

Water Planet - Tutorial Script

Earth is a water planet. Over 70% of the surface is covered with water in a series of interconnected basins creating one world ocean.

This rotatable sphere shows how this world ocean is distributed across the globe. The largest basin within the world ocean, representing 50% of it, is the Pacific Ocean, which sits between Asia, Australia, and the Americas. 25% of the world ocean is the Atlantic Ocean, which sits between the Americas, Africa, and Europe. 21% is the Indian Ocean, which sits south of India and between African and Australia. The smallest ocean is the Arctic Ocean. It sits mostly under sea ice at the North Pole. The portions of the oceans that sit around Antarctica toward the south pole are sometimes referred to as the Southern Ocean, but for our purposes, they will simply be parts of the Pacific, Atlantic, and Indian Oceans.

Since Earth is a sphere, the best way to see the relative sizes of the oceans and continents is on a sphere, like this one. However, we often use flat-map representations to allow us to see all areas of the planet at the same time. Such a map is naturally inaccurate. For example, in this image of the oceans, we end up stretching the North and South Poles much wider than they actually are and cut off the very top and bottom, so we can make a rectangle.

Now let's review the depths and heights of oceans and land. In this image, the light blue color represents the shallow margins or continental shelves of the continents and ocean islands - never deeper than 125 meters, or about 350 feet. The darker blue represents the deeper parts of the oceans - the deep abyssal plains, trenches, and mid-ocean ridges. These depths are, on average, 4000 meters or 4 km. The deepest part is the Marianas Trench, at 11 km. In comparison, when you look at the land, you see the higher-elevation areas are marked orange and red. Most of the land is not at a high elevation - the average height of land above sea level is 800 meters. The highest elevations are found in the Himalayas - Mt. Everest, the tallest, is approximately 9 km above sea level. This graphic shows how those depths and elevations compare. We can clearly see here that the average ocean depth is over 4 times deeper under sea level than the average continental surface is above sea level. In addition, the deepest spot is deeper by 2 km than the highest point. What that means is that the oceans have much more vertical relief than the land. If you think we have spectacularly large mountains on land, imagine what it would look like and feel like if we drained the oceans and could hike around the seafloor!

Here is another image that shows the average depths of the four major oceans and compares them to the average elevation of the continents. Again, we see how many times deeper the oceans are on average than the land is high. This image also shows how much shallower the Arctic Ocean is than all the others.

Meanwhile, what about all that water? No surprise that most of the world's water is in the oceans - 97.2%. Of the remaining 2.8%, most of it is trapped in glaciers, most of the rest is stored in the ground. All the water that you currently see in lakes and streams, as well as what's held in the soil and the atmosphere, represent much much much less than 1% of all the world's freshwater.

Pause now.

How does water move around between all these different reservoirs? To answer that question, we need to review the water cycle or hydrologic cycle, which you all probably first learned about back in grade school. What drives the hydrologic cycle? The sun. How? When it comes out, it dries up all the rain, or rather evaporation of water occurs. That evaporated water is carried in wind currents around the planet, where eventually it cools so much, water is forced out as precipitation - or rain. If it rains on land, it gets trapped in glaciers or streams or soaks into the ground. Eventually that water runs back toward the ocean, where it can get picked up again. Through continued evaporation and precipitation, water moves in and out of the various reservoirs, residing in each for limited time.

The residence time, or average length of time a water molecule resides in the oceans, is 4219 years. In comparison, the residence time of water in the atmosphere is 12.6 days. Why the difference? There is so much deep water in the oceans that isn't in contact with the atmosphere. That makes the oceans a large stable storage reservoir. The

atmosphere on the other hand is short-term storage, where water resides on average a little less than two weeks – water enters and leaves easily and quickly, through evaporation and precipitation, like a city bus with passengers getting on and off at stops along the way. For example, the residence time of a passenger on a San Francisco MUNI bus might be about 25 minutes.

Another element of the water cycle that we will include and describe in more detail over the next few lectures is the water that soaks into the sediment that covers the seafloor (which acts like a wet sponge) and then sinks back into the mantle under the continents, where it's squeezed under high pressures. The water is squeezed out, and because it's less dense than anything around it, it rises upwards where it combines with hot rock and drops its melting point, causing it to melt. This water-rich melted rock is now less dense (melting rock causes it to expand, which makes it less dense), so it, too rises up, where it erupts as a volcano, and the water is released as one of the primary gases, re-entering the atmosphere and the surface hydrologic cycle, as discussed in the previous lecture on Earth's formation.

Now let's look more closely at the glaciers. Today, glaciers (or land ice) cover 10% of the Earth's land surface. Periodically, during Earth's past history, these glaciers have grown up to three times larger, to cover, at their greatest extent, 30% of the planet's land surface (during periods we call Ice Ages). 6.5% of ocean volume is lost during those times and trapped on land as glaciers. This loss of water contributes to about 120 meters of sea level drop. Does that sound familiar, that depth? We mentioned it at the beginning of this lecture when we reviewed the depths of the oceans. It was the deepest part of the light-blue-colored continental margins, or continental shelves. These shelves are completely exposed when sea level drops during ice ages. The lowest edge of them is the shoreline and the limit of wave erosion. Sea level doesn't drop any lower. What do we call this lower limit? The continental shelf break. This image shows us the flat shelves, the edge or break, and then the deep abyssal plains that are as deep as 5000 m or 5 km.

This graph shows the temperature over the past 65 million years, since the time the dinosaurs went extinct. Notice how this temperature has been mostly many degrees Celsius higher than it is today. The cooling period that began about 15 million years ago, brought temperatures cold enough to produce glacial ice and a period of intermittent ice ages, called the Pleistocene Epoch, which has lasted for the past 1.6 million years of Earth's history.

This image shows how ice ages have progressed over the past million years. The high peaks on this image represent warming periods, such as the one we're in now – referred to as interglacials, because they happen between the low points, the glacials, or ice ages. Today's warming is an accelerated aspect of the normal warming that's been happening since the last ice age ended, about 10 to 15,000 years ago.

How do we get data on past ice ages? Our best source of that data comes from ocean sediments that collect on the bottom of the seafloor and contain shells of dead organisms. These shells can tell us the ocean temperatures at the time of the death, due to both chemical ratios in the shell as well as the species itself (warm-water versus cold-water species). From temperatures, we can infer sea level. We can also gather data on past global temperatures from studying ice cores.

Pause now.

In upcoming lectures, we will touch on this subject again and describe the relationship between sea level and ice ages in more detail.

[end credits]

Water Planet
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