The Aspen fire burns through a desert canyon in the Santa Catalina Front Range in July 2003. The fire later wreaked havoc on Summerhaven, a community at the top of Mount Lemmon. Ecologists are concerned that a warmer climate will make severe wildfires more common in the Southwest. Photo by Ellis Margolis.

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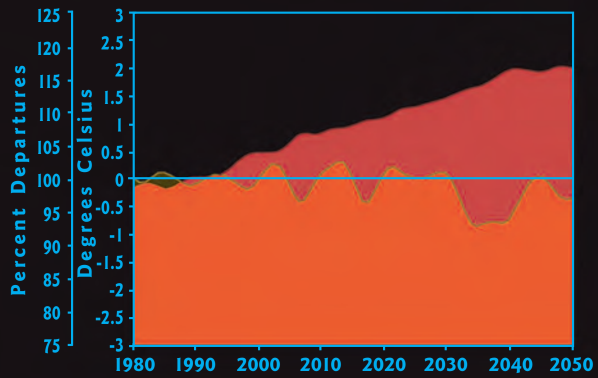
the Heat is on

The Southwest is in the midst of a potentially disastrous drought. At the same time its cities are growing by leaps and bounds. The implications are sobering: a Southwest with shortages of water and an overabundance of blazing wildfires in this century and beyond. Globally, average annual temperature is expected to rise by somewhere between 3 and 10 degrees Fahrenheit by 2100, according to a range of scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). Computer models are less adept at simulating regional climate change, but some researchers with NOAA (the National Oceanic and Atmospheric Administration) predict a rise in average annual temperature in the Southwest of 3 to 4 degrees Fahrenheit by 2050 (see chart on page 22). Their projection averages results from four different computer models, and doesn't assume the warming will stop at mid-century.

Winter Climate Projections for the Southwest US



By the year 2050, average annual temperature (top line) in the southwestern United States is projected to increase by about 2 degrees Celsius, or roughly 3½ degrees Fahrenheit, in an analysis done by researchers at the National Oceanic and Atmospheric Administration (NOAA) based on input from a variety of computer models. Meanwhile, the analysis projects that southwestern precipitation (wavy line) will follow its usual pattern of ups and downs, with perhaps an enhanced potential for longer dry spells. The straight line in the middle represents the average values for both temperature and precipitation based on instrumental records from 1971-2003. The projected departures from average, in percent, are given at the far left of the graphic. The analysis was done by Martin Hoerling, Jon Eischeid and Gary Bates of NOAA for the Western Governor's Association meeting in March 2004. Graphic produced by Jon Eischeid based on an analysis by M. Hoerling, J. Eischeid and G. Bates.

The IPCC expects the biggest temperature changes to come during winter and at night, but residents in the Southwest can also expect to feel more heat throughout the year as temperatures rise. Climate change could well usher in more of what we're experiencing now, with widespread drought in the Southwest. Higher temperatures mean the atmosphere holds more moisture, and this can aggravate drought conditions. In fact, one analysis found higher-than-usual temperatures helped create drought conditions between 1998 and 2002 in at least some of the area in the Four Corners states (Arizona, New Mexico, Colorado, and Utah).

Other studies have documented a nationwide trend toward an earlier spring, with snow melting and flowers blooming sooner than in previous decades. Dan Cayan of the Scripps Climate Research Division in California and several colleagues reported in 2001 that both lilacs and honeysuckle at long-term observation stations in the West were tending to bloom about 5-10 days earlier in recent decades compared to the first few decades of record. (Records go back to 1957 for lilacs and to 1968 for honeysuckle.) Gages measuring peak springtime river flow correlate well with blooming dates in the western United States, strengthening the argument for an earlier spring thaw.

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In addition to bringing on an earlier spring, climate change will likely mean more frequent torrential rains, fewer frost days, a longer growing season, a longer fire season, and lower reservoir levels.

Specific precipitation changes are difficult to pinpoint at regional levels. Although some general circulation models predict an increase in southwestern precipitation, others project a decrease or lack of change. However, even in a best-case scenario that bequeaths the Southwest more rain and snow, any increases in annual precipitation will likely be lost to even greater increases in evaporation.

