They Just Keep on Coming

By John Benson

August 2022

1. Introduction

This summer it seems that every time I read a scientific or news publication or watch a program on television with a similar subject-matter, I am confronted by major effects of climate change. Going forward, these will increase in frequency and severity stressing our ability to adapt to them. They are also very complex and thus difficult to predict in advance. Most of these are secondary, tertiary or higher-order effects.

These include the following, which we have known about for some time:[1]

- *The sea-level is rising primarily due to a secondary, a tertiary effect and a higher order effect of climate change. The secondary effect is the thermal expansion of sea water as it warms. The tertiary effect is the melting of glaciers and ice sheets (primarily the Antarctic and Greenland Ice Sheets) as they warm, providing run-off into the oceans thus further increasing the level of the oceans. The higher-order effect is Arctic- (and Antarctic-) amplification since global warming is more pronounced in the polar-regions, accelerating ice-sheet melting, etc.*
- *Both heat and CO_2 enter the oceans and the latter acidifies them, causing major damage to coral, shellfish and possibly other aquatic life.*
- *The melting of the Greenland Ice Sheet has freshened the water in the North Atlantic, which has disrupted the Meridional Overturning Circulation (MOC, the Gulf Stream and other major ocean currents).*
- *Increasing atmospheric temperatures and the MOC disruption have caused major changes to weather patterns around the world.*

The latter has led to the slow-down or stalling of the Jet Stream (via Rossby Waves) in summer, leading to long-term heat waves throughout much of the World.[2] Section 2 below will explore recent manifestations of the effects described in reference 2, and section 3 will describe other higher-order effects of climate change.

2. Effects of the Stuck Jet Stream

The following are recent reports of world-wide heat waves this summer:

Hundreds of millions of people around the world are currently experiencing sweltering, dangerous heat -- a new reality as the effects of climate change continue to manifest in severe weather events of every kind.[3]

[1] See "Emerging Negative Effects of Climate Change, rev a," Aug, 2021, https://www.energycentral.com/c/ec/emerging-negative-effects-climate-change

[2] See "Stuck," Aug 2021, https://energycentral.com/c/ec/stuck

[3] Julia Jacobo, ABC News, "Record-breaking heat waves in US and Europe prove climate change is already here, experts say," July 19, 2022, https://abcnews.go.com/Technology/record-breaking-heat-waves-us-europe-prove-climate/story?id=87069737

A scorching air-mass remains over the majority of the continental U.S. on Wednesday (7/13), with a heat dome sitting over the Southwest and Great Plains and triple-digit temperatures stretching throughout the Midwest and up and down the East Coast.

While Wednesday brought slight relief to Europe with its own block of boiling weather that helped to reach the hottest temperature ever recorded in London, there were wildfires across the continent and more than 1,500 heat-related deaths in Spain and Portugal alone.

The predictions climate scientists have been making for decades about what awaited the planet should the temperatures continue to rise are currently coming into fruition in the form of these heat waves that are occurring concurrently in lands thousands of miles apart, experts told ABC News.

The "most direct" connections between weather and climate change are the increase in intensity, frequency, duration and expanse of heat waves, said Jennifer Francis, senior scientist at the Woodwell Climate Research Center. And "even stronger extremes" are expected in the future, World Meteorological Organization Secretary-General Petteri Taalas said during a press conference Tuesday.

Extreme heat is a "basic consequence of climate change," and the fact that it's happening in several different locations at the same time is characteristic of the average global temperatures rising, Jason Smerdon, a climate scientist for the Columbia Climate School's Lamont-Doherty Earth Observatory in New York, told ABC News.

"While each heat wave itself is different, and has individual dynamics behind it, the probability of these events is a direct consequence of the warming planet," Smerdon said, adding that a break in low airmass off the Atlantic Ocean moved east and blanketed Spain and Portugal, which is why those countries experienced the worst of the prolonged heat.

Historically, when records are broken, they are done so in very small increments, such as a fraction of a degree -- another characteristic that makes the current heat waves much more severe than in years past, Smerdon said. The previous record in the U.K. occurred at the Cambridge Botanic Gardens at 101.6 degrees Fahrenheit in July 2019. On Tuesday, that record was broken when the temperature measured at 104 F -- a hallmark that the Earth's climate is currently in "uncharted territory," Francis said.

