

**eo**  
**Kids**  
earth observatory for kids

National Aeronautics and  
Space Administration



# **FRESH WATER**

Satellites See Everything from  
Raindrops to Great Lakes

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Lake Mead has lost 22.52 trillion liters (5.95 trillion gallons) of water – that is enough water to fill over 9 million Olympic-sized pools and could circle the globe.



Lake Baikal is the world's deepest lake. At more than 1,600 meters (5,000 feet) deep, its depth is almost equal to the combined heights of the Empire State Building in New York City, the Burj Khalifa building in Dubai, and the Eiffel Tower in Paris.



A rainforest with snow? Olympic National Park is full of rare temperate rainforests, but also receives up to 10.7 meters (35 feet) of snow per year.





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# RING AROUND THE RESERVOIR

Lake Mead is the largest freshwater reservoir in the United States. When full, it can hold 36 trillion liters (9.3 trillion gallons) of water. But it has been a long time since Lake Mead has held that much water, and it looks very different today than it did 32 years ago. Looking down from space, a thin tan line traces the shore of the lake, and the line is getting thicker. What is happening?

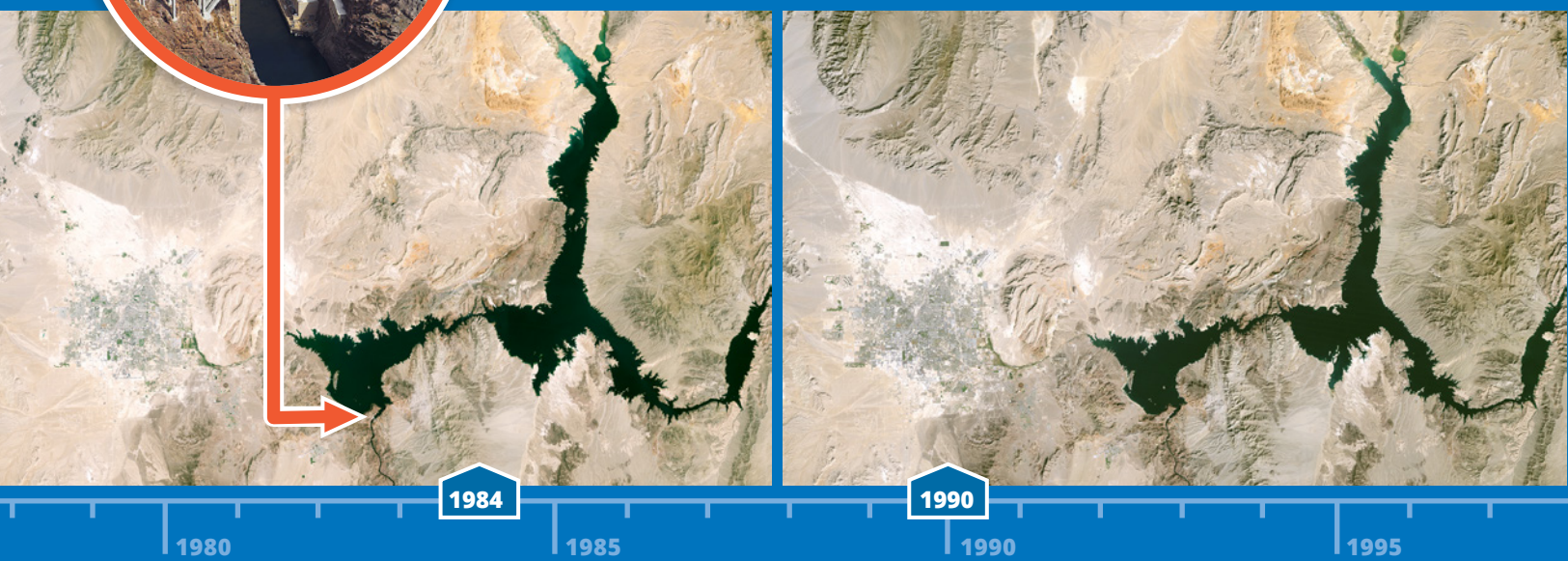
People in the southwestern United States live in a dry climate and rely on this **reservoir**. Lake Mead reservoir has provided water for drinking and other uses for millions of people in Nevada, Arizona, and California. For instance, farmers in the Imperial Valley of California use about 3.8 trillion liters (1 trillion gallons) of water from the reservoir each year to irrigate farmland and grow 85 percent of the winter vegetables consumed in the U.S. But what is different today?



Lake Mead was formed in 1936 when the Hoover Dam was built on the Colorado River. It took five years for the river to fill this reservoir.

**Reservoir:** 

A freshwater lake that stores a large supply of water.





## A River Runs Through It

Lake Mead is part of the Colorado River watershed. Most of the water in the lake comes from snow melting in the Rocky Mountains and flowing down the hills into the river. The river also collects rainfall that runs off the land. But lately, there has been less snow and rain falling in the mountains and less water in the river. For the past 16 years, the reservoir has not been refilling like it did in the past.

