The Fountain of Earth

Water arcs high into the air from the mouth of a large, green stone frog and splashes cheerily into a surrounding pool. No matter how much water the frog spews out, the pool never overflows. Why not? Because a pump at the bottom of the pool pushes the water back up through a pipe to shoot out the frog's mouth again. The same water molecules cycle through the fountain over and over. There may be only a couple hundred gallons of water in the fountain, but it seems to have an endless supply.

Earth's water system works somewhat like that of a fountain. How the water gets cycled and recycled is more complicated and on a much larger scale, but like the fountain, one thing does not change: The total amount of water.

Water. It covers 70 percent of Earth's surface, many miles deep in some places. It fills lakes and rivers and often falls from the sky in abundance. We turn on a faucet, and clean, drinkable water gushes unendingly. Water is cheap. Water is there for you when you need it.

But, consider this. Ninety-seven and one-half percent of the water on Earth is so salty that drinking it—provided you could keep down more than a few ounces—would kill you. Of the other 2.5 percent of Earth's water, over two-thirds is frozen at and near Earth's North and South Poles. That leaves about one-half of one percent of the water on Earth that is fresh and in liquid form.

We see some of that one-half percent flowing downhill in streams and rivers, eventually to drain into the ocean and join the already abundant supply of salt water. Even the water that runs into our city streets from lawn sprinklers and car washes eventually ends up in the ocean.

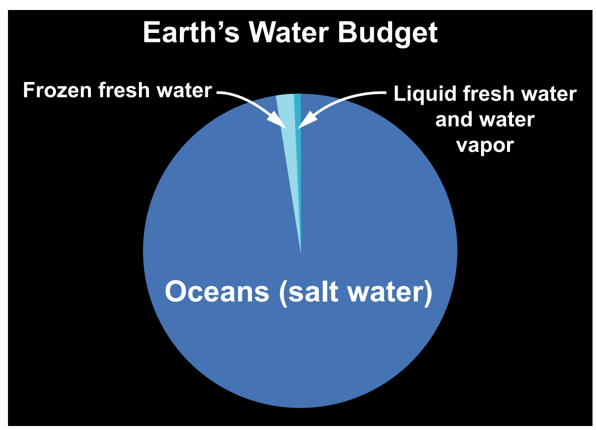
So are we watching our meager supply of fresh water literally go down the drain? Not to worry. Like the fountain, Earth is equipped with a "pumping" system, called the water cycle, that will bring the water back—eventually.

But before we talk about how the water gets "pumped" around, let's think about the fact that the total amount does not change, nor does the overall allocation to ocean, land, and air.

Planet on a Budget

How the water is divided up among the oceans, the land, and the atmosphere is called the water budget. Budgets are usually about money. You know exactly how much you have to spend, so you decide how much you will spend on what. The idea behind a budget is that you have a fixed total amount of some resource, and you must carefully manage its distribution. If you add more of the resource (spend more money) for one thing, you have to subtract the same amount from something else.