"These things are blowing the roof off of the previous record," Smerdon said, adding that the same applies to the record-breaking heat waves that occurred in the Pacific Northwest last year. Those heat waves would have been "virtually impossible" without climate change, a study published in 2021 found…

The fact that Britain, which is essentially at the same latitude as Calgary in Canada, is experiencing triple-digit temperatures at such frequency poses a danger to human health because the majority of the infrastructure was built during a century that never saw such heat, Smerdon said. A large portion of the population is not equipped with air conditioning in their homes, and therefore are not able to cool off all the heat exhaustion that built up during the day, Rachel Licker, principal climate scientist at the Union of Concerned Scientists, told ABC News. The heat is also colliding with other climate hazards, such as the wildfires in Spain and the poor air quality that comes with it, she added…

Many other areas that are experiencing heat waves also lack wide-spread air conditioning, including the U.S. Pacific Northwest mentioned above. Speaking of the Pacific Northwest, as I'm starting to write this paper:

"Authorities on Sunday (7/24) issued an excessive heat watch for the U.S. Pacific Northwest region for coming days as potential record-breaking temperatures were forecast to settle in and linger until next weekend.[4]

Temperatures could break daily records in Seattle, Portland and areas of Northern California by Tuesday, potentially reaching their highest levels since last year's deadly heat wave that killed hundreds of people across the Pacific Northwest.

Highs ranging from 95°F (35°C) to 110°F (43°C) were forecast for inland areas. An excessive heat watch was issued for central and eastern Washington state and the central Idaho Panhandle from Tuesday morning through Friday evening.

Much of the region is unaccustomed to such high temperatures and many homes don't have air conditioning. Authorities cautioned that indoor heat was likely to build through the week, increasing the chances for people to suffer heat-related illnesses.

And the Pacific Northwest is not the only area in the U.S. to be hit by a heat wave recently:

Temperatures of 115°F have been recorded in Texas and Oklahoma this week, and more than 211 million people across the country will experience heat of 90 degrees or higher on Wednesday (7/27). [5]

Residents of Texas, a state that has been subjected to daily triple-digit temperatures and is in the midst of a mega-drought affecting much of the West, have for weeks been asked to conserve water and electricity…

"When it's 110 outside, you're a prisoner in your home," Andrew Dessler, a professor of atmospheric sciences at Texas A&M University, told the Washington Post. "Is this the kind of life you want to live?"

Like Texas, Oklahoma has been particularly hard hit by the heat, with every one of the state's 120 weather monitoring stations recording temperatures of 102°F or higher on Tuesday (7/19).

Officials in Phoenix are worried that the city will once again break heat-death records this year, especially among the vulnerable homeless population.

"I wouldn't be surprised if we are in worse shape from a heat-associated-death standpoint than we were last year because there are so many more unsheltered folks that are at 200 to 300 times the risk of heat-associated death," David Hondula, director of the city's Office of Heat Response and Mitigation, told Yahoo News.

While climate change skeptics often argue that excessive heat is simply a normal seasonal consequence, scientists have established that the burning of fossil fuels since the start of the Industrial Revolution is responsible for rising temperatures.

---

[4] Associated Press via the Detroit News, "Heat wave to push Pacific Northwest to triple digits, linger for days," July 24, 2022, https://www.detroitnews.com/story/news/nation/2022/07/24/heat-wave-pacific-northwest-triple-digits-temperatures/10140686002/