A warmer atmosphere holds roughly 4 percent more water vapor for each rise of 1 degree Fahrenheit. Already water loss exceeds gains throughout most of the Southwest. For instance, the Arizona Meteorological Network measures cumulative evaporation rates that are about 10 times higher than precipitation rates in Phoenix. An increase in evaporation rates over the landlocked Southwest guarantees an increased rate of drying, most notably during spring and summer. This is partly why climatologists expect "extreme events" like droughts and floods to become more common as the world warms.

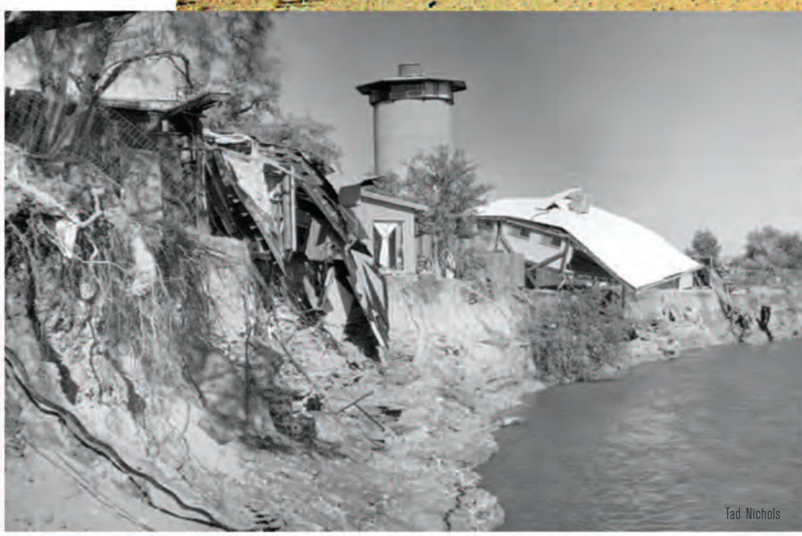
Long-term drought haunts the southwestern desert, in the past, present and future. A "megadrought" spanning more than 20 years in the 16th Century desiccated western North America from Mexico to Canada, according to tree-ring researchers such as Dave Stahle of the University of Arkansas. Scientists use the term "megadrought" to describe a widespread drought that lingers for a decade or more. The Chaco Canyon ghost town of structures built by the ancestors of the Pueblo people stands as a silent testament to how megadrought can affect society. Buildings that collectively housed more than 3,000 people were abandoned by this civilization during a long dry spell in the second half of the 12th Century.

While higher evaporation rates over land can promote drought, higher evaporation rates over the ocean contribute to the expectation of more floods. What goes up must come down, and there's reason to believe that some of the moisture in the atmosphere will come down in more frequent torrential rains. For instance, Thomas Karl and Kevin Trenberth at the National Center for Atmospheric Research analyzed daily precipitation values for a variety of climate regimes and found warmer climates were more likely to receive their moisture in large episodic doses.

The semi-arid lands of the Southwest already tend to have more than their share of extreme events compared to the rest of the country, at least when measured in terms of devastating drought and erosion from flooding. Climate change seems more likely to reinforce rather than temper the southwestern climate see-saw, which some climatologists sum up with the adage that droughts tend to end in floods.

An increase in aridity brings challenges for plants in southwestern deserts and forests alike. In the desert, plants already struggling for survival will face

▲ *During a "megadrought" all the vegetation in an area may die. Aguirre Valley, AZ.*



▲ *Flood damage along Tucson's Rillito River, October 1983. The semi-arid lands of the Southwest tend to have more than their share of extreme events compared to other parts of the country.*

Photo Right and on pg 22. ▶
Fires burning in Sabino and Bear Canyons light up the night sky over Tucson during the Aspen fire of July, 2003. Photos by Ellis Margolis.

more water stress. In the forest, catastrophic wildfires could rage more frequently during longer fire seasons in the future. It's no coincidence that the greatest fire danger occurs during the typically bone-dry southwestern late spring. What is less obvious, but well-documented by Thomas Swetnam of the University of Arizona's Laboratory of Tree-Ring Research and his colleagues, is that the see-saw of wet to dry years actually increases the potential for large wildfires in some southwestern forests.

