Chapter 12

Liquid Gold: Changes in Rainfall

From the poles to the equator, our earth spans a range of temperatures from around –104°F to 104°F (–75.6°C to 40°C), and air at 104°F can hold 470 times as much water vapor as air at –104°F. The low temperature and lack of water vapor explains why Earth's poles are frozen deserts. The capacity of warm air to hold more water vapor also dictates that, for every degree of warming we create, our world will experience an average 1 percent increase in rainfall. But it's critical to note that this rainfall increase will not be evenly distributed in time and space. Already, rain is appearing at unusual times in some places and not at all in others.

Over large parts of the world, rainfall is increasing; however, more rain is not always a good thing. One of the most certain predictions of climate science is that as our planet warms, increasing amounts of rain will fall at high latitudes in winter, since the air won't be cold enough to freeze the water vapor into snow. Flooding, of course, is expected to increase wherever rainfall does, but as extreme-weather events become more common, the incidence of flooding will grow even higher. For example, in 2004 in England, heavy spring rains so soaked the land that in many regions haymaking was difficult or impossible.

In other regions, climate change will lower the amount of rainfall. A major decrease in rainfall could transform these areas into new Saharas or at least into regions untenable for human habitation. A lack of rainfall is often referred to as a drought, yet droughts are by their nature transient: they end within a few years. But in the areas affected by climate change, there is no prospect that the rain will return. Instead, what occurs is a rapid shift to a new, drier climate.

We already have evidence that this kind of climate shift occurred in Africa's Sahel region during the 1960s. The area affected was huge—an enormous swath of sub-Saharan Africa extending from the Atlantic Ocean to Sudan. Four decades have now passed since the sudden decline in rainfall, and there is no sign that the life-giving monsoon rains will return. Even before the decline, the Sahel was a region of marginal rainfall where life was tough. In areas with better soils and more rain, farmers eked out a living growing crops, while in the drier areas, semi-nomadic camel herders followed the vegetation from one place to another in pursuit of feed for their herds. The decreased rainfall has made life difficult for both groups: herders struggle to find grass in what is now a true desert, while the farmers rarely get sufficient rain to stir their fields to life. The world's media periodically show images of the result—starving camels and desperate families struggling in a dust-filled wasteland.

For decades many people in more industrialized nations maintained that this disaster was brought on by the people in Africa themselves. The argument was that overgrazing by camels, goats, and cattle, as well as people gathering firewood, had destroyed the region's thin covering of vegetation, exposing the dark soil and changing the albedo of the area. With constant updrafts of hot, dry air and no plants to transpire moisture into the atmosphere, the rain-forming clouds had failed to gather. As this human-made "drought" lengthened, the soil began to blow away. It's an argument that has proved to be wrong in almost every respect.

The true origin of the Sahel disaster was revealed in November 2003, when climatologists at the National Center for Atmospheric Research in Boulder, Colorado, published a painstaking study that used computer models to simulate rainfall regimes in the region between 1930 and 2000. It was a massive exercise, since everything from sea and land temperatures to changes in the region's vegetation needed to be fed into the computer.

In the end, the model simulated past and current climate in the region, and it revealed that the amount of human-caused land degradation there was far too insignificant to have triggered the dramatic climate shift. Instead, climatologists found that one climatic variable was responsible for much of the rainfall decline: rising sea-surface temperatures in the Indian Ocean, which resulted from an accumulation of greenhouse gases. The Indian Ocean is the most rapidly warming ocean on Earth, and the computer study showed that as it warms, the conditions that generate the Sahelian monsoon, or rainy season, weaken. As a result, by the 1960s the Sahelian "drought" had begun.

As is commonly the case in such studies, not all of the observed rainfall decline could be explained, which means that some unidentified mechanism was at work. But now some scientists think that they have found the cause, which they've dubbed "global dimming."

Global dimming is a phenomenon that cuts down the amount of sunlight reaching Earth's surface. It has caused a cooling of the oceans around Europe, which has further weakened the monsoon. Global dimming is in large part due to

particles spewed out into the air by coal-fired power plants, automobiles, and factories. This bolsters the argument that the Sahelian catastrophe was not the result of ecological mismanagement by irresponsible farmers or herders. In fact, one could argue that the greenhouse-gas-producing countries were equally, if not more, responsible. In 2005, scientists published more results of climate modeling for this region. The conclusion? It seems seriously possible that the drought will persist, and perhaps worsen, in the twenty-first century.

The Sahelian climate shift is so big that it could influence the climate of the entire planet. This was first noted by researchers Joseph Prospero and Peter Lamb, who studied the dust that blows from the Sahel.

Dust is important stuff, because its tiny particles can scatter and absorb light, thereby lowering temperature. Dust particles also carry nutrients into the ocean and to distant lands, promoting the growth of plankton and plants, thereby increasing the absorption of CO_2. Around half of the global dust in the air today originates in arid Africa, and the impact of the drying is so great that the planet's atmospheric dust loading has increased by a third. Climatologists are still calculating what will result, but Earth's systems are so interconnected that a phenomenon of this scale is certain to have an impact.