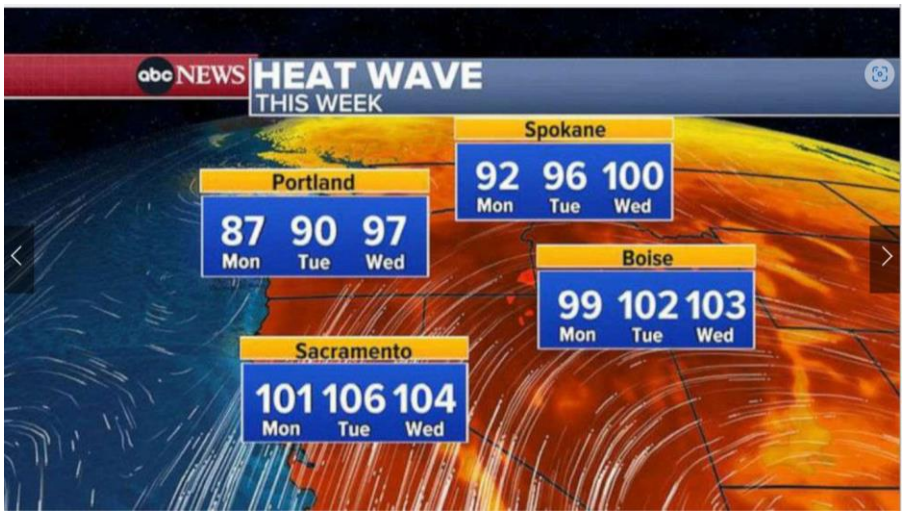
[5] David Knowles, Yahoo News US, "U.S. swelters in latest heat wave, with Texas and Oklahoma hitting 115°F," July 20, 2022, https://www.msn.com/en-us/weather/topstories/us-swelters-in-latest-heat-wave-with-texas-and-oklahoma-hitting-115-c2-b0f/ar-AAZNpDH

This year alone, there have been 92 new high-temperature records set in the U.S., compared with just five new records for low temperatures. That same pattern has played out across the planet, with 188 new high-temperature marks having been set through July 16 as compared with 18 new record lows, data from the National Oceanic and Atmospheric Administration shows.

Of course, that would be exactly what you would expect if, as has been proved, global temperatures are rising. In states sweltering in triple-digit heat, meanwhile, the reality of climate change is playing out in real time.

"It looks like we're going to stay in the range of highs of 100 to 105 degrees for the next week and a half," Erin Maxwell, a meteorologist at the National Weather Service in Norman, told the Oklahoman. "But in terms of real relief from the heat, that doesn't look to be on the horizon any time soon."

As I'm final-proofing this paper for posting, I found that the heat continues. See the images below from this source.[6]



[6] ABC News, "New heat wave builds as flash flooding targets several states," Aug 15, 2022, https://www.msn.com/en-us/weather/topstories/new-heat-wave-builds-as-flash-flooding-targets-several-states/ar-AA10GkuX

And where I live (Livermore, CA in the Eastern San Francisco Bay Area) per the National Weather Service it was 106°F on Tuesday and 95°F on Wednesday (8/17). The good news is that we have air conditioning.

3. Higher-Order Climate Change Effects

Most have heard that the Western U.S. is under a multi-year mega-drought. This is having a major impact on this region's largest reservoirs:

3.1. Lake Mead: Historically Low Water Levels

I clearly stated in a social media post earlier this week that water usage, natural variability, and climate change explained stunning images of Lake Mead released by NASA. However, a comment on one of the platforms said something like, "It wasn't wise to build it in the desert and consumption outweighs changing weather year to year." While aspects of this statement are true, there are parts of it that could convey misinformation about climate change. Several of my previous Forbes essays have dealt with the "naturally-varying climate" narrative. Let's dig a bit deeper into why Lake Mead is vanishing, and "yes," climate change is part of the answer.[7]

When I first saw the comment, I thought to myself, "you can pretty much say that about any weather-climate related disaster." People and businesses build things along the coasts even as we know hurricanes will always be a part of the landscape. Most homes in the United Kingdom do not have air conditioners. Roadways are constructed over creeks and rivers that inevitably flood. My point is that many things within our society are now being disrupted by "DNA" of climate change embedded in today's weather events. A growing number of climate attribution studies affirm that statement.

