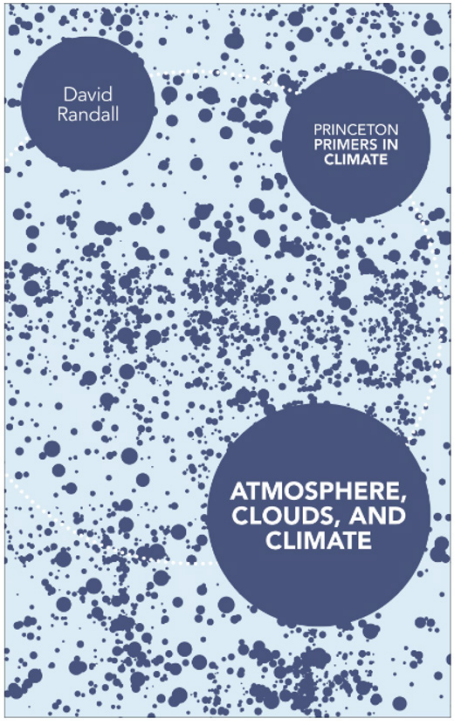
Atmosphere, Clouds, and Climate: Water Planet & Predictability

AOSC 680

Ross Salawitch

Class Web Sites:
http://www2.atmos.umd.edu/~rjs/class/fall2022
https://umd.instructure.com/courses/1327017



Lecture 15

27 October 2022

Ellicott City Floods

CAPITAL WEATHER GANG

The second 1,000-year rainstorm in two years engulfed Ellicott City. Here's how it happened.

Analysis by Jeff Halverson

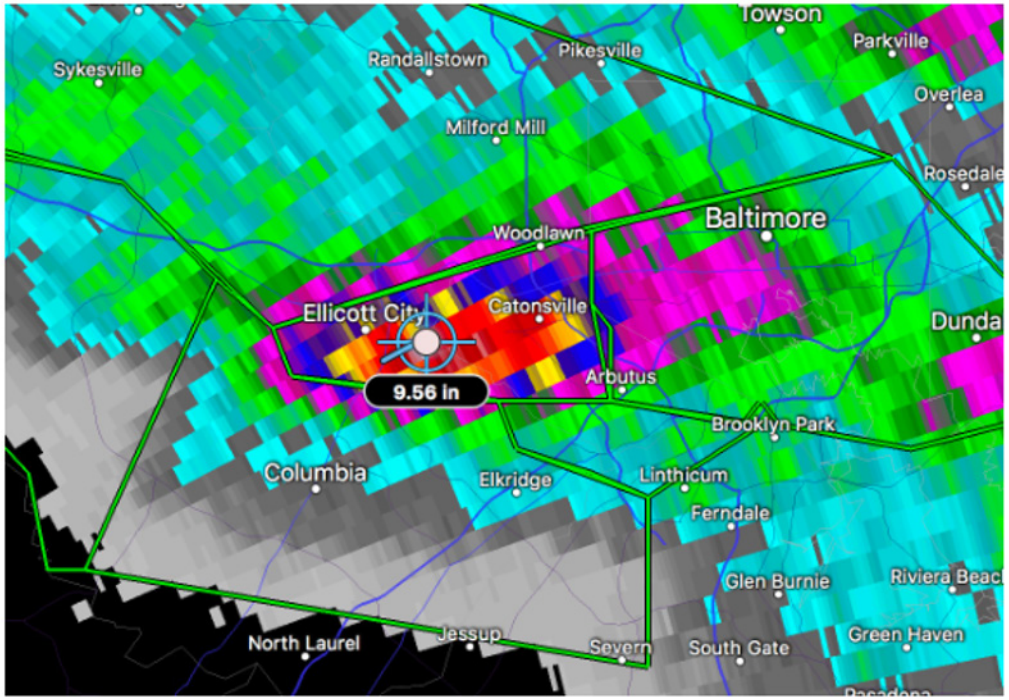
May 28, 2018 at 7:00 a.m. EDT

The National Weather issued a flash flood emergency for Ellicott City, Md., on May 27, after 3-6 inches of rain fell in just two hours. (Video: JM Rieger, Taylor Turner, David Bruns/The Washington Post)

https://www.washingtonpost.com/news/capital-weather-gang/wp/2018/05/28/the-second-1000-year-rainstorm-in-two-years-engulfed-ellicott-city-heres-how-it-happened