## Double Hitter – Drought and Heat

The southwestern United States has received less rainfall than normal since the year 2000. This means that people, particularly farmers, have had to use more of the water that was saved in the reservoir. Heat

is also a problem. Record high temperatures in the area are causing the fresh water to evaporate.

## Shrinking Shoreline

This is not the first drought to shrink Lake Mead. Droughts in the 1950s and 1960s increased the use of water from the lake. But in 2016, the lake reached a record low. The last time Lake Mead was this low was in 1937, when the reservoir was first filling up. By July 2016, Lake Mead was only 36 percent full, and the water level had dropped almost 42 meters (138 feet) from the average level in 1984. From space, this shrinking shoreline looks like a large bathtub ring.

—G. Butcher and T. Owen



The image from 2016 shows a much smaller lake as it hit a record low at just 36 percent full.

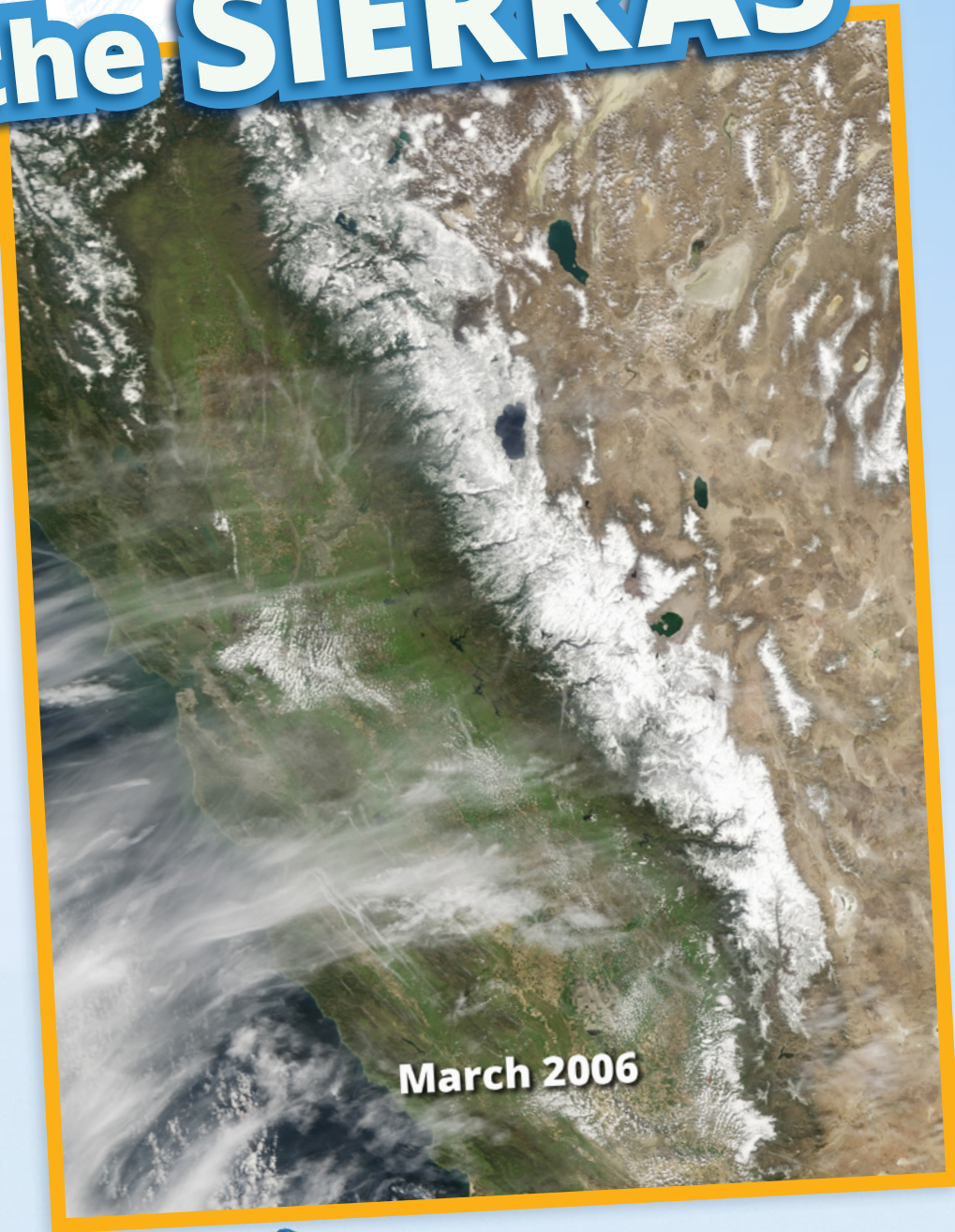


# sipping SNOW in the SIERRAS

**W**hen people think of water, they don't usually think of snow. But snow is water. Some of the water you drink may even have been snow.