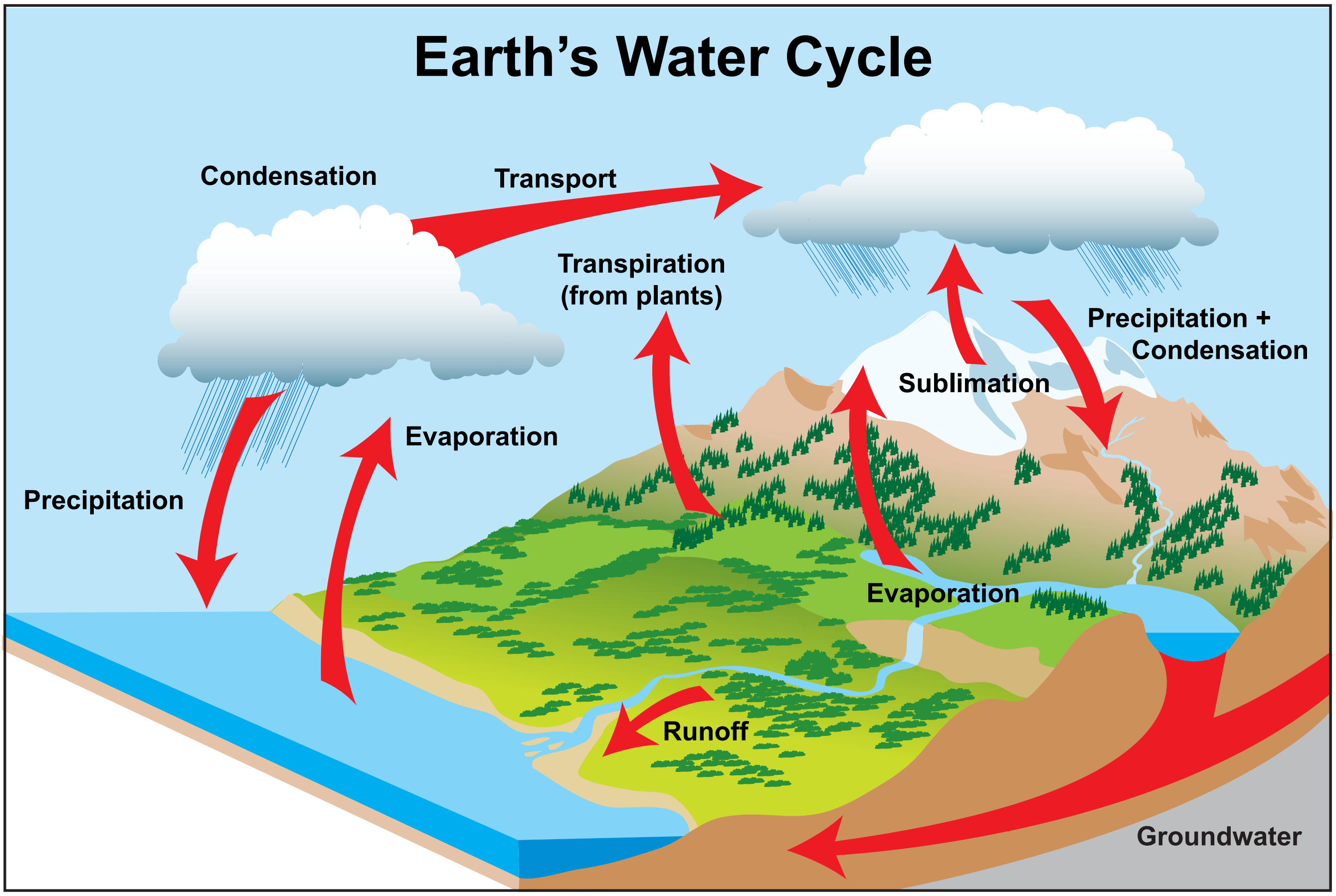
In the water budget, the oceans have and keep almost all the water. The total of all the fresh (that is, not salty) water on land (not counting the water in the atmosphere), including lakes, rivers, streams, ponds, puddles, bathtubs, kitchen sinks, and all the water under the ground, comes to only 2.4 percent of Earth's water. The atmosphere contains the rest, only .001 percent (that's 1/100,000th), in the form of water vapor and clouds.



This tiny percentage of the water that is in the atmosphere at any given time is what keeps the whole system moving. The atmosphere is the transportation system that enables the water to, well . . . cycle. Just to give you an idea how hard the atmosphere works to move water around, imagine the entire sky, horizon to horizon, top to bottom, over the whole world being filled with dark, gray clouds. This is how much water the atmosphere can hold. Each year, the total amount of water that gets dumped out of the sky (in the form of rain, hail, snow, sleet, etc.) is 30 times more than the atmosphere's total capacity to hold water!

Water's Ups and Downs

Even though the proportion of fresh water is small and does not vary a lot, how it is distributed does. Certain regions of the Hawaiian Islands get over 400 inches of rain



per year, while the Sahara Desert gets less than 5 inches. Some years a place is flooded with rain and snow. Other years that same place is dry as a bleached bone. Why? Well, Earth's water—or hydrologic—cycle is a complicated process, with wind, temperature, Earth's rotation, topography, latitude, Sun activity, plant behavior, and lots of other factors all mixing together in different ways to make water move.

- First, water gets from Earth's surface into the atmosphere in three different ways: *evaporation, sublimation*, and *transpiration*.
- Second, water gets back from the atmosphere to Earth's surface by *precipitation* and *condensation*.
- And third, water also gets from the land back to the oceans by *runoff* and *groundwater seepage and flow*.