Ellicott City Floods

The image below shows the devastating pocket of extreme rain that befell a small region of central Maryland, bracketing Ellicott City, Catonsville and the campus of the University of Maryland Baltimore County over a nearly three-hour period.



(Radarscope)

The radar estimates 9.6 inches of rain fell midway between Ellicott City and Catonsville, with somewhat lesser surrounding amounts. It indicates about 6 inches fell in Ellicott City proper.

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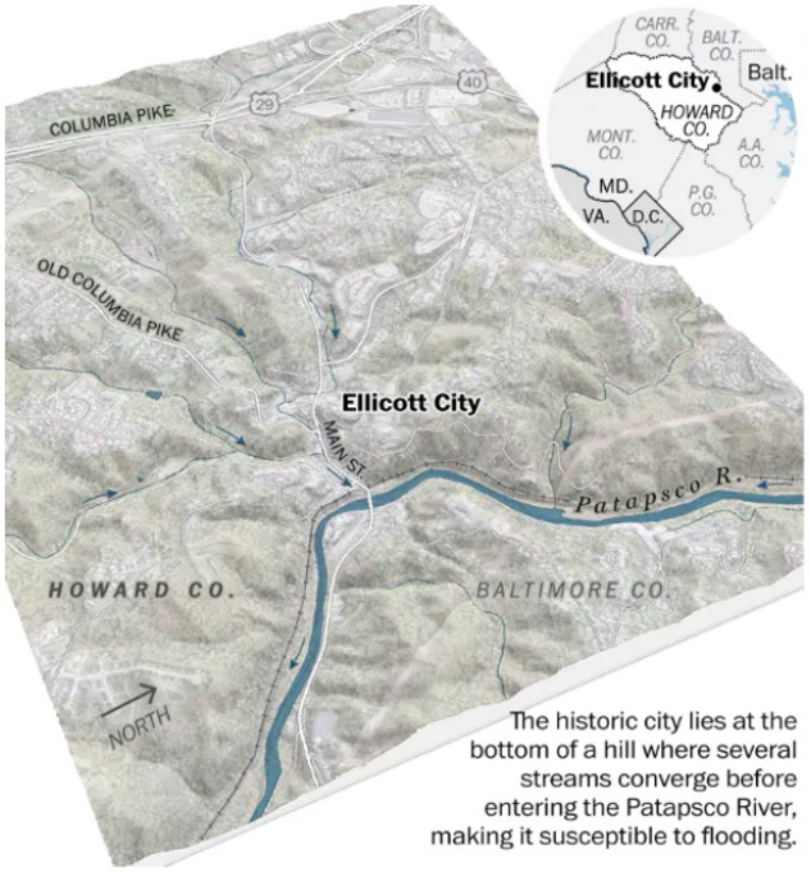
Ellicott City Floods

As we wrote after the 2016 flood, Ellicott City sits at the bottom of a topographical funnel, at the confluence of several streams feeding into the Patapsco River.



Sources: USGS, Google Earth

LARIS KARKLIS/THE WASHINGTON POST

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Ellicott City Floods

We have been stuck in a late July weather pattern, one in which the jet stream has built a ridge of high pressure over the Mid-Atlantic. This has allowed high levels of afternoon heat and humidity to build through our region. Afternoon warming becomes realized as the buoyant energy in thunderstorm clouds. The high humidity comes from the notorious Bermuda High, which pumps vast amounts of Atlantic moisture our way.