Other aspects of climate change also present challenges for natural and managed plant systems. The tendency toward earlier springs and longer growing seasons is bound to benefit some plant species, probably at the expense of others. Many species will face a change in their suitable range. The classic southwestern cactus, the saguaro, might relocate further east in Arizona, a 1997 study led by Robert S. Thompson of the U.S. Geological Survey suggested. Meanwhile, ponderosa pine populations could decline in Arizona yet increase in New Mexico. Other tree species that could decline in the Southwest include spruce, pinyon pine, Douglas fir, and Gambel oak. Species standing to gain ground from climate change in this region include other oak species, creosotebush, and Joshua trees.

A changing climate will shift the distribution of both plant and animal species. It's unlikely that things will move smoothly, synchronously or in ways that are easy to predict. (Imagine a musical chairs approach to shifting ecological niches.) The chance of seeing a smooth transition declines if climate change occurs abruptly, something that particularly concerns scientists because they've seen it before in records of prehistoric climate. Records of past climate inferred from marine sediments, for instance, indicate regional climate can make an abrupt switch in a matter of years. Of course, plant and animal communities may take longer than decades to adjust.

The giant saguaro, towering icon of the American Southwest, may relocate further east as the climate continues to warm. Earlier springs and longer growing seasons will tend to benefit some plant species, often at the expense of others.

Southwestern society may also struggle to adjust to the impacts of climate change, particularly impacts involving water supply. The many reservoirs storing Colorado River water help buffer many parts of this region in comparison to other western basins. Still, the inflow to the Colorado system accounts for only a fraction of the water allocated to various users each year. Water compacts were designed during a period of above-average stream flow in the 1920s, and the reservoirs themselves hold more water than can flow through the system even in a flood year. As a result, it takes the system many years to rebound from a regional drought. Having such a high ratio of storage capacity compared to river flow makes the Colorado reservoir system extremely sensitive to changes.

The tendency toward earlier springs and longer growing seasons is bound to benefit some plant species, probably at the expense of others.

The Lake Powell Reservoir system, shown here from a vantage point in Utah looking upstream toward the confluence of the Colorado River with the Dirty Devil River, is one of many reservoirs projected to face future difficulties from a warmer climate. Extended droughts in the Southwest are expected to be more common as a result of climate change. The results of the current drought are seen in this image, taken May 19 of this year. It took the reservoir about 17 years to fill up following the completion of Glen Canyon Dam in 1966, and as recently as March 2002, the deltaic sediments shown above were covered with water instead of the thin layer of vegetation shown in the 2004 image. Photo by Jeff Phillips of U.S. Geological Survey.

For instance, an Environmental Protection Agency report published in 1993 estimated that a consistent 5 percent decrease in streamflow runoff could reduce by a full quarter (25 percent) the capacity of the Central Arizona Project to deliver its full allocation of water to Phoenix and Tucson. In a state-of-the-art modeling study, University of Washington hydrologists used projections for early snowmelt and increased temperatures to estimate that Glen Canyon Dam releases to the states in the lower Colorado River basin would be met less than 75 percent of the time between 2010 and 2098. This would challenge the basin's capacity to store water, produce hydropower, and deliver water to Mexico as promised by the compact.

An increase in monsoonal rains may look impressive, but generally the water rushes downstream without much opportunity for replenishing groundwater supplies.

A monsoonal rain storm is seen in the distance. Monsoonal storms usually occur during the summer months of July and August in the southwestern United States, with timing dependent on location and variable by year. They bring much-needed water to the Sonoran Desert vegetation, but don't necessarily recharge declining groundwater aquifers.

