How Much Water is in the Atmosphere

Kasey Adams, Water From Air

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1 Introduction

Atmospheric water harvesting is an exciting new technology to tackle a growing water crisis. As climate change progresses, we will see more and more people without access to the water they need. One solution to this problem is atmospheric water harvesting systems. Tapping into the vast reservoir of water in the atmosphere provides a renewable source of water to help alleviate this crisis. In fact, the atmosphere holds so much water that taking the entire worlds water usage annually, the atmosphere has 3 times that available in 9 days and 125 times that over the course of a year! Let us look a little more locally though, what about places around the world that don't have water in the air to harvest like in deserts? Surprisingly, even in places like deserts, there is a wealth of water in the air! Even in the driest and most arid places on Earth, there is water in the air that can help those in need. Another question often asked is how the harvesting of water from the air impacts the local ecosystem and environment? In general, it has a very minimal impact, it will affect the area directly around it for a number of meters, but at a larger scale like that of an ecosystem, there is so much mixing of the air and so much more water than we can take from the atmosphere that the effects of water harvesting are minuscule. In fact, there may even be slight positive effects on the environment. Climate change adds an estimated 1-2% water to the atmosphere every decade and, in addition, water is a greenhouse gas which means it absorbs the heat coming off the Earth and re-releases it, and some of that heat goes back into the Earth. This creates a positive feedback loop that as the Earth gets warmer and more water goes into the atmosphere, the water in the atmosphere makes the Earth warmer. It is estimated that water more than doubles the warming that occurs by just carbon dioxide increases alone, so any extra bit of this water that we can help remove from the atmosphere will help slow this problem. This exciting technology will help us tackle the problems facing us and get to a point where freshwater is abundant and available for everyone!

2 The Water Cycle

Water on the Earth is not stagnant; like humans themselves, the water moves around the Earth in a process known as the water cycle. Powered by the Sun, water constantly moves between the atmosphere, the oceans, and the lands. Water can exist in three forms: liquid as water, gas as steam or water vapor, and solid as ice. All of the states exist simultaneously on Earth at any time, and switching between these states is a large component of the water cycle. The most well-known step of the water cycle is precipitation. As water vapor in the air and atmosphere is carried up by air currents, it begins to drastically cool down from the temperature near the surface. As the water vapor cools, it wants to condense into a liquid state, suspended

in the air as lightweight droplets that form clouds. As these droplets collect and accumulate more water they eventually get heavy enough to fall as rain or snow. When this water falls over the surface, some will seep into the ground, some will flow into rivers and streams, and some will evaporate directly back into the atmosphere, but a majority will make it back to the ocean. From the ocean, the Sun heats up the water on the surface until it evaporates, going back into the atmosphere and completing the water cycle.