Snow is made up of tiny, frozen water crystals and air. When snow melts, the water flows downhill and accumulates in streams, rivers, and underground **aquifers**. Some of this snowmelt ends up in reservoirs, where it is stored for people to use.

In the western United States, nearly 75 percent of the freshwater supply comes from snowmelt stored in reservoirs. A reservoir is like a bank account or piggy bank. Water is taken out of the bank in the summer and fall, and nature fills it back up in the winter and spring.



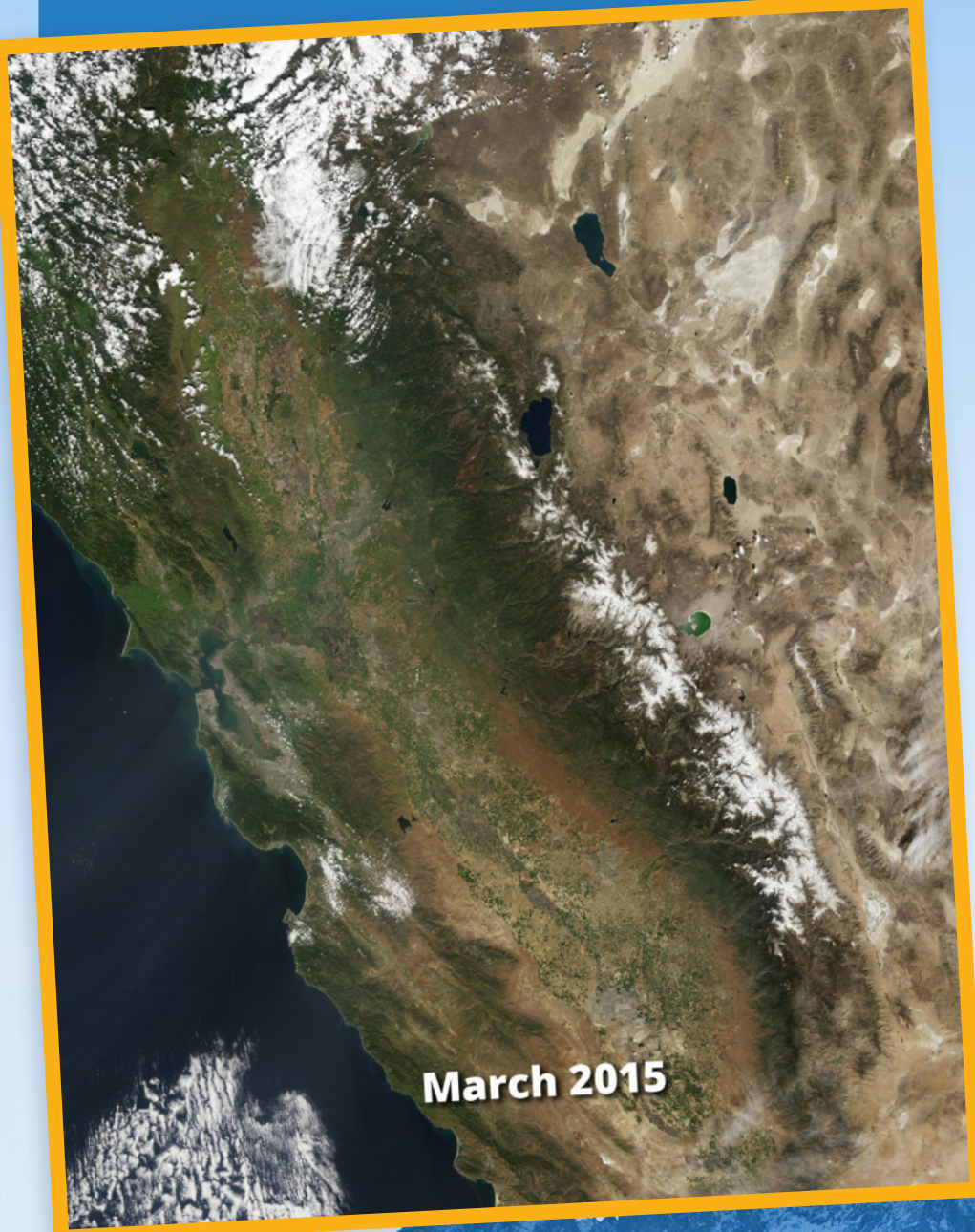
## Aquifer:



Underground layer of rock, sand, or gravel that water can travel through or that can hold water.



These satellite images show the Sierra Nevada of California in March 2006 and March 2015. Notice how the white snow covers more of the mountains in 2006 than in 2015. 2006 was a wet and snowy winter, but 2015 was hot and dry with little snow accumulation.



The larger problem is that less water is being added to the reservoirs and aquifers. As snow melts it gradually fills the aquifers and reservoirs. Snowmelt adds fresh water to aquifers and reservoirs even during dry seasons. When there is less snow covering the mountains, there may not be enough snowmelt to replenish aquifers and reservoirs through California's dry summers.