Obviously an increase in drought frequency would not bode well for reservoirs and aquifers. But what of the increase in floods that is also a possible outcome of climate change? In this case, the type of water storage system matters, as does the seasonal timing of precipitation.

Floods do little for aquifers. An increase in monsoonal rains may look impressive, but generally the water rushes downstream without much of an opportunity for replenishing groundwater supplies. If winter precipitation increases, however, aquifers could benefit. Aquifers do best when moisture can sink in over many weeks of fairly cool weather, such as when it trickles down from snowpack. Of course, if the snow evaporates into thin air – a process that consumed tons of southwestern snow this past March – then local soil moisture gains nothing.

Floods can boost reservoir levels, though. Rain-on-snow events, a recipe for floods, may become more frequent given the documented earlier springs and projected increase in torrential rainfall events. Floodwater, however, carries deposits of sediment to reservoirs, reducing their capacity. Also, an increased threat of spring floods may force water managers to make difficult choices about how much water to release downstream when reservoirs are running high. Reservoirs help reduce societal risk by allowing for the storage of potential floodwaters — but only if sufficient holding capacity remains when a flood strikes.

Water managers won't be alone in having to make tough decisions as a result of climate change. Society will need to make some difficult decisions. At the dawn of the 21st Century, Arizonans are lucky to have groundwater and abundant agricultural water allotments. (Agriculture accounts for more than 70 percent of Arizona water use.) These factors provide a buffer to help society get through drought. But as aquifers are depleted, and agricultural water is converted to urban use, the Southwest's ability to weather droughts will be diminished.

The most immediate climate change impacts are likely to be felt by riparian and non-irrigated areas. As society tries to cope with drier conditions via expanded infrastructure and conservation, natural areas could, quite literally, be left high and dry. Stream flow and groundwater tables could continue to drop just as temperatures raise the evaporative stress on plants and animals. There are other possible future climate scenarios, but they all likely include periods of prolonged drought on top of significantly warmer temperatures. The only way to reduce this threat is to curb anthropogenic climate change by reducing the societal input of greenhouse gases, which come mainly from burning fossil fuels in factories, power plants, and vehicles, and also from the burning and destruction of forests.

Even if society itself abruptly changed course and reduced greenhouse gas emissions, it would take time to reverse the warming that has begun. Still, there are actions individuals and society can take to reduce the impacts of climate change and the associated drought.

Even if society itself abruptly changed course and reduced greenhouse gas emissions, it would take time to reverse the warming that has begun. Still, there are actions individuals and society can take to reduce the impacts of climate change and the associated drought. Desert dwellers can plant drought tolerant species, and avoid exotic grasses or moisture-loving plants. Society can assist in groundwater recharge efforts during times of plenty. If timber managers, ecologists and environmentalists can work together, society could clear the forest of a proportion of fuels and understory trees. Defusing catastrophic wildfires is like putting carbon in the bank instead of into the atmosphere as carbon dioxide.

Here's another strategy society could adopt: Make sure each species exists in multiple reserves (or reservoirs and river systems, in the case of aquatic species). That's a logical response to the threat of climate change. As our ancestors would advise, don't put all your eggs in one basket. Finally, society would be wise to restrict development in flood plains and other riparian areas. There's no need to add more risk to life and structure to the climate change impacts. As it is, the challenges posed by climate change will be difficult enough on the Southwest. S

