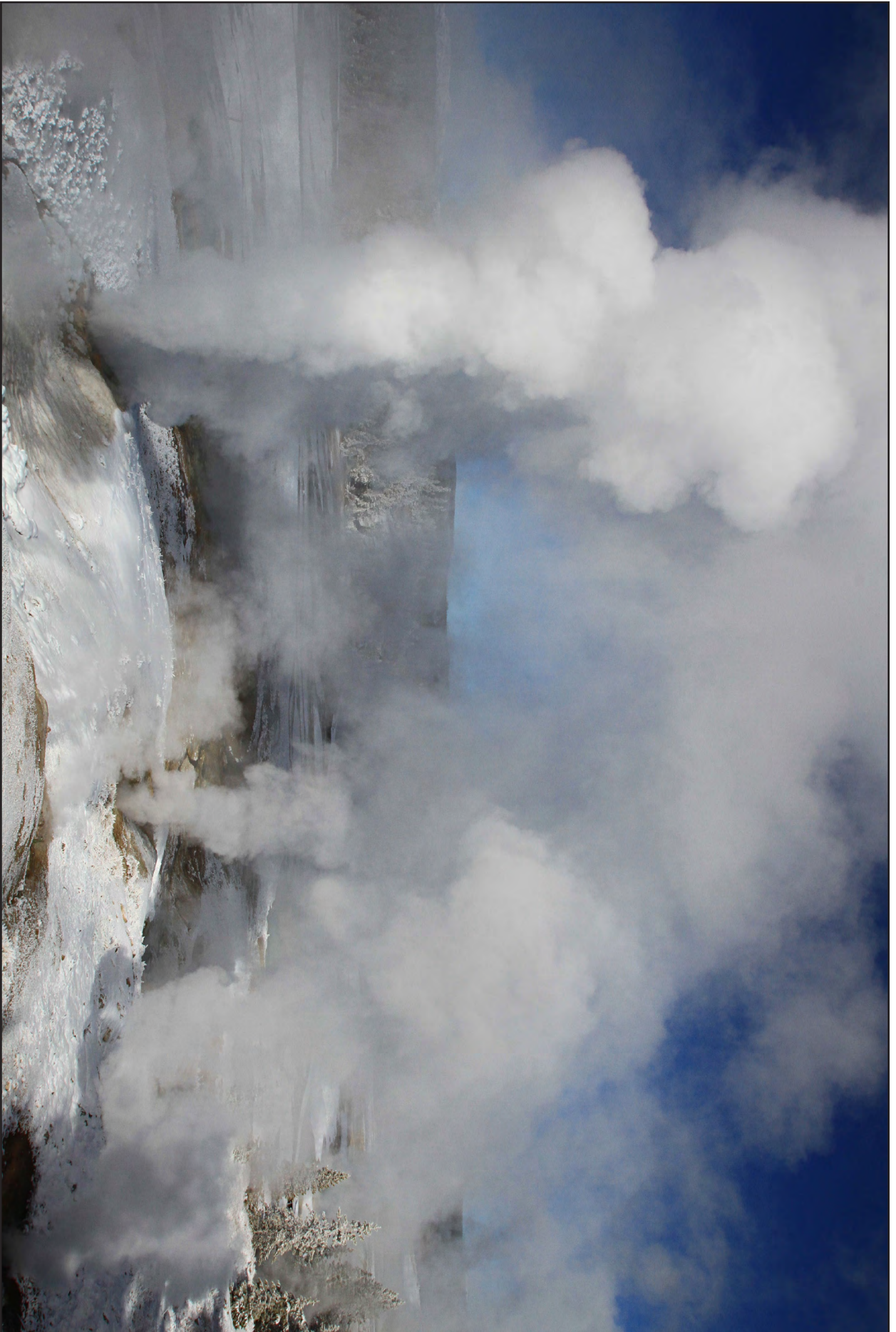
**Activity 3 - 3532** - Firehole River, Yellowstone National Park. February 26, 2014. Wyoming. (Neal Herbert/U.S. National Park Service)