The citizens of the industrialized world tend to feel that their technology will protect them from Sahelian-scale disasters, but nature has been busy proving them wrong. Australia is a dry country, and Australians—even urban ones—are obsessed with rainfall. The southwestern corner of western Australia once enjoyed one of the most reliable of rainfall regimes. Traditionally, the rain fell during the winter, with more than 40 inches (1 meter) falling annually at some locations. The area gained fame as the western wheat belt and was one of the largest and most predictable centers of grain production on the continent. Later, vineyards spread throughout the wetter areas and began producing some of the finest and most expensive wines made in the Southern Hemisphere.

During the first 146 years of European habitation of the southwest of Australia (1829 to 1975), the reliable winter rainfall brought prosperity and opportunity. But then things changed, and ever since, the region has endured a decrease in rainfall averaging 15 percent. Climate models indicate that about half the decline results from global warming, which has pushed the temperate weather zone southward. The Australian climatologist David Karoly thinks that the other half results from destruction of the ozone layer, which has cooled the stratosphere over the Antarctic, thus hastening the circulation of cold air around the pole and drawing the southern rainfall zone even farther southward.

While a 15 percent loss may seem trivial, its impact has been considerable. Farms in the region's drier margins particularly felt the change, because a variation of only a few inches makes the difference between a good crop and failure. In these areas, wheat is the principal crop, and it's grown in an unusual manner. In the 1960s, the goal of the western Australian farmers was to clear a million acres of native vegetation a year. When the bulldozers had done their work, farmers found themselves staring at sterile stretches of sand—some of the most infertile soil to be found anywhere on Earth—because here, as in rain forests, the region's natural wealth was bound up in its native vegetation. This, however, was what the farmers wanted, since wheat growing in the southwest was a gigantic

version of hydroponic gardening: farmers planted their wheat seed, dusted the sterile sand with nutrients, and then waited for the never-failing winter rains to add water.

By 2004, after decades of nature refusing to "just add water," the wheat-growing region began shifting westward, replacing dairy farming in country once considered too wet for wheat. But because of the Indian Ocean, wheat farming can shift westward only so far. As conditions worsen over the coming century, one high-rainfall activity after another must face being pushed into the sea.

The situation is further complicated by the summer rainfall, which has increased, but in very erratic downfalls. Because summer rains cannot be depended upon, farmers do not plant summer crops, so the rain falls on bare fields, allowing the water to soak down to the water table. There it meets salt, which steady westerly winds have been blowing in from the Indian Ocean for millions of years.

Under every square yard of this land lies an average of between 150 and 250 pounds of salt. Before land clearing, this didn't matter, because the diverse native vegetation used every drop of water that fell from the heavens, and the salt stayed in its crystalline form. As the summer rains began to fall on the vacant wheat fields, however, water far saltier than seawater began to creep upward, killing everything it touched. The first sign of trouble was a salty taste in the previously sweet brooks of the region. In many cases the brooks' water quickly became undrinkable and brookside vegetation died; within a decade or two, many brooks had turned into collapsed, salty drains. Today, impoverished and bankrupt farmers are facing the worst case of dry-land salinity in the world. Neither science nor government has been able to provide solutions, and the damage bill is in the billions. Roads, railways, houses, and airfields are now besieged by salt, and unless the original vegetation can be returned and induced to grow in the drier and saltier conditions that now prevail, there appears to be no hope of a turnaround.

Western Australia's capital is Perth, a city of 1.5 million people and the world's most isolated metropolis. For Perth, the most crucial impact from the decline in winter rainfall was less water in the city's reservoirs, because after 1975 the rain tended to fall in light showers that sank into the soil rather than replenishing the reservoirs. Between 1975 and 1996, the city's surface water supply dropped 50 percent lower than in the early part of the twentieth century. Between 1997 and 2004, it dropped even lower—to little more than a third of the flow received three decades earlier.

Severe water restrictions were put in place in 1976, but the situation was soon eased by drawing on a reserve of groundwater known as the Gnangara Mound. For a quarter of a century, the city mined this subterranean water, but the failing rains meant that it was not being recharged. By 2004, the situation of the Gnangara Mound was critical, with the state's Environmental Protection Authority warning that drawing more water from it would threaten some species with extinction. Today, the western swamp tortoise, which is a living fossil, survives only because water is pumped into its habitat.

By early 2005, nearly thirty years after the crisis emerged, the city's water experts rated the chances at one in five that a "catastrophic failure of supply"—meaning no water coming out of the tap—could occur. Were that to happen, the city would have no choice but to squeeze what water it could out of the Gnangara Mound and in doing so destroy much ancient and wondrous biodiversity. Even then, the fix would be only temporary.

In response to the growing water crisis, a desalination plant was constructed in Perth. The plant, which began operation in November 2006, converts seawater from the Indian Ocean into freshwater that is pumped into the city water supply system. Government officials expect that the desalination plant, which is Australia's first large-scale operation of its kind, will supply 17 percent of Perth's drinking water. An added bonus is that the plant buys its power from a power plant that generates electricity with wind turbines, reducing the desalination plant's carbon emissions.