2015 was a warm and dry winter. The lack of snow and rain caused California to restrict the amount of water people could use in the summer of 2015. Some farms in southern California had to use water from Lake Mead (in Nevada) to make up for the lack of water in their reservoirs. Read more in "Ring Around the Reservoir" (page 4).

The winter of 2016 was better, with more snow and rain in parts of California due to El Niño. Snowmelt in 2016 did a lot to pay back the water supply, but after years of drought, there is still less water in California's reservoirs than in the past.

—T. Owen

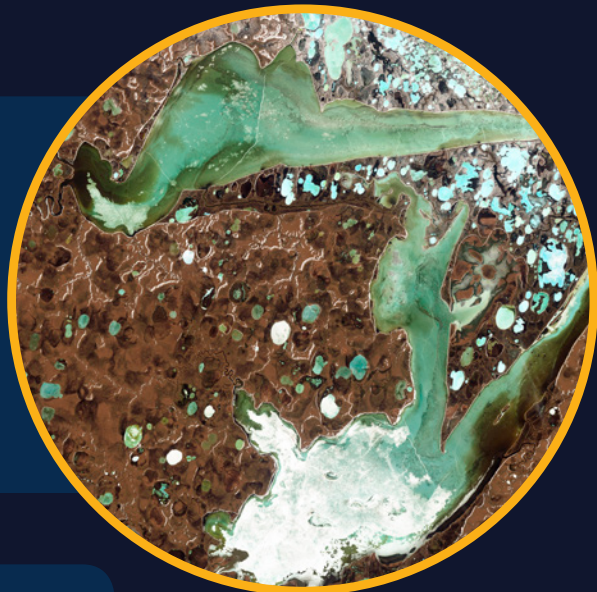


### Wildlife and Water

People are not the only ones who depend on water. The Sierra Nevada is home to black bears. Recent droughts have diminished the animals' natural food sources, such as acorns and berries. Bears have been forced to travel elsewhere to find food and water, sometimes into cities.



**1. Permafrost:** A little over 2/3 of the world's surface and other fresh water is found in ground ice and permafrost: water frozen into the soil. We find a lot of permafrost in such places as Alaska and Siberia. The melting and re-freezing of permafrost causes pockmarks in the landscape and creates ponds and marshes, as seen in this image of the Siberian coast.



**2. Groundwater:** Experiencing a drought? Live in a desert? There is not a lot of water in a desert. Farmers in Saudi Arabia tap into aquifers deep below the sandy surface to access groundwater to water their plants. Pictured here are aquifer-fed circular farm fields.



**3. Surface Water:** About 1/5 of the world's surface and other fresh water is stored in lakes. And nearly 1/5 of that is in Russia's Lake Baikal.



**Water,**

**Water**

**Everywhere!**

If all the Earth's water fit into 40 cups, then ...



39 cups = Salty Ocean Water

1 cup = Fresh Water

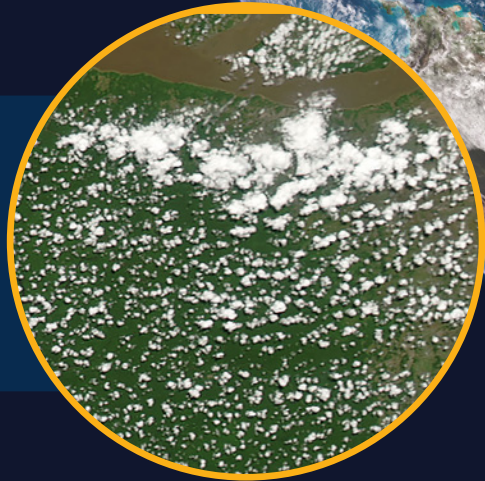




**4. Ice:** About 2/3 of all fresh water is frozen in glaciers and other forms of land ice. A glacier is made up of dense snow that accumulates faster than it melts. These thick blocks of ice can last for hundreds of thousands of years. Two such icy places are Greenland (pictured left) and Antarctica. By the way, Greenland is more white than green.