Earth to Atmosphere:

Evaporation is the process of water turning from a liquid to a gas. After a rain, any little dip in the ground becomes a puddle. When the sun comes out, the puddle disappears. Where does the water go? It becomes water vapor (which is an invisible gas) and lifts up into the atmosphere. Water is evaporating off the surface of the oceans all the time. (Luckily for us, the salt is left behind!) Lakes, rivers, swimming pools, all contribute to the water vapor load in the atmosphere. *Sublimation* is the process of water turning from a solid (snow or ice) directly to a gas (water vapor) without melting first.

Transpiration is the process of plants giving off water and oxygen as waste products of photosynthesis. As far as the water is concerned, this process is similar to evaporation, but simply refers to the water coming from the ground up through the plants, rather than coming from the ground directly.

Atmosphere to Earth:

Once the water vapor gets into the air, it rises and cools, *condensing* again into water droplets when particles of dust or other solid particles are present to act as "seeds." Collections of these water droplets are called clouds. If the temperature is below freezing, the clouds may also contain ice and snow. Clouds get pushed great distances by atmospheric winds, and thus become the long-distance trucking industry of the water cycle. This part of the water cycle is called *transport*. Water vapor can also condense back out of the atmosphere as dew or frost without actually moving very far.

So far, the atmosphere has lifted water into the sky from one place and carried it to another place. Now it sets the water down again in the form of dew, frost, rain, snow, hail, or sleet.

Land to Ocean:

When the water hits land, some of it soaks in and some runs off into lakes, streams, or rivers. The water that soaks in is called groundwater. Groundwater and runoff water eventually get back to the ocean.

All these processes—evaporation, sublimation, transpiration, condensation, transport, precipitation, runoff, and groundwater seepage and flow—are going on all the time all over the Earth. And still, the total amount of water on our little blue planet remains the same.

Create Your Own Water World

This is a suggestion for a very open, creative activity. Working individually or in pairs, make a poster. Or, working in small groups or with the whole class together, make a large mural. You will be depicting the water cycle of planet Earth. If you make a mural, you could either use a large piece of butcher paper (which comes in rolls), a chalk board, or a paved area outside. To create on paper, whether poster or mural, you could use (water-based) tempura or acrylic paints, crayons, chalk, or pastels. To create on concrete, use sidewalk chalk, which comes in large pieces and washes off with the first precipitation event.

You can include all different kinds of terrain in your picture—forests, deserts, farmlands, mountains, valleys, plains, rolling hills, cities—all different kinds of clouds, rivers, lakes, streams, calm oceans, angry oceans, glaciers, cross-section views of the underground, rain, blizzards, thunderstorms, tornadoes, waterspouts, hurricanes—whatever seems interesting and dramatic and shows all the different ways water moves up into the air from one place and back down again to the surface someplace else. Label the water elements of the picture to show which of the processes of the water cycle are being shown: evaporation, sublimation, transpiration, transport, precipitation, condensation, runoff, and groundwater seepage and flow.

If you like, you can cut the clouds out of separate pieces of paper to make a dynamic water transport system. You can show how the clouds "pick up" water from one part of the picture and carry it to another. Of course, you can also draw or cut out different types of clouds and label them too.

If you have individuals or teams making posters, have a contest to see whose poster includes the most different types of water cycle events and types of clouds.

Of course what drives evaporation and precipitation and the other parts of the water cycle are the basic laws of physics. For example, gravity makes water run downhill and raindrops fall from the sky. But things could look very different on our planet and still not violate any laws of physics.

Consider these scenarios:

1. What would happen if all the continents were well above sea level, but perfectly flat?
2. What if it were warm enough on Earth that all the water was in liquid form (no ice)?
3. Given that the atmosphere cannot hold any more water than it already does, what if precipitation fell equally on all parts of Earth?
4. What if the oceans were only half as deep, but there was still the same total amount of water on Earth?
5. What if Earth's ocean floor and land topography were the same, but Earth had only half as much water as now? Do you think Earth would still support life? Would life look any different?