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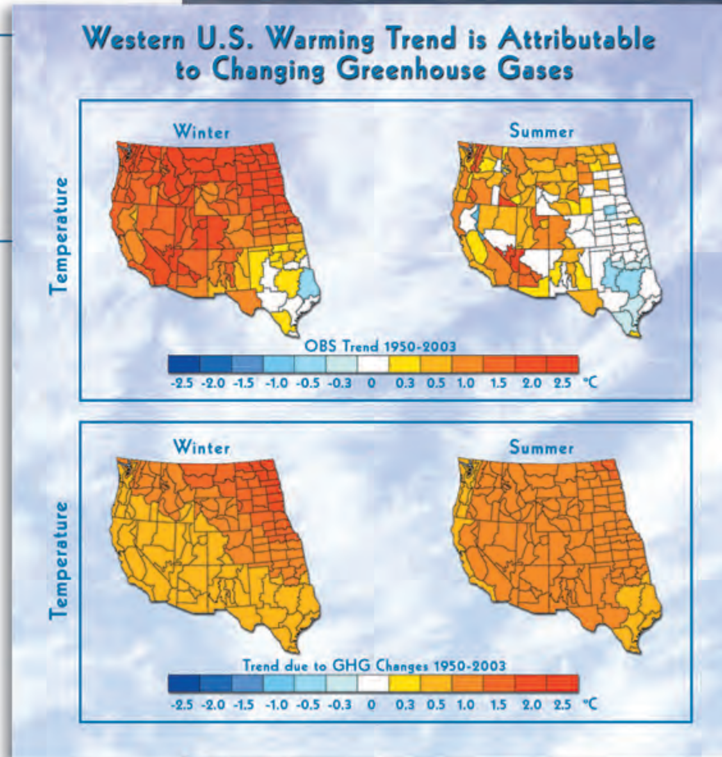
Is the Climate Really Changing?

The earth's atmosphere warmed in the past century, particularly at planetary and northern hemisphere scales. The evidence for this is clear. The thermometer record shows a clear rise of about one degree Fahrenheit since the beginning of the 20th Century, after the effects of urbanization have been taken into account. What's more, the warming has accelerated in the last several decades. The warming trend of the past century also shows up in longer term natural archives of climate such as tree-ring and ice-core records. Even most global warming skeptics generally acknowledge that the temperature is rising, preferring to limit their argument to whether the modern increase relates to natural climate variability or the societal input of greenhouse gases such as carbon dioxide to the atmosphere.

Although natural climatic variation certainly has an influence, most of the surface temperature increase scientists have documented for recent decades fits the warming pattern scientists have long been predicting would result from the increase input of greenhouse gases (see graphic at right). The annual input of greenhouse gases includes more than 15,000 billion pounds (about 7 petagrams) of carbon dioxide released by fossil fuel burning and deforestation worldwide, with about a quarter of these emissions coming from the United States.

Greenhouse gases trap heat at the earth's surface by blocking the escape of infrared heat to space. In its 2001 report, the Intergovernmental Panel on Climate Change attributed "most of the observed warming over the last 50 years" to the societal input of greenhouse gases. Water vapor, methane, ozone, nitrous oxides and chlorofluorocarbons all contribute to the greenhouse effect, but carbon dioxide alone accounts for about 60 percent of the enhanced warming projected for this century. The input of all these gases continues to rise, with the exception of chlorofluorocarbons. So it's logical to expect a continuing rise in temperature in years to come.

And that's exactly what computerized climate models predict for the future. Although some climate change scenarios suggest ocean changes could actually lead to less warming over parts of Europe that are currently graced by the balmy breezes borne by the Gulf Stream, there's scant hope for a cooling influence in the Southwest. So there's plenty of cause for concern about the impacts of climate change in this region. S



The pattern of warming observed in the instrumental record in the West (top panel) is well matched by the pattern that would be expected based upon changes in greenhouse gas levels (bottom panel), based on an analysis done in 2004 by Martin Hoerling, Jon Eischeid and Gary Bates of the National Oceanic and Atmospheric Administration (NOAA). Winter (on left in both panels) refers to December through February, while summer (on right, both panels) refers to June through August. The top panel shows the observed (OBS) net change in surface temperature based on the instrumental record since 1950, with each 1 degree Celsius representing about 1.8 degrees Fahrenheit. The bottom panel shows the warming trend that would be predicted as a result of greenhouse gases (GHG) for that same time frame, based upon a combination of eight climate models that are described in the Intergovernmental Panel on Climate Change Third Assessment Report. The IPCC report is available online at http://www.grida.no/climate/ipcc_tar/wg1/ .
Graphic produced by Jon Eischeid based on an analysis by M. Hoerling, J. Eischeid and G. Bates presented to the Western Governor's Association in March 2004.

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