Across the Pacific Ocean, much of the American West is experiencing drought. Research shows that such dry conditions have not been seen in the region for around 700 years, since a time when the American Southwest was even warmer than it is today. This suggests a relationship between drought and warmer conditions, and as with the Sahel, the link seems to lie in rising ocean temperatures.

Between 1998 and 2002 the Pacific Ocean was in an unusual state. Waters in the eastern tropical Pacific were a few degrees cooler than normal, while those in the central western Pacific were about 86°F (30°C), far warmer than average. These conditions shifted the jet stream northward, pushing storms that would usually track at around latitude 35°N, about the location of San Luis Obispo, California, to north of latitude 40°N, which is about 250 miles north of San Francisco. The rising sea-surface temperature caused a shift in winds that ultimately affected areas far away. And, of course, what was driving warmer ocean temperatures was CO_2 in the atmosphere.

Some people, including some climatologists, claim that the drought conditions in the American West are just part of a natural cycle. The only way to be absolutely sure if this is the case is to wait the decades or hundreds of years required for any natural cycle to play itself out. But the fact that the changes are consistent with those expected from global warming and that they have been observed during warm times in the past is worrying. Furthermore, the potential of climate change to spawn drought almost anywhere on the planet is so great that leading climatologists have recently warned that "it would be a mistake to assume any region is safe from megadrought." It is worth pointing out that the near-record rains the United States experienced over the winter of 2005 in parts of the Southwest were not sufficient to make up for the preceding dry years.

Much of the water in the American Southwest comes in the form of winter snow that accumulates in its high mountains. When this snow melts during the spring and summer, it provides stream flow when it is most needed by farmers. In effect, the snowpack has offered an inexpensive form of water storage that has minimized the need for dams, which are used to create reservoirs. The amount of snow that falls has always varied considerably from year to year, and this variability can hide any long-term trend from the casual observer. Over the last fifty years, however, there has been a decline in the average amount of snow received. If this trend continues for another five decades, western snowpacks will be reduced by up to 60 percent in some regions, which could cut summertime stream

flow in half. This will devastate not just water supplies but hydropowered electricity and fish habitats as well.

Changes in the overall volume of snowfall, however, are not nearly as worrying as changes in the way the snowpack forms and melts. Over the past fifty years, the Southwest region has warmed by 1.4°F (0.8°C)—slightly more than the global average, and even in regions that are now receiving more snow, this warming, along with seasonal changes in rainfall and temperature are affecting water supply. These factors have conspired to reduce the snowpack. This is because the higher temperatures are melting the snow before it can consolidate as snowpack. On the whole, the snowpack is melting earlier, which means that the peak of runoff into streams is now occurring three weeks sooner than in 1948. This leaves less water for the height of summer, when it's most needed, and increases water flow in winter and spring, which may lead to more flooding. With temperatures in the region set to rise between 3.6°F and 12.6°F (2°C and 7°C) over this century (unless we significantly reduce CO_2 emissions), it can be anticipated that most streams will eventually flow in winter, when the water is least needed.

Some people suggest that the solution is to build more dams: they would hold the water in reserve for summer. It's possible this will happen. But there are a limited number of sites suitable for dams in the Southwest, and dams mean that farmers will pay for water storage that was once provided by nature. Unfortunately, the changes under way are so vast that even a new program of dam building may be insufficient to counter them. Researchers forecast that snowpack changes could lower farm values by 15 percent, costing billions. The biggest problem, that ultimately affected areas far away. And, of course, what was driving warmer ocean temperatures was CO_2 in the atmosphere.

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These vast metropolises are impossible to relocate, and some may, if the rate of change accelerates, have to be abandoned. If this sounds extreme, it's important to remember that we are only at the beginning of the West's water crisis. Five thousand years ago, when the American Southwest became a little warmer and drier even than it is today, the Native American cultures that had flourished across the region all but vanished. Only when conditions cooled again was the region habitable. For more than a millennium, the Southwest was little more than one big ghost town.

CALL TO ACTION

Eat Locally

Chances are the shelves in the produce section of your local supermarket are overflowing with fresh fruit and vegetables. If you live in Chicago and see strawberries in the market in February, you can bet they were shipped from out of state. Ask where your produce comes from. If it isn't grown locally, transporting it increases CO_2 emissions.

In the summer, whenever possible, buy locally grown produce. Try shopping at farmers' markets. If your town does not host a farmers' market during the summer months, suggest that the town governing body investigate the possibility of starting one. Ask your grocer or local food cooperative if it is possible to buy from suppliers who don't transport produce from hundreds, maybe even thousands, of miles away. Eat fruits and vegetables when they are in season. For example, in the fall and winter, choose butternut squash, apples, and broccoli. In the spring, look for strawberries, lettuce, and peas. You'll find that the fruits and vegetables have a lot more flavor when they are in season.