Fire & Storms Part 5: Steam and Smoke

By John Benson

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1. Introduction

Mother Nature must be really upset with us. As the effects of climate change multiply, she keeps delivering surprises, and not of the nice kind. The one piece of positive news for me is that these provide increased content for my posts.

It was only a few weeks ago that I posted a part 4 paper for this series, and now comes enough content for a part 5. Part 4 is described and linked below:

Fires and Storms Part 4, 2021 California & Alaska: *The 2021 California Wildfire Season did not appear to be as severe as the prior two seasons, but the way it ended was severe in a different way – with a historically-strong atmospheric river rainstorm. At that point it wildfires were already starting to wind-down.*

This post will review the 2021 season in reverse chronological order, starting with the major rain event that finished it off, and ending with the report of season itself. Then we will visit a state a bit further north that has been experiencing some major climate change driven wildfires of their own.

https://energycentral.com/c/ec/fires-and-storms-part-4-2021-california-alaska

Increased atmospheric humidity increases rainfall from all storms. It also has bad health effects in the world's hottest areas. Smoke from wildfires are also hazardous to our health without good air filtration. Now a new negative effect of smoke above the tropopause is looming. This post is about these subjects.

2. Steam

As the atmosphere heats up, it is capable of carrying more water vapor, and thus dumping more water. Thus unusually high rain amounts are no longer unusual, and will become more common unless we get climate change under control. Also, with increasing surface humidity plus increasing ambient temperature, many areas in our world are no longer suitable for human habitation without air conditioning.

2.1. Storms

The summer of 2021 was a glaring example of what disruptive weather will look like in a warming world. In mid-July, storms in western Germany and Belgium brought up to eight inches of rain in two days. Floodwaters ripped buildings apart and propelled them through village streets.[1]

A week later a year's worth of rain—more than two feet—fell in China's Henan province in just three days. Hundreds of thousands of people fled rivers that had burst their banks. In the capital city, commuters posted videos showing passengers trapped inside

[1] Jerry Lincecum, Herald Democrat, "Vapor storms are threatening people, property," Nov 2 2021, https://www.heralddemocrat.com/story/lifestyle/2021/11/02/lets-reminisce-vapor-storms-threatening-people-property/6253756001/

flooding subway cars, pushing their heads toward the ceiling to reach the last pocket of air above the quickly rising water.

In mid-August a sharp kink in the jet stream brought torrential storms to Tennessee that dropped an incredible 17 inches of rain in just 24 hours; catastrophic flooding killed at least 20 people.

None of these storm systems were hurricanes or tropical depressions. Soon enough, though, Hurricane Ida swirled into the Gulf of Mexico, the ninth named tropical storm in the year's busy North Atlantic season. On August 28 it was a Category 1 storm with sustained winds of 85 miles per hour. Less than 24 hours later Ida exploded to Category 4, at nearly twice the rate that the National Hurricane Center uses to define a rapidly intensifying storm. It hit the Louisiana coast with winds of 150 miles an hour, leaving more than a million people without power and over 600,000 without water for days.

Ida's wrath continued into the Northeast, where it delivered a record-breaking 3.15 inches of rain in one hour in New York City. The storm killed at least 80 people and devastated a swath of communities in the eastern U.S.

What all these destructive events have in common is water vapor—lots of it. Water vapor—the gaseous form of good old H_2O—is now playing an unprecedented role in fueling destructive storms and accelerating climate change. As the oceans and atmosphere warm, additional water evaporates into the air.

Warmer air, in turn, can hold more of that vapor before it condenses into cloud droplets to create flooding rains. The amount of vapor in the atmosphere has increased about 4 percent globally just since the mid-1990s. That may not sound like much, but it is a big deal to the climate system.

A juicier atmosphere provides extra energy and moisture for storms of all kinds, including summertime thunderstorms, nor'easters along the U.S. Eastern Seaboard, hurricanes and even snowstorms. Additional vapor helps tropical storms like Ida intensify faster, too, leaving precious little time for safety officials to warn people of danger.