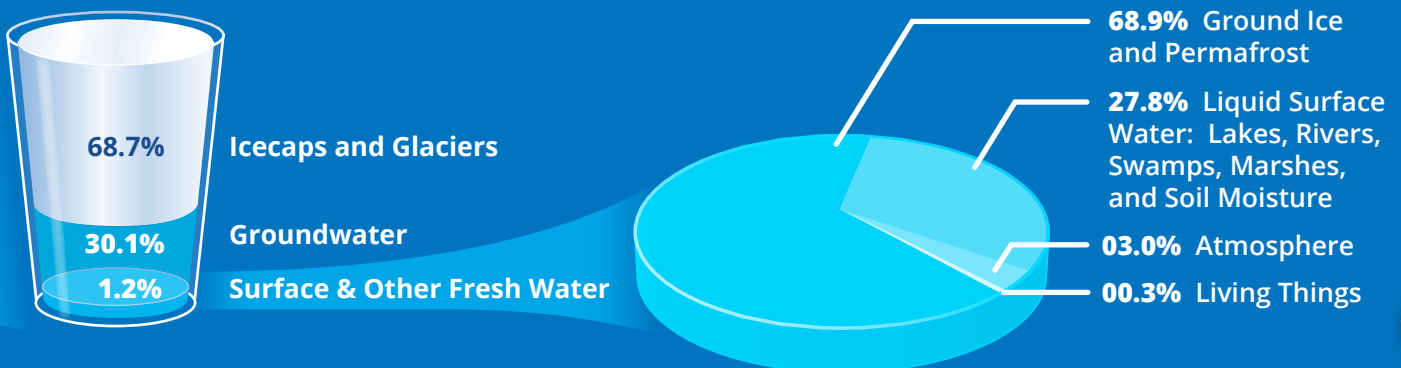
**5. Atmosphere:** Water exists in our atmosphere and falls to Earth as precipitation (rain, snow, sleet, and hail). We see water vapor as clouds, mist, and fog, such as these clouds over the Amazon rainforest.



**W**ater Planet. Blue Marble. Face it: Earth is known for its water. In fact, nearly three-quarters of our planet is covered with water. That is a lot, especially when we consider that we spend most of our time on dry land. Did you know that only 2.5 percent of the water on Earth is fresh? The rest – a whopping 97.5 percent – is salty and undrinkable. All of the seven billion people on the planet (not to mention the bears, birds, bullfrogs, and bugs) drink that little bit of fresh water. Our crops and forests and flowers need water too.

Where do we find fresh water on Earth and how do we monitor it? Satellites provide us with views of fresh water from space. These images show us just some of the ways fresh water is stored on and in the Earth.

—A. Burdick



# Data Viz

## How Thick is Greenland's Ice?

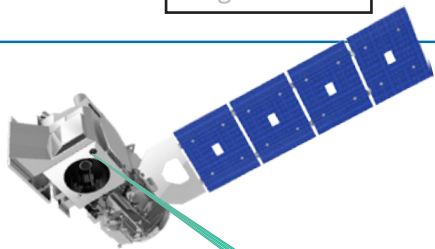
**M**ost of Earth's fresh water is locked up in ice. After the Antarctic ice sheet, the Greenland ice sheet is the second largest ice body in the world. Ice sheets form in areas where snow that falls in winter does not melt entirely in the summer, building up over thousands of years. ICESat, a NASA satellite, measured heights across the Greenland ice sheet. Scientists can estimate the ice sheet thickness, using the difference between the height at the top of the ice sheet and the ground below.

—V. Casasanto and G. Butcher

**Instructions:** The numbers in each square represent height in kilometers. Color in the scale bar from light green to purple, then fill in the squares in the grid using the same scale.

### Scale: Height in Kilometers

2.9 - 3.4 km	Purple
2.3 - 2.8 km	Dark Blue
1.6 - 2.2 km	Light Blue
0.1 - 1.5 km	Light Green



Discover how ICESat-2 uses lasers to measure ice:  
<http://icesat-2.gsfc.nasa.gov>

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0.7	0.1	0.8	1.2	0.6	0.2	0	0	0	0	0
0	0	0	0.3	1.1	1.1	1.4	1.8	1.4	1.2	0.5	0.0	0	0	0
0	0	0.3	0.9	1.3	1.7	2.0	2.0	1.9	1.4	0.8	0.1	0	0	0
0.8	1.1	1.2	1.6	1.8	2.0	2.2	2.2	2.0	1.6	1.1	0.6	0	0	0
0.7	0.9	1.7	2.0	2.1	2.3	2.4	2.4	2.2	1.9	1.4	0.7	0.1	0	0
0.4	1.0	1.6	2.0	2.3	2.5	2.6	2.5	2.4	2.2	1.9	1.3	0.6	0	0
0	0.1	0.7	1.6	2.2	2.5	2.7	2.7	2.6	2.4	2.3	1.9	1.4	0	0
0	0	0.1	1.2	2.1	2.5	2.8	2.8	2.7	2.7	2.6	2.2	1.6	0.7	0
0	0	0	1.0	2.0	2.5	2.8	2.9	2.9	2.8	2.7	2.0	1.1	0	0
0	0	0	1.0	1.9	2.5	2.8	3.0	3.0	3.1	2.9	2.1	1.3	0	0
0	0	0	0.9	1.9	2.5	2.8	3.0	3.2	3.2	2.9	2.3	1.6	0	0
0	0	0	1.3	1.7	2.3	2.7	2.9	3.1	3.1	2.9	2.3	1.4	0	0
0	0	0	0	1.3	2.1	2.5	2.8	3.0	3.1	3.0	2.5	1.4	1.5	1.1
0	0	0	0	0.9	1.8	2.3	2.7	2.9	3.0	2.8	2.5	2.2	1.8	0.7
0	0	0	0	0.8	1.6	2.2	2.6	2.8	2.9	2.5	1.7	1.4	0.9	0
0	0	0	0	0.9	1.6	2.1	2.5	2.7	2.8	2.6	1.2	0.3	0	0
0	0	0	0	1.0	1.7	2.2	2.5	2.4	2.5	2.6	1.2	0	0	0
0	0	0	1.2	1.1	1.8	2.3	2.4	2.1	1.5	1.1	0.6	0	0	0
0	0	0	1.1	1.3	2.0	2.4	2.2	1.5	1.1	0.1	0	0	0	0
0	0	0	0.4	1.5	2.2	2.6	2.3	1.1	0	0	0	0	0	0
0	0	0	0.8	1.4	2.3	2.7	2.4	0.8	0	0	0	0	0	0
0	0	0	0.3	1.6	2.4	2.7	2.0	0.7	0	0	0	0	0	0
0	0	0	0.3	1.2	2.1	2.5	1.5	0	0	0	0	0	0	0
0	0	0	0	0.8	1.3	1.7	1.3	0	0	0	0	0	0	0
0	0	0	0	0	0	1.2	0.9	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