But the vestiges of winter hang on, paradoxically. The waters of the North Atlantic, off New England, are still chilly. Now and then, pockets of this cool air slip south, in the form of a backdoor cold front. These fronts are so-named, in contrast to ordinary cold fronts, which arrive from the west-northwest.

A surge of cool North Atlantic air moving southward into the Mid-Atlantic can push a cold front into our region — curiously — from the north, during late spring and early summer. It's a quirk of our region's geography.

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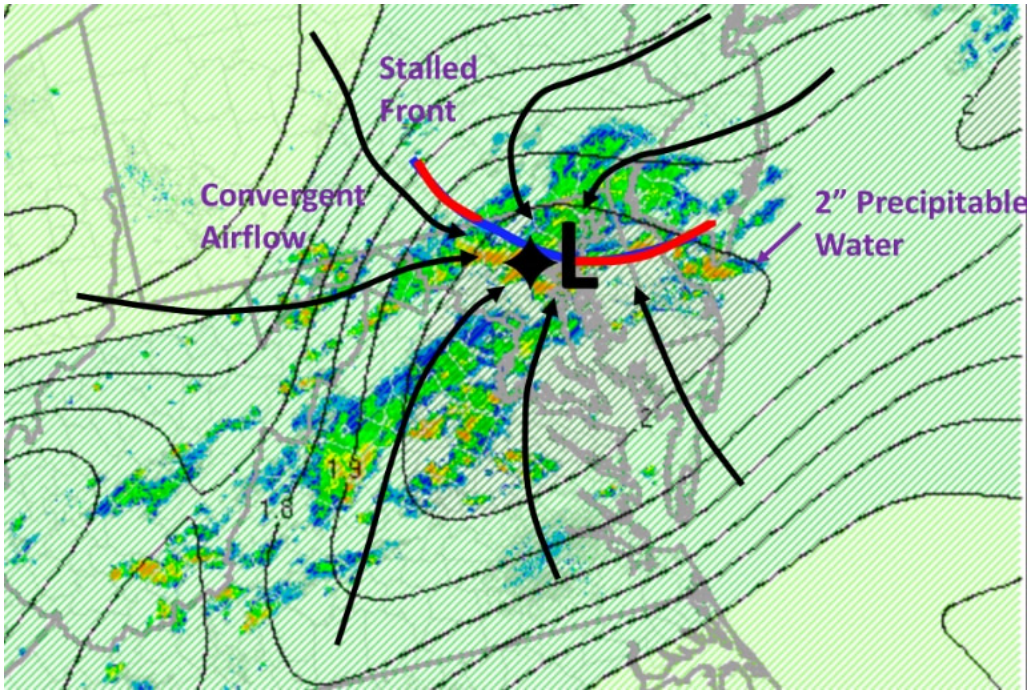
Ellicott City Floods

A backdoor front with an accompanying area of low pressure straddled the D.C.-Baltimore region Sunday morning. The low pressure drew in air from all directions, creating a convergence of moisture at ground level. As moist air rushed inward, it flowed upward. Rising moist air leads to rain. Add instability (the buoyant energy of a warm afternoon), and the air ascends more forcefully, as updrafts of thunderstorm clouds.



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The image also shows a great pooling of atmospheric moisture, called precipitable water. Take a one-meter-by-one-meter square air column, from the ground to the top of the troposphere, and condense all the water vapor. The liquid equivalent at the bottom is a measure of the total water content. On Sunday, our precipitable value was nearly record-breaking for this region, for May 27.

Now it's time for some simple geometry. The winds in the layer of the atmosphere that steers thunderstorm cells were blowing from west to east. This air current was parallel to the backdoor front pushing into the area. As moisture on south winds impinged on the front, near Ellicott City, storm cells blossomed in the unstable afternoon air. They were then blown eastward, moving along the stalled front. Ellicott City lay beneath the trajectory. What resulted was a train of rain-bearing storm cells, moving one after the other over Ellicott City.