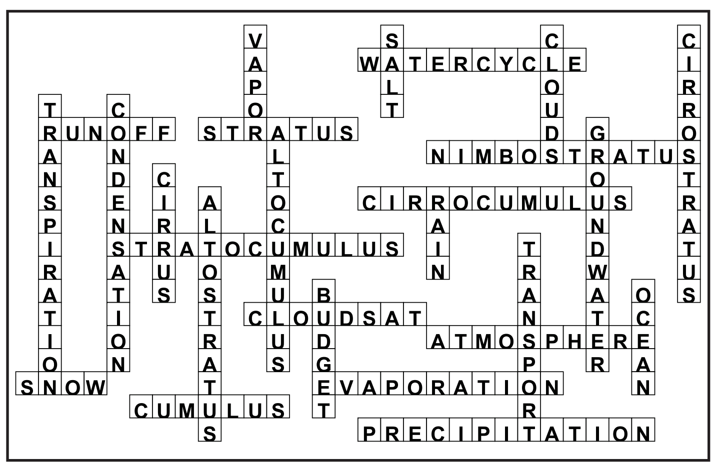
More About Clouds

Clouds are the key element of the water cycle, since they are the transporters that move water from one place on Earth to another. They are also important in determining how much of the Sun's energy is absorbed and trapped in the atmosphere. They are thus very important in altering the temperature of the air and Earth's surface. The warmer the air, the more water it can hold. The warmer the oceans, the faster water evaporates from them. Surface winds also increase evaporation. (Notice that after a rainstorm, the road dries faster if it is windy.) And the more water in the air, the more the sun's energy is trapped, making things still warmer.

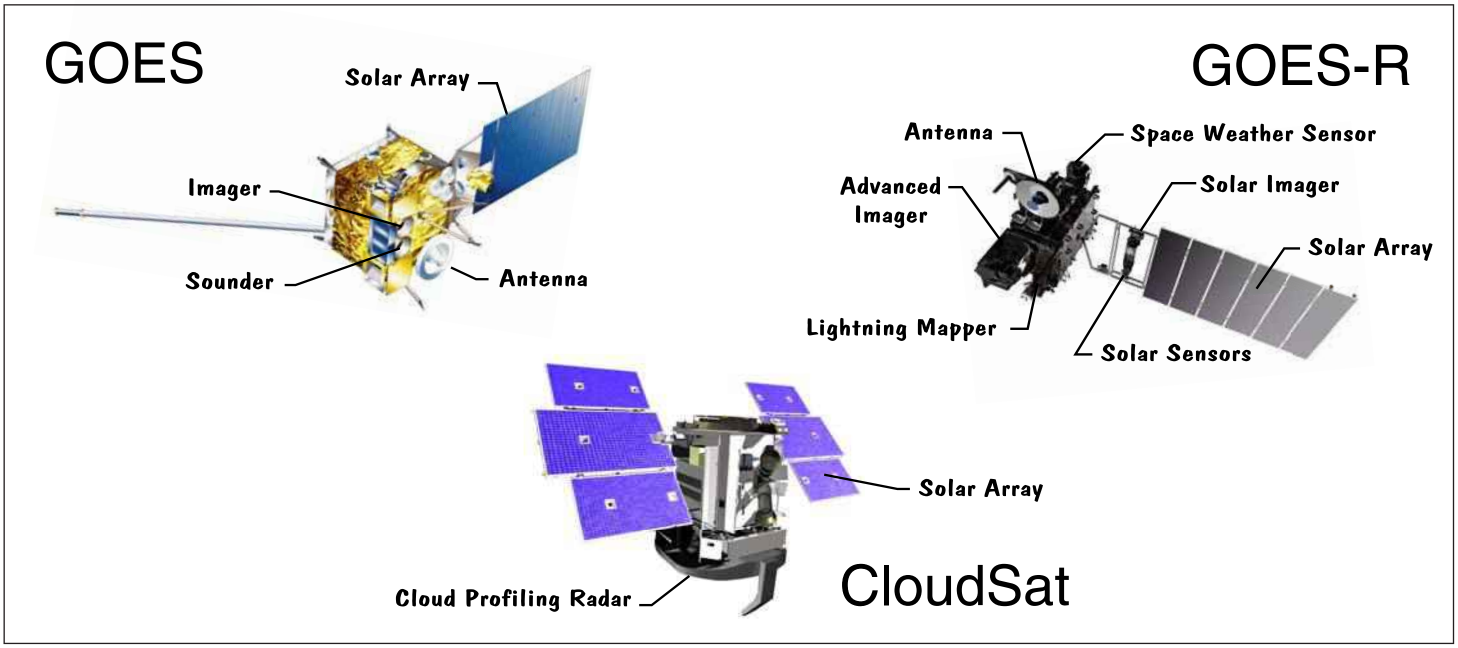
It is a very complex cycle, and scientists need to understand better how clouds affect climate.