### Question:

Where is the highest elevation? Why?

Answer on page 15



# DIY Science

## Snowmelt Science

**W**hen snow melts, it turns into water. Snow in the Sierra Nevada mountains becomes the water that people drink when it melts and fills reservoirs and aquifers. But how much water does snow produce?

– T. Owen

### What you need:

1. Ice cubes or snow
2. Clear plastic cup
3. Blender or a plastic bag and hammer
4. Marker

### Experiment:

1. Collect snow. Or crush ice to make snow.
2. Scoop your snow into the cup until it is  $\frac{3}{4}$  full.
3. Measure and mark the top of the snow level with a marker. Then mark where you think the water level will be once the snow melts.
4. Wait for the snow to melt.
5. Compare the water level with where you thought the water level would be.

### Conclude:

How close were you? Did the water take up more, less, or the same amount of space as the snow? If more or less, how much more or less? Why do you think this happened?

Find out why in Snowmelt Science Answers on page 15.

### You Do the Math!

In December 2015, an average of 45.7 cm (18 inches) of snow covered the Sierra Nevada mountains.

If 25.4 cm (10 inches) of snow makes 2.54 cm (1 inch) of water on average, how many centimeters (or inches) of water did 45.7 cm (18 inches) of snow make?

Note: Wetter snow, such as sleet, will produce more water than drier snow.

Check your answers on page 15.



Step 1a: Finely crush ice in a blender to make the snow sample.



Step 1b: Or, with help from an adult, crush ice in a plastic bag with a hammer.



Step 2: Measure and mark the height of the snow before it melts.



# Data Detective

## The Case of the Appearing Lake



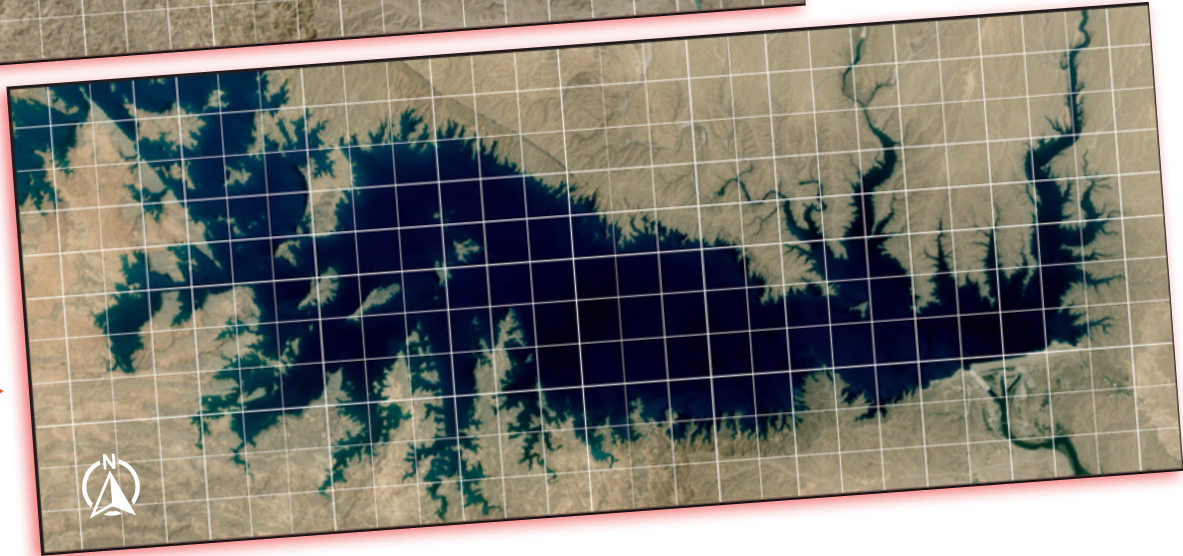
The Karkheh River is in the Khuzestan Province of Iran.