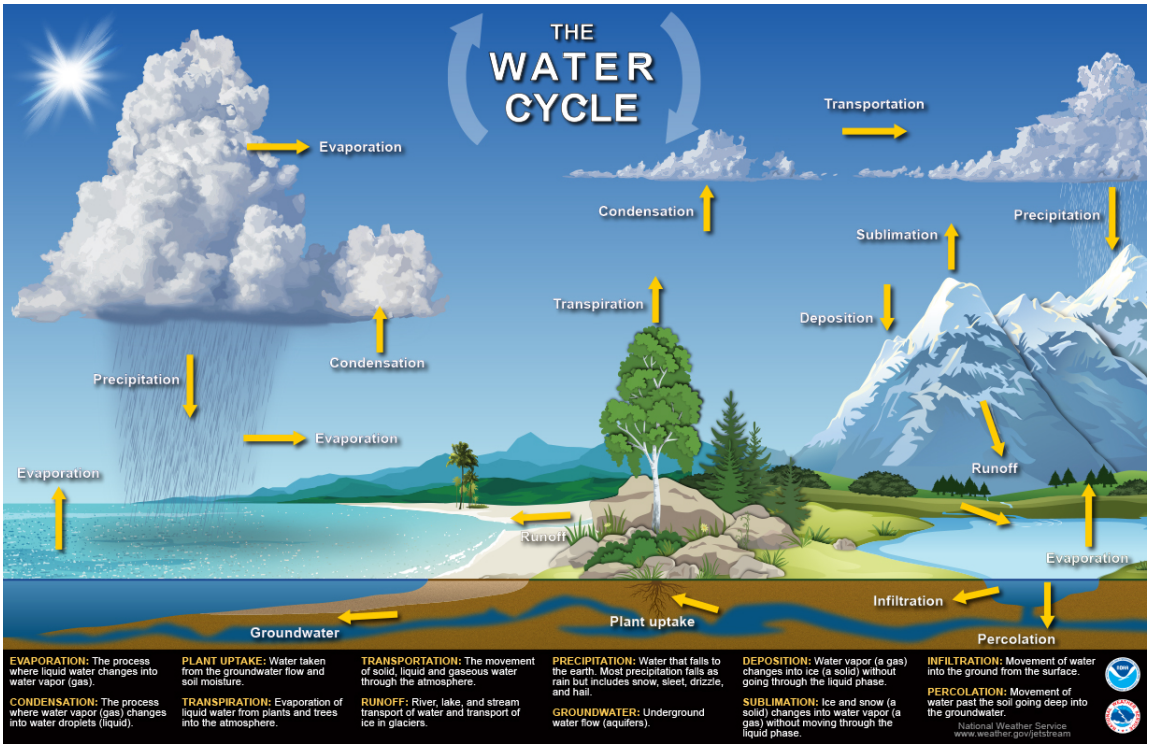

Figure 1: Diagram of the water cycle showing the process which air moves about the Earth. Evaporation from the surface of the oceans,seas,lakes, and rivers provides about 90 percent of the water in the atmosphere. Image courtesy from NOAA National Weather Service.

3 Water Usage on the Earth

Throughout the Earth every year we use about 4 trillion cubic meters, or 4,000 cubic kilometers annually. This is driven mainly by 3 sectors, agriculture, industry, and domestic with agriculture driving a majority of that usage at around 90% of the global water usage. In addition, around the world different places use different amounts of water; not always corresponding to places that can meet the water needs of the place around it. Currently, 4 billion humans face severe water scarcity for at least one month of the year. As temperatures continue to rise around the Earth, this problem could be exacerbating, potentially affecting another 2.2 billion by the end of the century. Known as a "water gap", various places around the Earth need more fresh water than is available from renewable supplies. This "water gap" is the most severe in India, the US, Pakistan, Iran, and China and globally totaled 2,400 cubic kilometers in 2019, more than half of the global water used came from sources where water is not renewable.

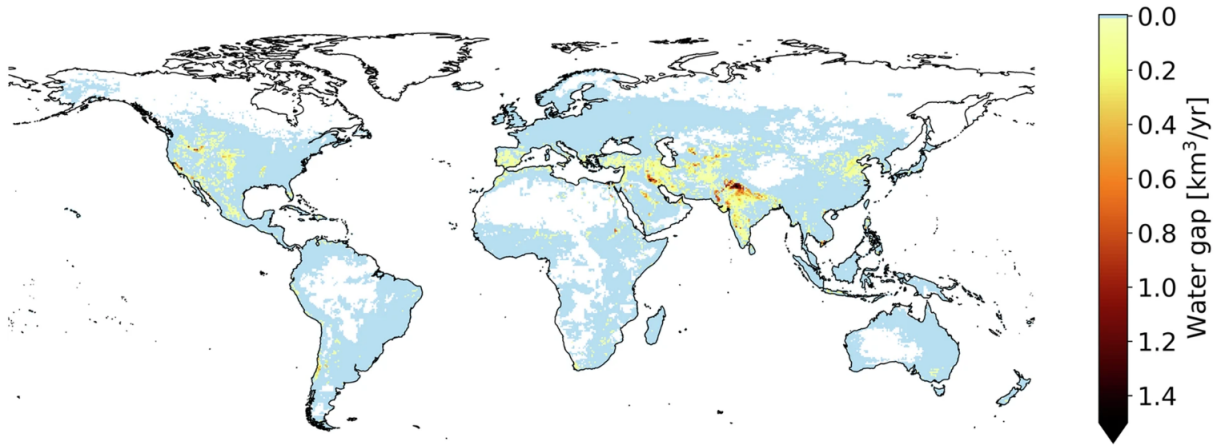

Figure 2: The water gap is a metric that shows when a location is using more water than there is available from renewable water supplies. Blue is the areas where there is no water gap, white is parts of the world without significant human water consumption, and then darker yellows, oranges, and reds indicate a larger water gap. In India, the U.S., Pakistan, Iran, and China the water gap is largest but all over the world we see water gaps forming and this trend is only getting worse with climate change. Image courtesy of Rosa and Sangjorgio showing the water gap for 2010.