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Ellicott City Floods

Given this setup, both the National Weather Service and Capital Weather Gang recognized, as early as Saturday, the potential for heavy rainfall and flash flooding in the region on Sunday. But realizing potential is one thing; trying to narrow the threat down to a specific town, hours before, is still nearly impossible, given the state of our understanding, lack of weather observations and limitations of the computerized forecast models. The National Weather Service did successfully highlight the general zone where flooding rain was most likely by mid-Sunday afternoon.

After flood waters ripped through historic Ellicott City, Md., on May 27, shredding buildings and flipping cars along Main Street. (Video: Jon Gerberg, Erin Patrick O'Connor/The Washington Post)

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Ellicott City Floods

Is this climate change?

Yes and no. This was an extremely localized, small, relatively short-lived storm. Climate change unfolds on time scales of decades and over very large regions, by comparison. Climate change did not "cause" this thunderstorm complex.

However, climate change has probably altered the larger environment in which these small thunderstorms are embedded. Notably, the water vapor content of the atmosphere, as a whole, has increased and scientific studies have shown a statistically meaningful uptick in the frequency of extreme rain events over the eastern United States. Statistically, over the long term, these types of extreme floods are probably becoming more common, in areas that are normally rainy as a result of global warming.

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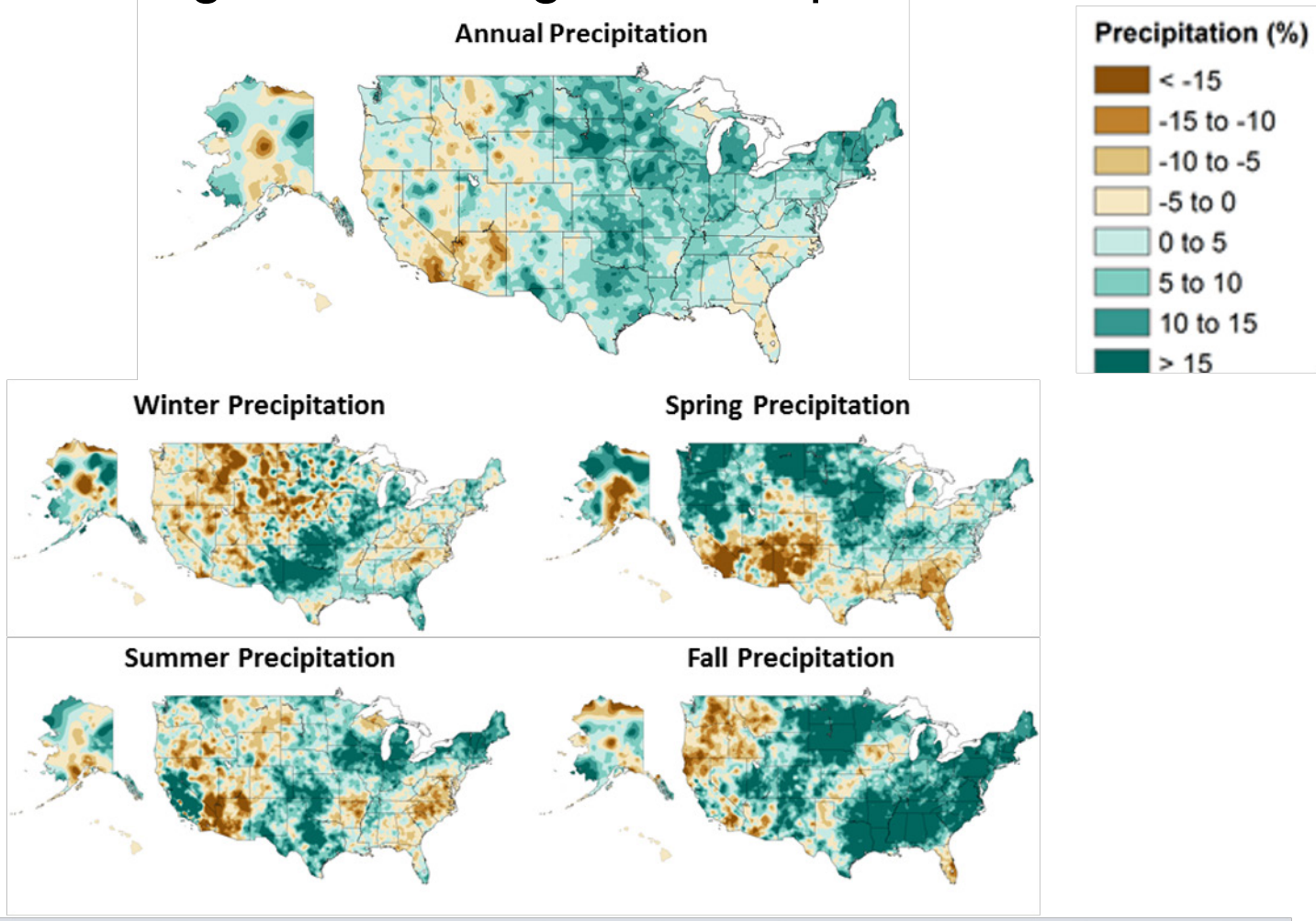
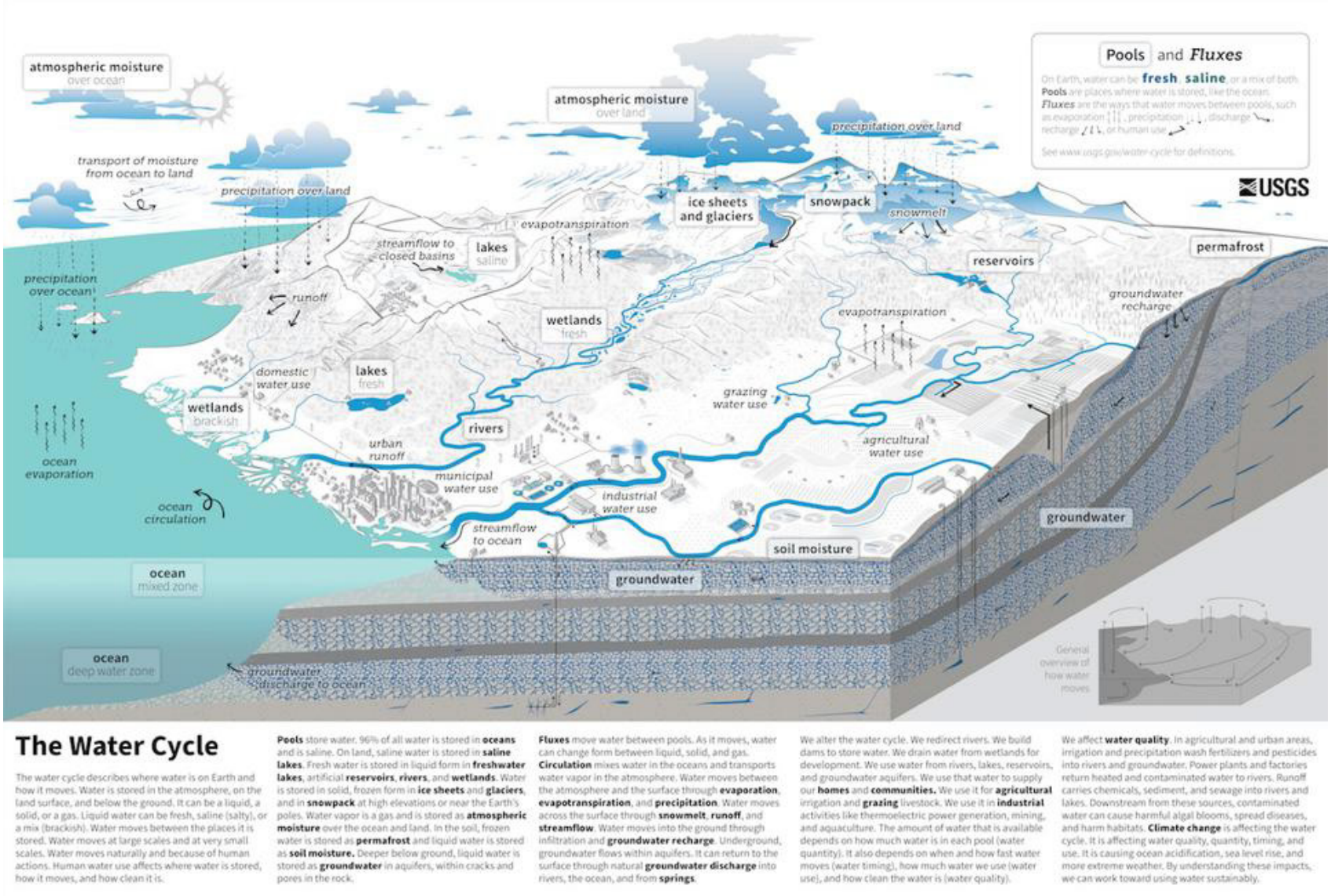
Long-Term Change in Precipitation, US