**Activity 3 - 3536** - Morning fog in the Yellowstone River Valley, Yellowstone National Park. June 28, 2014. Wyoming. (Neal Herbert/U.S. National Park Service)





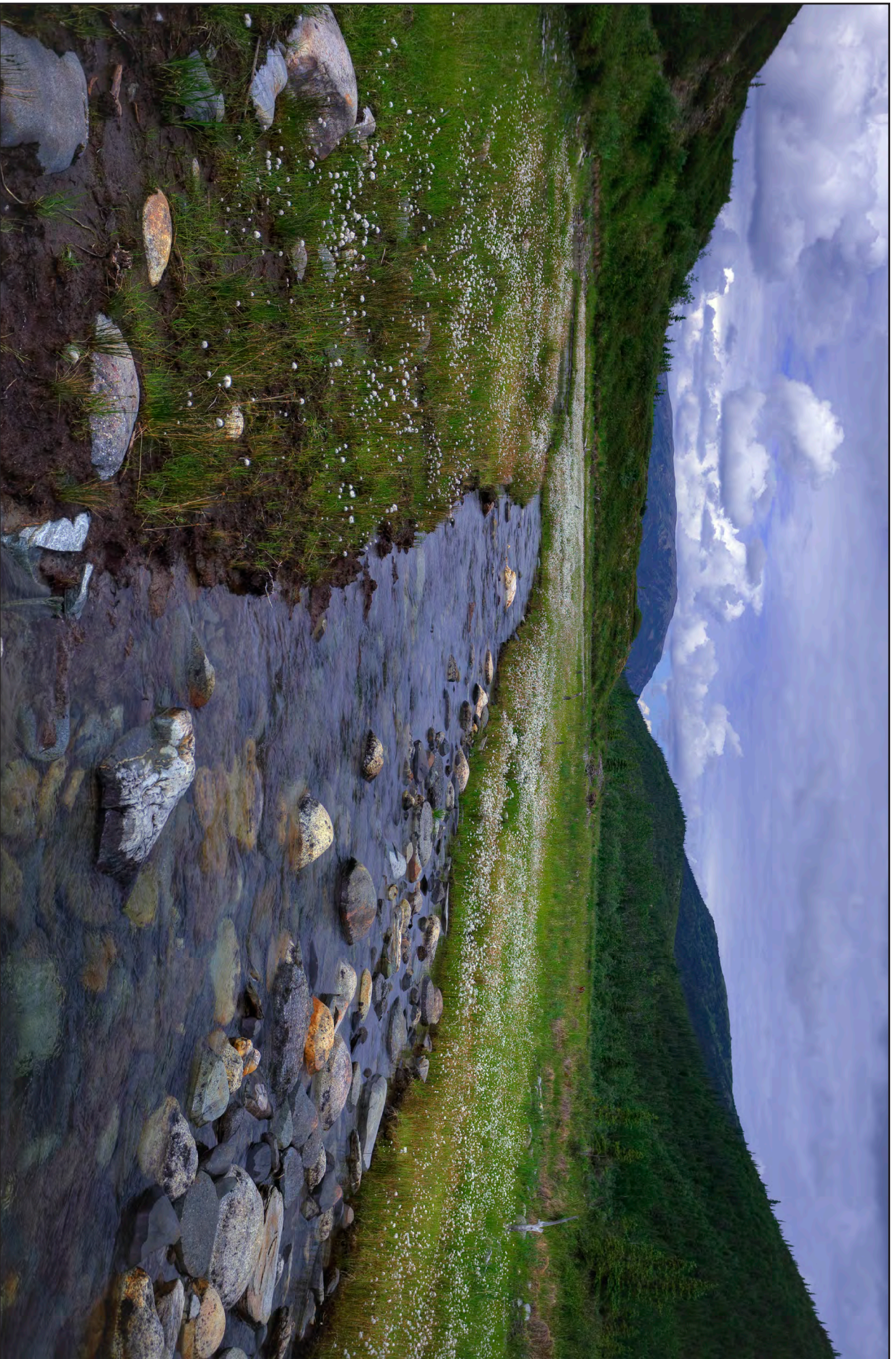
**Activity 3 - 3537** - Porcelain Basin in Norris Geyser Basin, Yellowstone National Park. November 2013. Wyoming. (Jim Peaco/U.S. National Park Service)