Scientists have long anticipated that climate change would create more airborne vapor, fueling what might be called "vapor storms" that are unleashing more rain and snow than storms did only a few decades ago. Measurements now confirm that heavy-precipitation events are hitting harder and occurring more often across the U.S. and the globe. Since the late 1980s about one third of U.S. property damage caused by flooding—$73 billion—has been attributed to increases in heavy precipitation. It's time we began to expect more vapor storms that damage people and property.

Also see section 2 of Part 4 of this series, linked in the Introduction.

2.2. Tropical Storms

Increasing water vapor means that tropical storms and hurricanes have plenty of fuel to rapidly intensify, both from above (more humid atmosphere) and below (warmer ocean temperatures). A storm "rapidly intensifies" when the maximum wind-speed increases by at least 35 miles per hour or the central atmospheric pressure drops by at least 42 millibars in 24 hours. In the past 40 years the probability that a storm will rapidly intensify in a given year has quadrupled.[2]

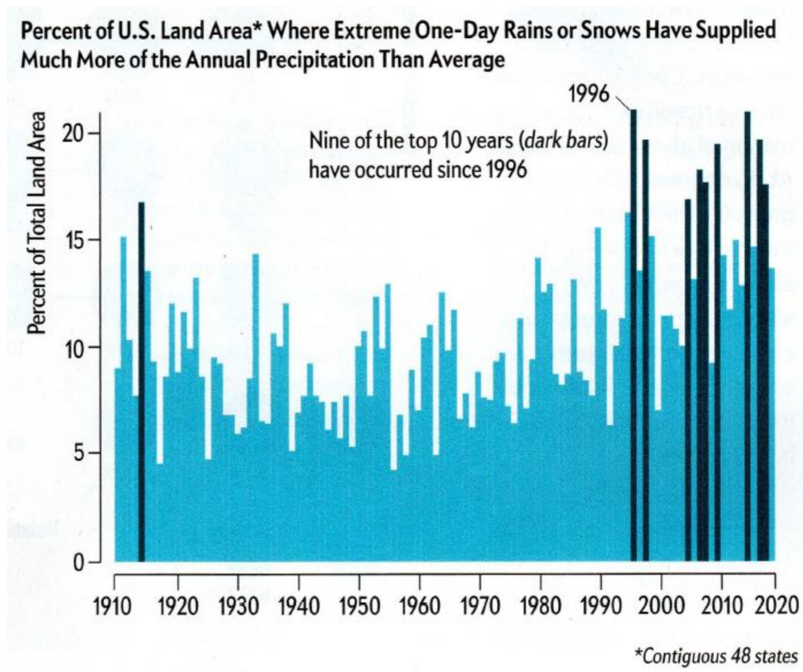
[2] Raj Patel, Scientific American, "Vapor Storms," November 2021 Issue – hardcopy, To Order a copy of a Scientific American Issue, call (800) 333-1199

In 2020 alone, 10 Atlantic hurricanes did just that: Hanna, Laura, Sally, Teddy, Gamma, Delta, Epsilon, Zeta, Eta and Iota. In 2021 five of the six Atlantic hurricanes that formed as of mid-September underwent rapid intensification, including Ida and Nicholas. Recent studies agree with physical common sense: rapid intensification becomes increasingly likely as oceans warm, evaporating more water and delivering more latent heat to the atmosphere. Oceans absorb about 90 percent of the heat trapped by extra greenhouse gases we humans have emitted. That heat raises water temperatures both at the surface and deeper below; the warm water acts like a powerful battery that storms can draw energy from.

Increasing water vapor is not the only impact of climate change on tropical storms, however. Decreasing wind shear-the difference in speed or direction between winds closer to the ground and those high in the atmosphere-also favors storm development because the towers of rising air are less likely to be torn apart. Other variables now being studied include changes in the amount of dust and pollution particles in the air, as well as differences in atmospheric warming at lower and higher altitudes, which affect how fast those bubbles of warm air rise.

For more than two decades much of the tropical North Atlantic Ocean has been abnormally warm, creating excess evaporation that fuels strong hurricanes. Non-tropical storms are gorging on the atmosphere's extra vapor and energy too, leading to more heavy-precipitation events and perhaps even heavier snowfalls.