Lake Mead is the reservoir created when the technological marvel that is the Hoover Dam was created. The Landsat 7 images at the beginning of this essay confirm that the reservoir is at the lowest mark since it was filled in 1937. According to NASA's Earth Observatory website, "As of July 18, 2022, Lake Mead was filled to just 27 percent of capacity." To the commenter's point, the nation's largest reservoir supplies water to tribal lands, seven states and even parts of Mexico. Ok, so what's going on with the climate

[7] Marshall Shepherd, Forbes, "Why Is Lake Mead Shrinking? Climate Change Is A Major Reason," July 22, 2022, https://www.forbes.com/sites/marshallshepherd/2022/07/22/why-is-lake-mead-shrinking-climate-change-is-a-major-reason/

change that amplifies the reservoir levels? The ongoing drought in the West is one of the worst in 1200 years according to NASA. In fact, it may be "the" worst. NASA's website goes on to say, " The low water level comes at time when 74 percent of nine Western states face some level of drought; 35 percent of the area is in extreme or exceptional drought." The geographic headwaters of the Colorado region are situated within drought-stricken Colorado and winter snowpack was below average.

Changes in Lake Mead elevation from 2000 to 2022 NASA EARTH OBSERVATORY

According to NASA, Lake Mead was last at full capacity (1220 feet near dam-level and 9.3 trillion gallons) in 1983 and 1999. Where does the water from Lake Mead come from? The vast majority of its water comes from inflow from the Colorado River with smaller contributions from Las Vegas Wash and smaller rivers (Virgin and Muddy Rivers). The National Park Service website points out, "Flow in Las Vegas Wash has more than doubled over the past 30 years as a result of the rapid population growth in Las Vegas." Local precipitation and groundwater account for roughly 10% of the water in Lake Mead.

If the Colorado River is the main water source for Lake Mead, then we know there is a climate change connection. A 2019 study published in the peer-reviewed Journal of Climate confirmed climate change has reduced the Upper Colorado River flow by 10%, and natural variability alone could not be the only factor. They attributed the reductions to reduced precipitation over the basin and increased temperatures. Several studies also find that recent warming results in reduced snowpack and shifts to earlier runoff times. A U.S. Geological Survey website starts with this statement, "Declining snow cover is playing a key role in decreasing the flow of the Colorado River, "the lifeblood of the Southwest," by enabling increased evaporation."

Yes, the paleoclimate record has established past mega-droughts in the region, but a 2022 study entitled, "The Press and Pulse of Climate Change: Extreme Events in the

Colorado River Basin," can be found in the Journal of the American Water Resources Association. The authors make a startling point that current warming projections will push natural and human systems past critical thresholds. Often in climate science, such thresholds are referred to as tipping points.

When you factor in these changes and the fact that over 25,000,000 people rely on water from Lake Mead, "Vegas, we have a problem...Or Phoenix, Los Angeles, and so on." People need water for drinking, cooking, irrigation, infrastructure and so forth. It was already hot in these regions, but studies confirm that temperature distributions are shifting to a warmer regime. Climate change-amplified heat in the West and increasing urban heat islands in the cities are also factors in water consumption. The National Park Service website says, "As communities like Las Vegas become more urbanized, roads, parking lots and buildings have caused an Urban Heat Island (UHI) — a warming of urban areas....coupled with forecasts of drier weather and our continued population growth, will challenge what our urban environment can withstand." The bottom line is that even if you look at the consumption side of Lake Mead, climate change still rears its ugly head…

3.2. Ditto the Great Salt Lake

The Great Salt Lake in Utah has now dropped to levels lower than ever reached before.[8]

On July 3, 2022, the lake—the largest saltwater lake in the Americas and 8th largest in the world—recorded its lowest water levels since records began in 1847, falling to 4,190.1 feet above sea level at the Salt Air gauge location, and is expected to further drop throughout the rest of the summer.

The previous record low occurred in October 2021, when the lake's water level was measured as being 4,190.2 feet above sea level. The water level trends in 2022 have been consistently lower than they were in 2021, both of which are lower in turn than in 2020.

As a result of this drop in water level, the lake has also seen a huge reduction in its surface area. While in the 1980s, the lake covered around 3,000 square miles, it now only spans about 950 square miles.

"This is not the type of record we like to break," Utah Department of Natural Resources Executive Director Joel Ferry said in a U.S. Geological Survey news release. "Urgent action is needed to help protect and preserve this critical resource. It's clear the lake is in trouble. We recognize more action and resources are needed, and we are actively working with the many stakeholders who value the lake."