4 Water in the Air

At any given time, there are about 12,900 cubic kilometers of water vapor in the atmosphere. If this water was condensed and spread over the surface of the Earth, it would create a 2.5-centimeter shell around the entire Earth. Now, compared to the 4,000 cubic kilometers of annual water use around the world, the amount of freshwater in the air easily covers it. Even more importantly, this giant freshwater reservoir is a renewable resource. Through the water cycle, the atmosphere generates a whopping 495,000 cubic kilometers a year! 40 times a year, more than 3 times a month, the water in the atmosphere is replenished by this cycle. Now, this atmospheric water is not evenly distributed over the Earth. Humidity is a measurement of how much water is in the air, and different locations have very different levels of humidity. Relative humidity, generally the number that is reported when watching the weather, is a specific type of humidity that compares not the absolute amount of water in the air, but how much water is in the air as a percentage of the maximum amount of water that air can hold. Specific and absolute humidity, by contrast, is actually a measurement of the direct amount of water in the air measured in g water per kg air and g water per cubic meter of air respectively.

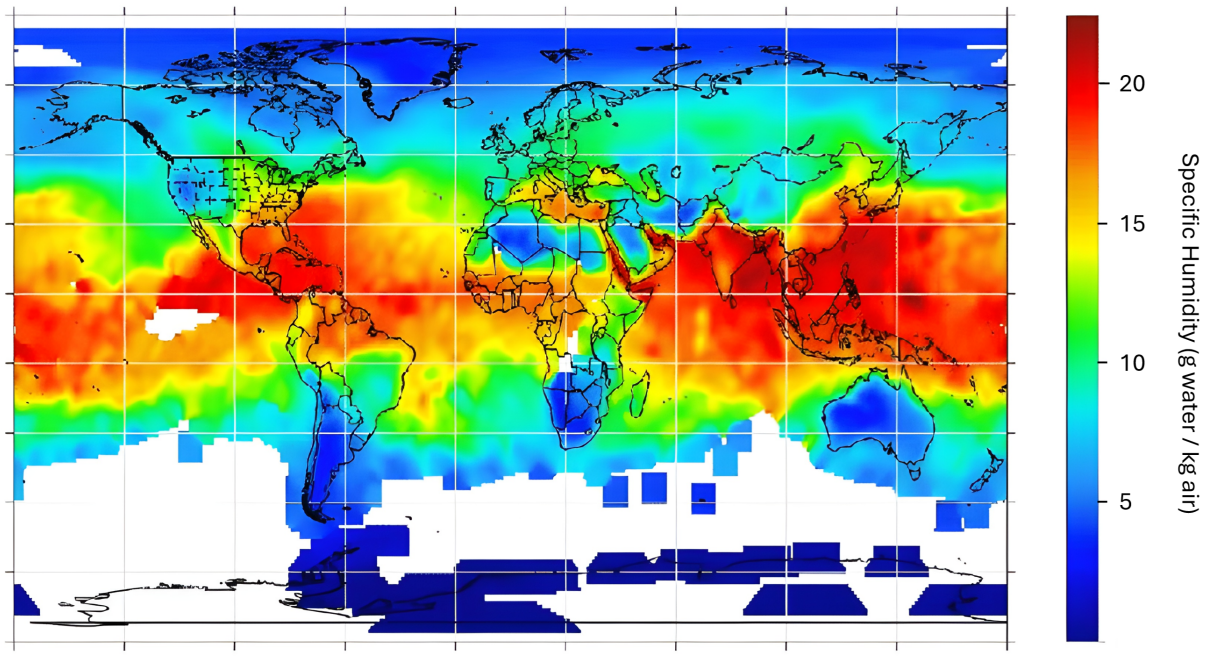

Figure 3: Specific humidity over the world, reported in g water per kg air. This shows where the water in the atmosphere is concentrated, existing most densely over the oceans and equator. Even areas classically considered extremely arid like sub-Saharan Africa and the Atacoma desert do have a decent amount of water in the air to tap into. Image courtesy of Zurbenko and Luo.

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