The chart to the right reinforces the above text.



2.3. Steamy Weather

The threat from increased water vapor extends beyond storms. It is also making summer nights intolerably steamy-more often and in more places.

Since the mid-1990s summer nighttime minimum temperatures over global land areas have been rising faster than daytime highs. That is because water vapor is a greenhouse gas, and more of it means more warming: heat that would normally escape to space at night is instead trapped, preventing Earth's surface from cooling. And unlike carbon dioxide, which spreads worldwide regardless of where it is emitted, vapor tends to stay local.

More vapor also makes hot nights perilous. Higher nighttime humidity prevents your sweat from evaporating-the body's natural cooling system leaving you to overheat and *interfering with sleep. One measure of this discomfort is the heat index, which combines the effects of temperature and humidity to represent the stress one's body really feels. An index above about 100 degrees Fahrenheit is considered dangerous; prolonged exposure can be fatal, especially to the elderly and infants. Heat stresses livestock and pets, too, and animals in the wild are adapting by moving toward higher latitudes or higher elevation if they can. Without a period of nighttime cooling, heat can also build up in soils, killing some plants and insects while allowing other, warmth-loving species to flourish. According to "A Declaration on Climate Change and Health 2021[3];' published in August by a group of 32 health organizations, nighttime heat also heightens the risk of exposure to diseases carried by insects, threatening humans, animals and crops…*

IF INTENSE STORMS and sweltering nights are not troubling enough, water vapor is also making global warming worse. Even though carbon dioxide gets most of the attention, water vapor is by far the most important greenhouse gas in the atmosphere. It absorbs much more of the infrared energy radiated upward by Earth's surface than do other greenhouse gases, thereby trapping more heat. To put this into perspective, a doubling of atmospheric carbon dioxide concentrations by itself would warm the globe approximately one degree C. But feedback loops vicious cycles-make the temperature rise twice as much. Again, although feedbacks such as disappearing sea ice get a lot of attention, the water-vapor feedback loop: warming causes evaporation, which traps heat, creating even more warming-is the strongest one in the climate system.

3. Smoke

Two years ago, the crew of the Polarstern, a German icebreaker frozen into Arctic sea ice, shot a green laser up into the night. The beam's reflected light was meant to help researchers study icy winter clouds. Instead, the beam encountered something unexpected: a kilometers-thick layer of particles in the stratosphere, more than 7 kilometers up. The haze, the researchers later concluded, was smoke from enormous wildfires that had ripped through Siberia that summer.[4]

The smoke was more than a curiosity. By March 2020, as the Siberian smoke lingered, satellite measurements of ozone levels in the Arctic hit a record low—not quite a "hole," by Antarctic standards, but worryingly low. Although the case is far from closed, it seems likely the smoke helped deplete the ozone, says Kevin Ohneiser, a graduate student at the Leibniz Institute for Tropospheric Research (TROPOS). Similar dips have occurred the past 2 years in Antarctica following Australia's record-breaking "Black Summer" fires, which injected more than 1 million tons of smoke into the stratosphere. "We cannot prove this," he says. "But these [results] seem to be a hint."

The findings, which Ohneiser and his colleagues published last month in Atmospheric Chemistry and Physics, suggest climate change may have an unexpected impact on atmospheric chemistry, as smoke from increasingly severe wildfires invades the stratosphere and potentially erodes the ozone layer that screens out damaging ultraviolet (UV) radiation. "Until recently, smoke was really discounted in terms of a global impact," says Catherine Wilka, a stratospheric chemist at Stanford University. Now, she adds, it's "shaping up to be one of the new frontiers."

[3] https://www.acponline.org/acp_policy/policies/2021_declaration_on_climate_change_and_health_jan_2021.pdf
[4] Paul Voosen, Science, "High-flying wildfire smoke may threaten ozone layer," Nov 18, 2021, https://www.science.org/content/article/high-flying-wildfire-smoke-may-threaten-ozone-layer

“This is really new,” adds Omar Torres, a remote sensing scientist at NASA’s Goddard Space Flight Center. Since the late 1970s, satellites have been capable of tracking smoke particles, easily visible from space because they are strong absorbers of UV light. Until 2017, however, the satellites saw no sign of smoke penetrating the stratosphere in any appreciable amount, Torres says.