Satellites are important tools for atmospheric scientists and weather forecasters. Current weather satellites give scientists information about how clouds look from the top, and even how high they are. Scientists also would like to know more about the vertical structure of the clouds in order to really understand them.

Answers to Water World crossword



This publication was funded by the National Aeronautics and Space Administration (NASA) and the U.S. Department of Commerce National Oceanic and Atmospheric Administration. It was provided by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA.



Studying Clouds from Space

CloudSat

CloudSat is a space mission to study the insides of clouds, taking vertical cross-sections through them using advanced radar technology. CloudSat flies in formation with other satellites that take cloud measurements using different kinds of instruments. CloudSat measures how much liquid water and ice are in the clouds at what heights, and how these measurements affect the clouds' ability to reflect or trap the sun's energy. Data collected by the satellites is combined to give a better understanding than we have ever had before of how clouds work and how they affect climate all over Earth.

CloudSat is an international and interagency mission. The major sponsor is NASA. It is managed by the Jet Propulsion Laboratory, under a contract with NASA, and scientific activities are directed by Colorado State University. Other partners including Ball Aerospace & Technologies Corp., the Canadian Space Agency, the U.S. Air Force, and the U.S. Department of Energy.

GOES

Other satellites in orbit high above Earth provide images and other data about the atmosphere that enable meteorologists to study Earth's water cycle.

GOES stands for Geostationary Operational Environmental Satellite. Among other instruments, the GOES carry imagers that continuously observe Earth's surface, oceans, cloud cover, cloud temperature and height, surface temperature, and water vapor.

Another instrument on the GOES is a sounder, which gathers data about the atmosphere in three dimensions by receiving signals of various visible and infrared wavelengths through the atmosphere. From this information, meteorologists develop vertical profiles of atmospheric temperature and moisture, surface and cloud-top temperatures, and ozone distributions.

GOES-R

GOES-R is the next generation of GOES satellites, the first of which is planned for launch in 2015. GOES-R will be a giant leap forward in technology. It will gather much higher resolution imaging data, in much larger quantities, and deliver it faster. Its data will improve the accuracy of weather forecasts and weather models that help forecasters predict future weather behavior based on current conditions. GOES-R will also create large scale maps of lightning activity and monitor solar activity, space weather near Earth, and the magnetosphere.

To Learn More

To learn more about CloudSat, visit

cloudsat.atmos.colostate.edu

To learn more about GOES and GOES-R, visit

- *www.noaa.gov*
- *goes-r.gov*
- *www.nws.noaa.gov*
- *scijinks.gov*

To learn more about weather and clouds, visit

- *www.srh.noaa.gov/jetstream/synoptic/clouds_max.htm*
- *eo.ucar.edu/webweather/cloudhome.html*
- *www.windows2universe.org/earth/Atmosphere/clouds/cloud_types.html*

Name the Clouds

What kind of clouds does each picture show? Write the answers in the blanks below. Some of them may be especially hard to identify because you may not be able to judge the altitude of the clouds. Hint: Try using the process of elimination.

For more help identifying clouds, visit http://asd-www.larc.nasa.gov/SCOOL/tutorial/clouds/cloudtypes.html or http://www.srh.weather.gov/srh/jetstream/synoptic/ll_clouds1.htm.