0 1 2 3 4 5  
Kilometers

▲ This satellite image from 1990 shows the Karkheh River snaking through the dry, rugged landscape of Iran.

▶ In 2006, after the Karkheh Dam was completed, the river valley was filled by a sprawling blue lake.



Be a Data Detective and find out how much of the Karkheh Valley is now covered with water. ▶

**T**his is no magic trick. This is what capturing 5.9 billion cubic meters (7.7 billion cubic yards) of water looks like from space. Satellite images are used to monitor changes on Earth's surface over time. Scientists can compare images to calculate how much has changed. In the case of the Karkheh Dam, scientists can calculate how much of the landscape is covered with water after a dam is built.

The dam on Iran's Karkheh River was completed in 2001. It was designed to capture enough fresh water to irrigate a patch of farmland the size of Rhode Island and to produce electricity for almost 400,000 homes – that is one home for every person who lives in Cleveland, Ohio.

—T. Owen

1. What is the total area of each satellite image (1 square = 1 km<sup>2</sup>)?
2. How many square kilometers of the 1990 image contained river water?
3. How many square kilometers of the 2006 image is covered by the lake?
4. How much of the satellite image has changed?

Answers on page 15



# Maker Corner

## Make a Model Aquifer!

Some of Earth's fresh water is stored in underground reservoirs called aquifers. Rain and snowmelt seep into the ground until it reaches a layer of rock or soil that can hold water. The water is stored in the spaces between rock or soil particles until it is pumped back to the surface through a well.

—G. Butcher and K. Weaver

### What you need:

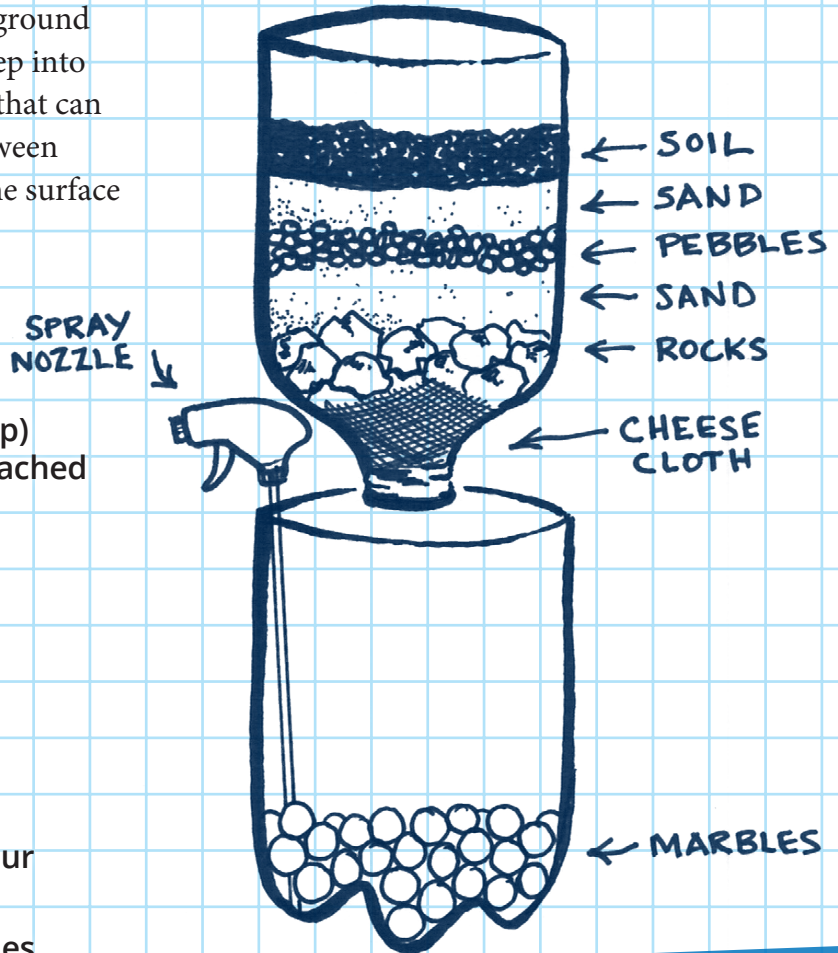
- One 2-liter plastic bottle (without the cap)
- Clean spray bottle nozzle with straw attached
- Soil, sand, pebbles, and rocks
- Marbles or glass vase gems
- A piece of fabric or cheesecloth
- Scissors
- Small watering can or cup
- Water and ice

### Make your model:

1. Cut the bottle in half and fill the bottom with seven to ten centimeters (three to four inches) of marbles.
2. Insert the spray nozzle so the straw reaches all the way to the bottom between the marbles. Then place the top portion of the bottle upside-down into the bottom half of the bottle.
3. Fill the top half of the bottle in layers. Start with a piece of cheesecloth to cover the opening, then layer rocks, sand, pebbles, more sand, and finally soil. Fill to about two inches from the top.
4. Pour water from the watering can on top of the soil (like rainfall). Put ice or crushed ice on top of the soil (like snow) and let it melt.
5. The water will collect between the marbles (like an aquifer). Once the aquifer is full, pump out the water using the spray nozzle (like a well).