The Arctic smoke event is particularly worrisome because it had no business being there. “Everyone thought the Arctic would be really clean,” Ohneiser says, because it lacks the thunderstorms that can propel pollutants into the stratosphere, a calm, isolated layer above the troposphere. Today’s fiercest wildfires, such as those in Australia, can generate their own towering storm systems, capable of pumping material into the stratosphere like volcanoes. But while Siberia burned, it was trapped in a heat wave and a high-pressure system that smothered the convective updrafts that form large storms. The smoke must have had another route to the stratosphere.

In a model not yet published, the TROPOS group attempts to explain how the region could feed smoke so high, invoking a decade-old theory called “self-lifting.” Their model suggests the dark smoke particles absorbed sunlight so effectively that they rapidly heated the air around them, causing the smoke to rise. After only a few days, the process could have lofted smoke 10 kilometers above the ground, where winds could then usher it into the low Arctic stratosphere. And indeed, on passes over the Siberian fires, NASA’s Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) laser satellite captured plumes of what seemed to be smoke rising from 4 to 10 kilometers, Ohneiser says.

The self-lifting idea, never documented in the troposphere, is controversial. In the small world of fire storm research, “Somehow the idea has been advanced that the only way smoke aerosol can get to the stratosphere is due to direct injection,” says Torres, who identified self-lifting as part of the way that smoke from 2017 fires in British Columbia reached the stratosphere. “But the observations are showing it is still happening when we have no pyrocumulonimbus (pyroCB) clouds.”

Others are not convinced. Michael Fromm, a pyroCB researcher at the U.S. Naval Research Laboratory, calls it an “extraordinary claim,” requiring more robust evidence. He thinks that without the extra boost from a firestorm, smoke is unlikely to penetrate the tropopause, a boundary that helps isolate the stratosphere. Instead of smoke, Fromm believes most of the Arctic particles are lingering sulfate aerosols from Raikoke, a volcano southwest of Russia’s Kamchatka Peninsula that in 2019 heaved gas and ash into the stratosphere. He points out that CALIPSO can’t distinguish between smoke and sulfates.

But Ohneiser and his colleagues are standing firm. Their advanced lidar measures light absorption and reflection at two different wavelengths, and observations of the Australian fires using the same instrument showed smoke particles have a distinctive signature. These are “unambiguous optical fingerprints of wildfire smoke,” Ohneiser says. “There is no room for other interpretations.” In the paper, the TROPOS team does see sulfate particles from Raikoke, but they form a thin layer even higher up in the stratosphere.

Once smoke is in the stratosphere, “the potential is certainly there” for it to deplete ozone, says Jessica Smith, an atmospheric chemist at Harvard University. Polar ozone loss depends on chlorine, still lingering in the stratosphere from chlorofluorocarbons and *other pollutants even though they were banned decades ago. The chlorine attacks in winter, when thin iridescent clouds form in the stratosphere. Their droplets provide a surface for chemical reactions that result in free radicals of chlorine, which chew through ozone. Smith says smoke particles might boost ozone loss by seeding the formation of these clouds and endowing them with smaller, more abundant droplets.*

Smoke particles might also be coated in chemicals such as sulfates that could reduce ozone by directly reacting with chlorine. Or the smoke could somehow strengthen a collar of stratospheric winds called the polar vortex, further chilling the poles and boosting depletion. The loss mechanisms are speculative, Smith says, but they "could take a strong year and tip into an extreme year."

The influence of stratospheric smoke isn't necessarily limited to the poles. At midlatitudes, the stratosphere is much higher, and in theory more insulated from pollution. But as wildfires worsen, Wilka says, smoke might even have a shot at reducing ozone above the midlatitudes, home to most of the world's population, much as the 1991 volcanic eruption from Mount Pinatubo did. Throw enough smoke and other particles up there, she says, and "you can absolutely start driving this chemistry."