1. ____________________

2. ____________________

3. ____________________

4. ____________________

5. ____________________

Photo by Jim W. Lee

6. ____________________

7. ____________________

8. ____________________

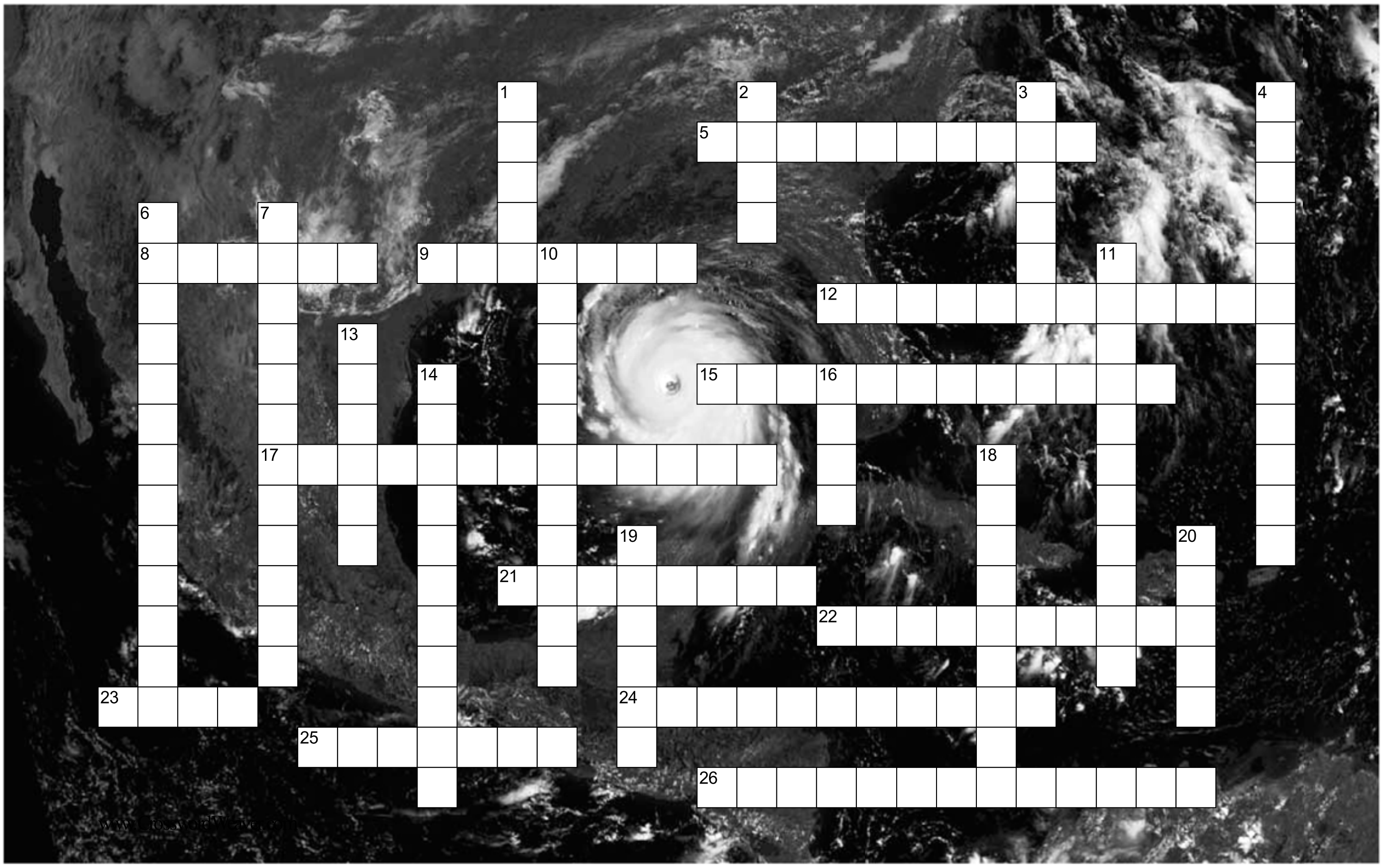
9. ____________________

10. ____________________

Answers:

1. Cumulus; 2. Nimbostratus; 3. Cirrus; 4. Stratocumulus; 5. Cumulonimbus; 6. Cirrocumulus; 7. Altostratus; 8. Stratus; 9. Altocumulus; 10. Cirrostratus

Water World!



Hurricane Katrina image from GOES-12 data. 8/29/2005

Across

5 Lifts a dew drop to a cloud and returns it as a snowflake.
8 The stuff of rivers and streams.
9 Low-level layers covering the sky.
12 Low-level givers of rain.
15 High in the sky and ripply.
17 Low-sky rolling masses.
21 Studies clouds from top to bottom.
22 Airy wrapping around our planet.
23 Without which a sled is useless.
24 Oh, dry up.
25 Low-sky fluffy cotton balls.
26 What went up comes down.

Down

1 Invisible water.
2 ______ and pepper.
3 Hydrological moving vans.
4 High in the sky and stretched thin.
6 Like sweating, for plants.
7 Was gas, now liquid.
10 Puffy patches in the middle-high sky.
11 The stuff of wells.
13 High and wispy with no sense of humor
14 Thin, wide stretches of gray in the middle distance.
16 Falls mainly in the plain in Spain.
18 Let's get this water moving!
19 When it comes to water, Earth's on a fixed __________.
20 A drink of this leaves you thirstier.