Naturally, the lake would empty and refill with the seasons, losing water in the summer from evaporation. However, the mega-drought currently plaguing the Western states of the U.S.—and a large portion of the area around the Great Salt Lake is classified by the U.S. Drought Monitor as being in a state of "extreme drought"—has meant that the balance of water has shifted towards the dry end of the scale.

[8] Jessica Thomson, Newsweek, "Utah's Great Salt Lake Drops to Lowest Levels After Years of Drought," July 14, 2022, https://www.msn.com/en-us/weather/topstories/utahs-great-salt-lake-drops-to-lowest-levels-after-years-of-drought/ar-AAZzHUK

This is only being exacerbated by climate change as a result of human activity, with 42 percent of the past 22 years of drought conditions being attributed to climate change in a 2022 study published in the journal Nature Climate Change.

Another factor contributing to the lake's dropping water levels is the reduction in ways that the lake regains water. Around 3.3 trillion liters of water (about 872 billion gallons) are redirected from the streams that feed the lake each year to agriculture and nearby residential areas, meaning that the lake cannot easily replace the water it loses via evaporation.

The consequences of this dramatic reduction in water levels are serious on a number of levels. The lake is an essential habitat for plants, brine shrimp, reptiles, amphibians, mammals, shorebirds and waterfowl, forming a critical part of the Pacific Flyway between North and South America for over 10 million birds annually.

The community around the lake relies on the body of water to bring in a lot of income. Tourism, mineral extraction and brine shrimp production bring in around $1.53 billion per year.

Additionally, as the lake dries up and reveals more and more lakebed, the dry soil leads to an increase in the dust in the air, worsening the air quality nearby. There is also a build-up of heavy metals like lead, arsenic and mercury in the lake as a result of not having an outflow of water, which then ends up in this dust as the water evaporates away…

3.3. Snow Metrics Erode

Climate change will lead to more unpredictable water levels in snow-dominated regions in the Northern Hemisphere as snow melts at accelerated paces because of warming temperatures, according to a study published in PNAS on Monday, a finding researchers warned could significantly disturb the management of freshwater resources in the future.[9]

Several regions of the world use snow-related metrics, including the accumulation of snow during the winter and resulting runoff and streamflow from the melting of snow in the spring and summer to help inform management of water resources, according to the study.

But rising global temperatures—which will reduce winter snow accumulation and increase the amount of snow that melts during the winter—will blur this seasonal pattern, leading to "pervasive" changes in water flows and water storage by the end of the century, according to the study, which used a simulation database known as the Community Earth System Model to compare snowpack and water resources from 1940 to 1969 with a future period of 2070 to 2099.

These changes will force those involved in water management to be "at the whim of individual precipitation events" instead of having four to six months in advance to

[9] Madeline Halpert, Forbes, "Melting Snow From Climate Change Could Lead To Unpredictable Water Levels, Study Suggests," July 18, 2022, https://www.forbes.com/sites/madelinehalpert/2022/07/18/melting-snow-from-climate-change-could-lead-to-unpredictable-water-levels-study-suggests/?ss=sustainability&sh=598947163768&utm_source=newsletter&utm_medium=email&utm_campaign=currentclimate&cdlcid=628673ca6e1a1d1211f1d747

anticipate snowmelt and runoff, National Center for Atmospheric Research scientist Will Wieder said in a statement.

Regions that rely most heavily on seasonal patterns of snowpack and melting to predict water resources, including the Rocky Mountains, the Canadian Arctic, Eastern North America and Eastern Europe, will suffer the most as rising temperatures affect this trend, researchers suggested.

Scientists are "in a race with predictability," trying to improve forecasts through better data and modeling, but such efforts are complicated by the "rapid disappearance" of the best predictor: snow, Flavio Lehner, study co-author and professor of earth and atmospheric science at Cornell University, said in a statement.

Final Author's Comment: My home state (California) uses snow-pack measurements as a primary metric to estimate the amount of water flowing into our reservoirs. Thus the above described effects will impact these. Also, California receives most of its precipitation in November through March, and historically January and February have had the most rain and snow. But in recent years, January and February have been mostly dry. The good news for the 2021-2022 water year is that we had good early and reasonable late rains.