**Activity 3 - 3538** - Mist from the lower falls drifts into the Grand Canyon of the Yellowstone. August 2013. Yellowstone National Park, Wyoming. (Jim Peaco/U.S. National Park Service)





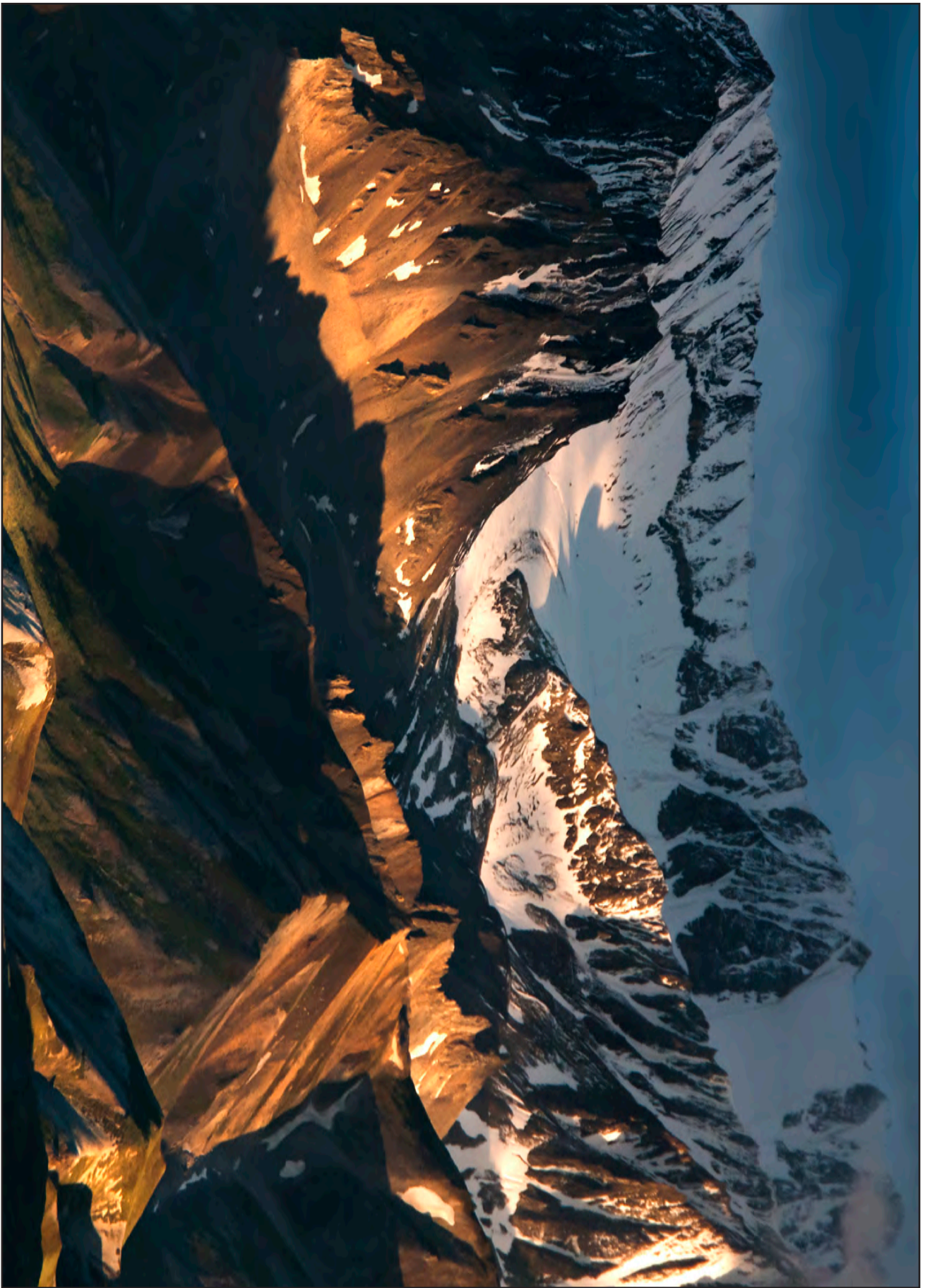
**Activity 3 - 3544** - Moose Creek, Denali National Park and Preserve. July 2, 2012. Alaska. (Jacob W. Frank/U.S. National Park Service)