### Go further:

During the 2012-2016 drought in California, water was pumped out of underground aquifers faster than rain and snow could refill them. Learn more on page 6.



### Make This!

You can use the same idea from your model aquifer to create a self-watering planter.



Place 3 to 4 marbles in a plastic cup and enough water to cover the marbles.

Thread a couple pieces of string through the bottom of a second cup then fill with potting soil and a plant.

The string will wick the water up into the soil and water your plant.

# Notes from the Field

## Soaking up Science in the Rainforest

**P**recipitation—rain, snow, and ice—gives us the fresh water we need to survive.

Scientists can measure precipitation from the ground using rain gauges, radar, and other weather instruments. But they can't make such measurements all over the planet because they cannot get to many remote places. Over 70 percent of Earth is covered by oceans, and the only reliable way to measure how much precipitation falls there is to do it from space.

Satellites can give us a big picture of where, when, and how much precipitation is falling around the world. The Global Precipitation Measurement (GPM) mission measures how much precipitation is falling around the world, and it gives us an updated amount every three hours! But we need scientists to compare the measurements from the satellite with measurements from the ground to verify the accuracy of the satellite's data.

A group of scientists have been working together to do just that in Washington. From

October 2015 through May 2016, scientists with OLYMPEX (the Olympic Mountains Experiment) carefully measured different forms of rain, snow, and sleet that fell over the Pacific Ocean and across the Olympic Peninsula and Olympic Mountains.

This region gets 250 to 450 centimeters (100 to 180 inches) of precipitation a year, making it one of the few rainforests outside of the tropics. That made it an ideal location to see how accurately the satellite could measure different types of precipitation.

The team used many types of instruments on the ground, including rain gauges, advanced weather radars, and weather balloons. In some locations, they had to hike in and use mules to help carry equipment because there weren't any roads!

Joe Zagrodnik, a graduate student from the University of Washington, had some exciting adventures as he worked to set up the instruments. One of the storms created a mudslide that washed out the road, and Joe and others needed picks and shovels to clear the debris so they could continue on their way! In another storm, Joe had to cross a



The OLYMPEX team preparing to hike with their equipment into the park.

To find out more, you can visit these websites:

<https://pmm.nasa.gov/olympex>

<http://go.nasa.gov/1YqiM0K>





The "Doppler On Wheels" observed precipitation systems as they approached the mountains.

river with water up to his knees. It was also hard to protect the instruments and keep them running as the rain kept falling.

Dr. Lynn McMurdie was surprised by a major snowstorm that brought close to 240 cm (almost 8 feet) of snow in late December. A team of National Park rangers and graduate students who were assisting in the campaign had to hike, ski, and use snowshoes to dig out the equipment and recharge the batteries.

So the next time you are outside in the rain or snow, think about how satellites and scientists are counting those drops and flakes. The GPM mission tells us how much freshwater is falling to Earth every three hours for almost the entire planet.

—D. Janney

# Answers

Answer: Lake Michigan

## Where on Earth?

1. The satellite image is 11 km by 27 km.  $11 \times 27 = 297 \text{ km}^2$
2. In the 1990 image, the river runs through 53 squares. Approximately 53 km<sup>2</sup> contain some portion of the river.
3. In the 2006 image, water covers some or all of 193 squares. That means approximately 193 km<sup>2</sup> of land is covered with water.
4. The difference between 2006 and 1990 is:  $193 - 53 = 140 \text{ km}^2$ .

## Data Detective:

**DIV Science:** Snow is made up of frozen water crystals and air. When snow melts, the air escapes and the water molecules take up the space where the air used to be. Therefore, water takes up less space than snow.

**You Do the Math:**  
 $145.7 \text{ cm (or 18 inches)} \times 2.54 \text{ cm (or 1 inch)} \div 25.4 \text{ cm (or 10 inches)} = 4.6 \text{ cm (or 1.8 inches) of water}$

**Data Viz:** The highest elevation, coinciding with the thickest ice, is inland. Thinner ice is near the coasts. Greenland's ice sheets are constantly in motion, slowly flowing down-hill under their own weight, like pancake batter spreading on a griddle. The ice near the coast slides into the sea through outlets called ice streams, glaciers, and ice shelves.



# Where on Earth?



This lake is the sixth largest in the world, holding enough fresh water to cover the entire United States with a layer 51 centimeters (20 inches) deep. The shoreline is 2,640 kilometers (1,640 miles) long, roughly the distance from New York City to Denver. On average, a single drop of water spends 99 years in this lake.

**What is the name of this lake?**

*Answer on page 15*

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[earthobservatory.nasa.gov](http://earthobservatory.nasa.gov)