Global warming in the Southwest: An overview

By Melanie Lenart

Global warming will impact different regions and sectors in different ways, creating many losers and even a few winners around the world. Unfortunately, it looks like the Southwest will be on the losing side.

Losing water. Losing cool summer nights. Losing plant and animal species to changing climate patterns. Losing homes, forests, and Sonoran Desert to wildfires.

These are some of the impacts associated with the gains in temperature the Southwest has faced in recent decades–and is projected to continue experiencing for decades to come. The degree of the temperature rise will depend on whether society manages to curb the greenhouse gas emissions spurring on global warming.

The ways global warming and its associated climate changes are likely to affect the Southwest include higher temperatures, with more heat waves; more droughts and, paradoxically, more floods; less snow cover, with more strain on water resources; and an earlier spring with more large wildfires.

Many of these projected and sometimes already observed climate changes have been described in a series of *Southwest Climate Outlook* articles on global warming that ran from December 2003 through this month. The series has been pulled into a compilation, with additional contributions from other University of Arizona (UA) researchers. The book, *Global Warming in the Southwest* (GWS), is available at http://www.ispe.arizona.edu/climas/pubs.html. This article serves as an introduction to the book as well as an update on materials published since the articles were initially written.

The latest research papers and reports generally support the global warming projections, observations, and impacts described in GWS. If anything, they heighten the cause for concern. The case for the Southwest facing extensive drought has gotten stronger. Similarly, more research concludes that the West faces future water shortages because of changing climate. The connection between hot weather and widespread tree die-off has been established more explicitly, as has the link between large wildfires and rising temperatures.

Temperature rise

The warming trend that took hold during the past century, particularly since the mid-1970s, has gotten even more entrenched since the article series started in 2003. The year 2005 went on to surpass 1998 as the world's hottest year in the instrumental record. By the end of 2006, the 10 hottest years on record all had occurred within the past 12 years, based on World Meteorological Association records from 1861.

It's unlikely that every year ahead will continue on this record-setting trend. A large volcanic eruption could cool things down globally for a year or two, as the Mount Pinatubo event in 1991 briefly slowed the temperature rise in the early 1990s. Annual variability could provide temporary relief. Overall, however, temperatures are expected to continue shifting upward throughout the century, as long as society continues to add heat-trapping greenhouse gases to the atmosphere.

The Intergovernmental Panel on Climate Change (IPCC) projects average annual temperature in the Southwest could rise by about 4½ to 7 or more degrees Fahrenheit during this century (*IPCC 2007 Summary for Policymakers*). More details about the IPCC projections, considered the most reliable because they involve the consensus of hundreds of scientists, will be released in May.

Arizona and New Mexico's average annual temperatures could both rise by 7 degrees Fahrenheit throughout this century, based on another projection that applies information from 18 global climate models to the climate division scale (*Southwest Hydrology*, January/February 2007). That amounts to roughly 1 degree Fahrenheit every 14 years. Summer temperatures could rise even more than winter temperatures by these projections, making parts of the Southwest even more intolerable between monsoon rains (see GWS, page 7).

A 1-degree Fahrenheit rise every 14 years may sound dramatic considering it took a whole century for the world's average annual temperature to rise by 1 degree. But this projected rate of increase is actually slightly slower than the rise Arizona experienced since the mid-1970s, and only slightly higher than the increase New Mexico registered in that time frame (Figure 1). These observed values include warming from the urban heat island effect as cities expand.

The number of extremely hot days is also projected to rise over the decades, leaving parts of the region with heat waves lasting an extra two weeks by the end of the century (*Proceedings of the National Academy of Sciences*, November 1, 2005). Hot summers boost the demand for water and electrical cooling (see GWS, page 69). Even worse, heat waves can create health risks, especially among the frail elderly and young children living in inner cities (*Environmental Health Perspectives*, May 2001).

Drought

Drought has further extended its grip on the Southwest in recent years, despite occasional excursions into times of plentiful precipitation, such as the winter of 2004–2005 and the summer of 2006. The latest projections for Southwest precipitation offer no relief in sight.