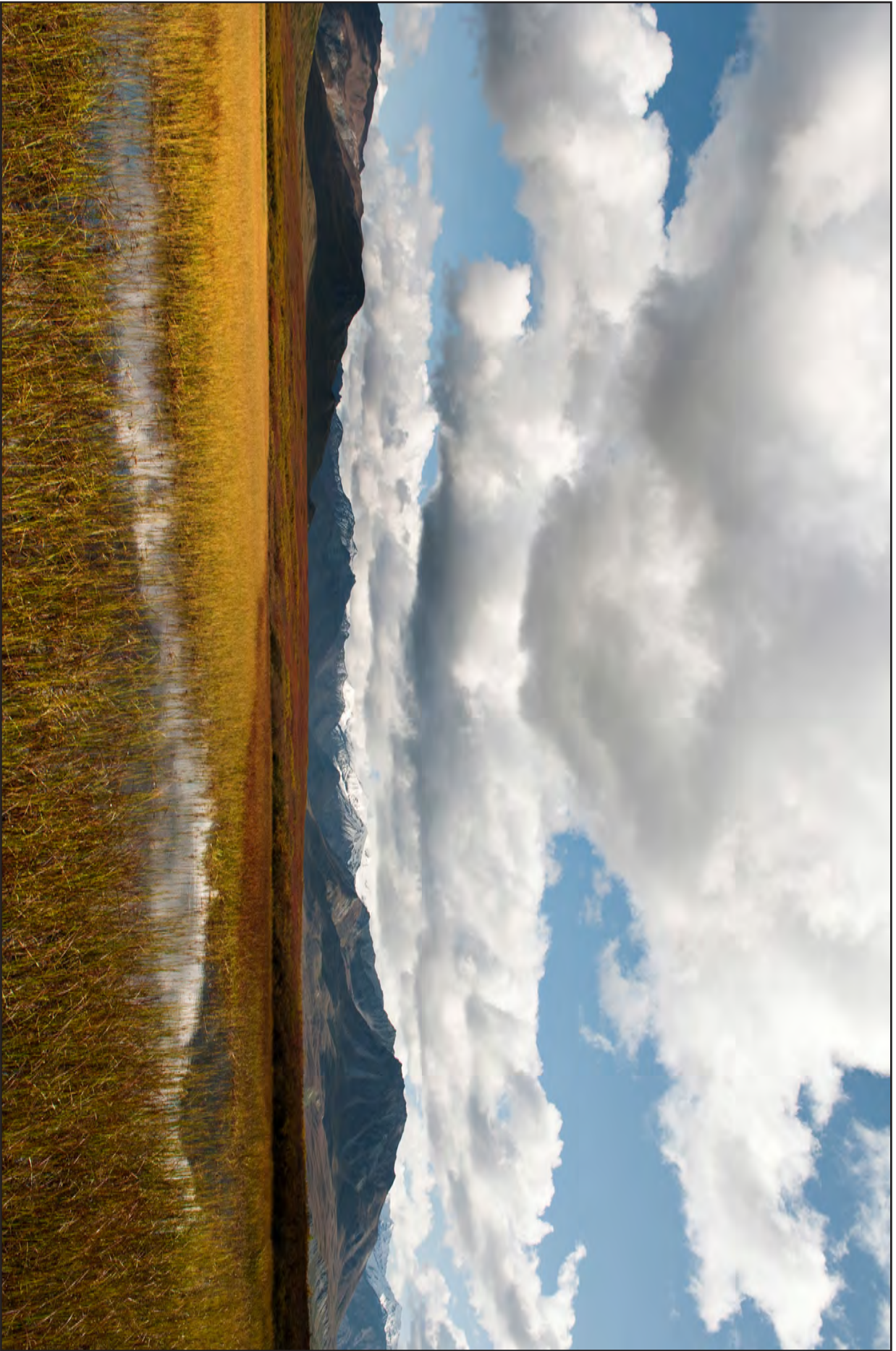
**Activity 3 - 3545** - Droplets of Song: Spruce, Denali National Park and Preserve. September 23, 2011. Alaska. (Tim Rains/U.S. National Park Service)