Annual and seasonal changes in precipitation over the United States. Changes are the average for present-day (1986–2015) minus the average for the first half of the last century (1901–1960 for the contiguous United States, 1925–1960 for Alaska and Hawai'i) divided by the average for the first half of the century. (Figure source: [top panel] adapted from Peterson et al. 2013,[6] © American Meteorological Society. Used with permission; [bottom four panels] NOAA NCEI, data source: nCLIMDiv].

https://science2017.globalchange.gov/chapter/7/

Marshall Shepherd



The Water Cycle

The water cycle describes where water is on Earth and how it moves. Water is stored in the atmosphere, on the land surface, and below the ground. It can be a liquid, a solid, or a gas. Liquid water can be fresh, saline (salty), or a mix (brackish). Water moves between the places it is stored. Water moves at large scales and at very small scales. Water moves naturally and because of human actions. Human water use affects where water is stored, how it moves, and how clean it is.

Pools store water. 96% of all water is stored in **oceans** and is saline. On land, saline water is stored in **saline lakes**. Fresh water is stored in liquid form in **freshwater lakes**, artificial **reservoirs**, **rivers**, and **wetlands**. Water is stored in solid, frozen form in **ice sheets** and **glaciers**, and in **snowpack** at high elevations or near the Earth's poles. Water vapor is a gas and is stored as **atmospheric moisture** over the ocean and land. In the soil, frozen water is stored as **permafrost** and liquid water is stored as **soil moisture.** Deeper below ground, liquid water is stored as **groundwater** in aquifers, within cracks and pores in the rock.

Fluxes move water between pools. As it moves, water can change form between liquid, solid, and gas. **Circulation** mixes water in the oceans and transports water vapor in the atmosphere. Water moves between the atmosphere and the surface through **evaporation**, **evapotranspiration**, and **precipitation**. Water moves across the surface through **snowmelt**, **runoff**, and **streamflow**. Water moves into the ground through infiltration and **groundwater recharge**. Underground, groundwater flows within aquifers. It can return to the surface through natural **groundwater discharge** into rivers, the ocean, and from **springs**.

We alter the water cycle. We redirect rivers. We build dams to store water. We drain water from wetlands for development. We use water from rivers, lakes, reservoirs, and groundwater aquifers. We use that water to supply our **homes** and **communities.** We use it for **agricultural** irrigation and **grazing** livestock. We use it in **industrial** activities like thermoelectric power generation, mining, and aquaculture. The amount of water that is available depends on how much water is in each pool (water quantity). It also depends on when and how fast water moves (water timing), how much water we use (water use), and how clean the water is (water quality).

We affect **water quality**. In agricultural and urban areas, irrigation and precipitation wash fertilizers and pesticides into rivers and groundwater. Power plants and factories return heated and contaminated water to rivers. Runoff carries chemicals, sediment, and sewage into rivers and lakes. Downstream from these sources, contaminated water can cause harmful algal blooms, spread diseases, and harm habitats. **Climate change** is affecting the water cycle. It is affecting water quality, quantity, timing, and use. It is causing ocean acidification, sea level rise, and more extreme weather. By understanding these impacts, we can work toward using water sustainably.

https://www.forbes.com/sites/marshallshepherd/2022/10/26/a-new-water-cycle-graphic-gets-it-right-for-science-education-and-humanity/?sh=44fe7658e765
https://twitter.com/DrShepherd2013/status/1585357846694473728

Marshall Shepherd

Earlier this month, the USGS announced a new water cycle diagram. Their press release stated, "The revised version replaces one used by hundreds of thousands of educators and students internationally every year since 2000....This depiction brings humans into the picture, showing the water cycle as a complex interplay of small, interconnected cycles that people interact with and influence, rather than one big circle."

The new diagram (graphic above) includes enhanced runoff associated with urban impervious surfaces, human water use (industrial, municipal, domestic, grazing or agricultural), and human-constructed reservoirs. This is an amazing upgrade, and I encourage educators to immediately adopt it for their water cycle lessons.

https://www.forbes.com/sites/marshallshepherd/2022/10/26/a-new-water-cycle-graphic-gets-it-right-for-science-education-and-humanity/?sh=44fe7658e765

Marshall Shepherd

As wonderful as the new graphic is, the scientist in me thought about what is missing. Here is a list of additional things that could have been included:

- Reduced infiltration due to urban impervious surfaces
- Modification of cloud and precipitation processes due to anthropogenic aerosols, urbanization, irrigation, deforestation and other land use
- Enhanced ice melt due to black carbon aerosols (soot) in the cryosphere
- Accelerated water cycle components due to greenhouse gas-related warming.

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State, UMD Partner to Build World-class Weather Observation System

Hogan Announces $4M for Maryland Mesonet to Bolster Response to Volatile Events

By Maryland Today Staff / Oct 24, 2022

Gov. Larry Hogan on Monday announces the Maryland Mesonet, a statewide system of 75 advanced weather towers to monitor changing conditions and provide early warnings, supported by a $4 million state investment.

https://today.umd.edu/state-umd-partner-to-build-world-class-weather-observation-system

Maryland Mesonet

Gov. Larry Hogan today announced a groundbreaking partnership between the state of Maryland and the University of Maryland to build and operate a network of 75 weather-observing towers that will span the state and provide real-time community-level monitoring to boost situational awareness during rapidly changing weather conditions.

Known as the Maryland Mesonet, the system will feature state-of-the-art environmental monitoring stations to provide real-time data around the clock, Hogan said in an event held at UMD's Physical Sciences Complex.

"I am pleased to announce that we have committed $4 million to this ambitious project, which will give our emergency managers even faster and more accurate satellite data to make critical decisions about preparedness and deploying resources," Hogan said.

The Maryland Mesonet will enhance public safety, reduce community risk and aid in applications for disaster relief programs, officials said. It will also provide high-resolution meteorological observations to the National Oceanic and Atmospheric Administration (NOAA), helping improve the regional weather forecast and better protect residents and businesses.

"We are proud that the Maryland Mesonet expands the University of Maryland's deep commitment to service for our state," said UMD President Darryll J. Pines. "Weather has been increasingly challenging to predict, and our scientists will play a leading role in providing high-resolution atmospheric data to NOAA to improve regional weather forecasts. We will also work to inform local decision-makers who can better protect Marylanders and their businesses."

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