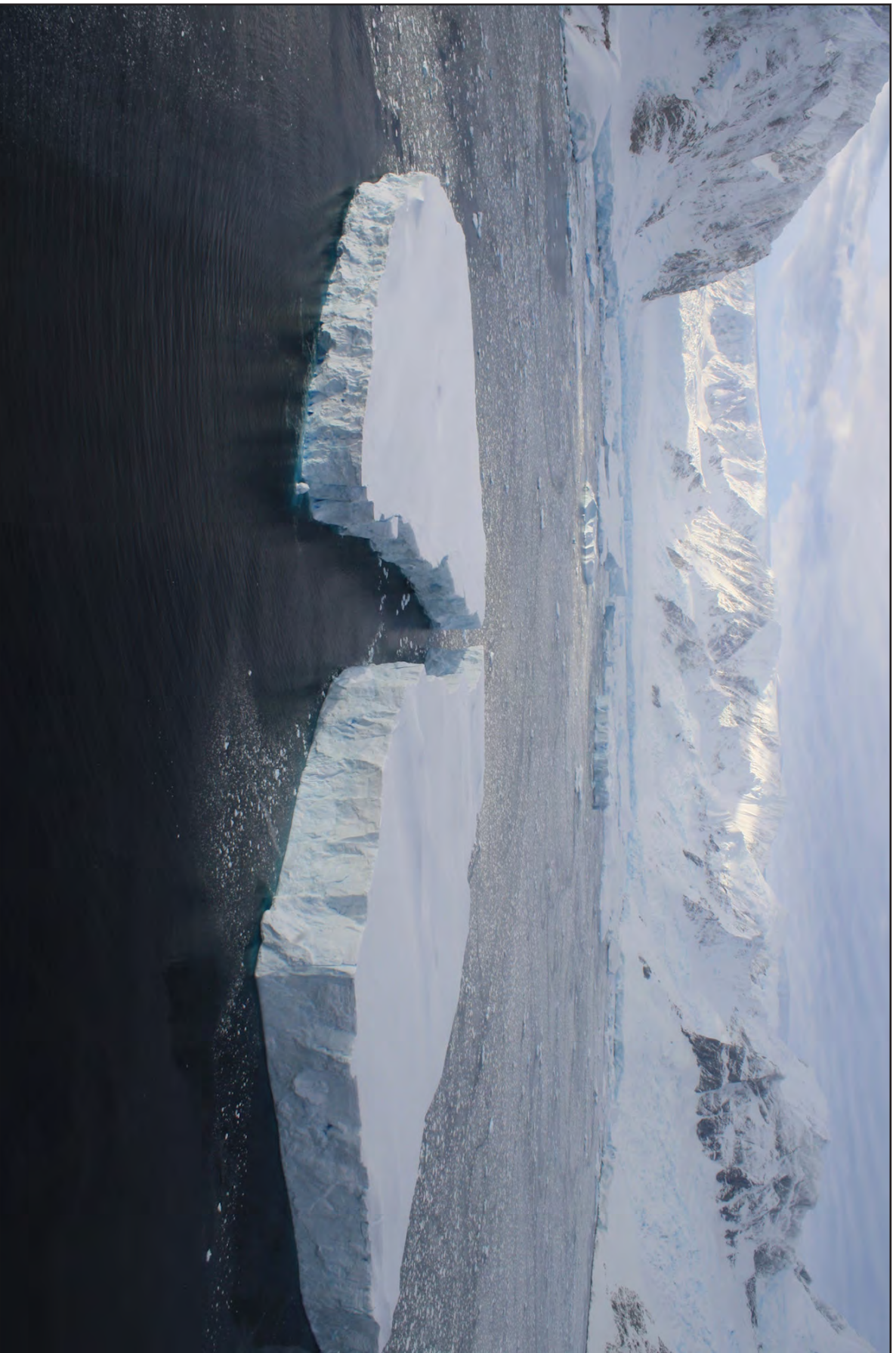
**Activity 3 - 3546** - Muldrow Glacier, Denali National Park and Preserve. November 7, 2011. Alaska. (Tim Rains/U.S. National Park Service)





**Activity 3 - 3549** - Ephemeral pond, Denali National Park and Preserve. December 21, 2009. Alaska. (Tim Rains/U.S. National Park Service)





**Activity 3 - 3552** - Icebergs in Beascochea Bay, photographed during the 2013 LARISSA Expedition. The Larsen Ice Shelf System, Antarctica (LARISSA) Project is a large, interdisciplinary, multi-institute study to explore every aspect of the deteriorating Larsen Ice Shelf region in Antarctica. Participating researchers set up instruments on the glaciers that feed into the remaining portion of the Larsen ice shelf. As changes occur on the ice, the stations will record it in data and pictures. 2013, Antarctica. (Ted Scambos/National Snow and Ice Data Center, University of Colorado, Boulder)





**Activity 4 - 3556** - High in the Alps at more than 3000 m/9700 ft, botanists re-establish plots, set up and inventoried ten years before, to see how climate warming has affected alpine plants. The regional average temperature is up 1.20 C/2.0 F in the last 30 years, and wildflowers and grasses adapted to colder elevations are being forced up the mountain. Botanist Harold Pauli who, with colleagues from University of Vienna, set up the original study, counts individual plants and compares their location with the photos made in 1994. Other effects of climate change can be seen on the glaciers behind. August 2001. Schrankogel Mountain, Austria. (Gary Braasch Photography)





**Activity 4 - 3557** -Dr. Harald Pauli notes increased growth of moss campion and decreases in other plants in a plot first inventoried in 1994 (see photo record in his hand). The site is part of a world-wide study of how climate is changing ecosystems in mountains. August 2004. Schrankogel Mountain, Austria. (Gary Braasch Photography)





**Activity 4 - 3569** Identifying alpine species during a vegetation survey on Pitamokan Peak in the Two Medicine region of the park for the Global Observation Research Initiative in Alpine Environments (GLORIA) project. GLORIA surveys are conducted in the same locations every four years to study changes in vegetation patterns on conical mountaintops all over the world. Photographs are used to verify that each plot is set up in the precise location of previous surveys. August 2009. Glacier National Park, Montana. (U.S. National Park Service)





**Activity 4 - 3570** - Students during the Cascades Climate Challenge at North Cascades National Park, July 2012. Washington. (Karlie Roland/U.S. National Park Service)





**Activity 4 - 3571** - Students during the Cascades Climate Challenge at North Cascades National Park. July 2012. Washington. (Karlie Roland/U.S. National Park Service)





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