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The Dust Bowl years of the 1930s could become the new norm, based on results from 19 global climate models considered by Columbia University researcher Richard Seager and colleagues (*Science Express*, April 5, 2007). The projections suggest that the Southwest's immediate future would look much like the peak years of 2000–2003 in the Southwest's current drought. Things would only get worse in time, by this projection.

The IPCC also projects dry areas will get drier—in the Southwest and throughout the subtropics (*IPCC Summary for Policymakers*, 2007). This is a reversal of earlier projections in the 2001 IPCC summary that the Southwest might receive more rainfall as climate warms.

The mechanism behind the updated projection relates to a global atmospheric pattern known as Hadley Cell circulation (Figure 2). Globally, rising hot air from the tropics eventually descends in the subtropics. The high pressure of the descending air makes it difficult for clouds to form. This helps explain the seemingly endless supply of sunny days found in subtropical regions like the northern Africa, southern Australia and, of course, the U.S. Southwest.

The area under the Hadley Cell's descending air is projected to widen in years to come. As a result, the jet stream that transports rain and snow during winter and spring is expected to move poleward. In theory, the poleward pattern could mean El Niño events might often fail to bring hoped-for rain and snow to the Southwest. In practice, that pattern might look a lot like this past winter, when Denver received record snowfall while Arizona's dry winter pushed much of the state back into drought. This projection adds another element to the debate over the future of El Niño, one that was not addressed in the original article on page 17 of GWS.

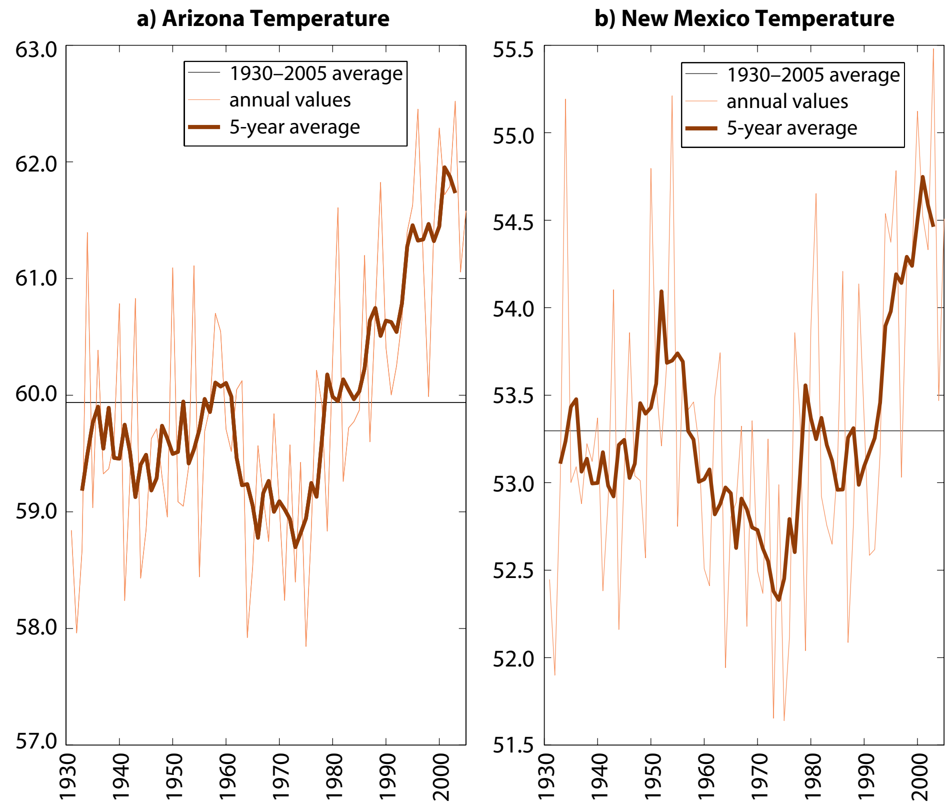

Figure 1. Southwest temperatures have been rising, above. Since 1976, the average annual temperature increased by 2.5 degrees Fahrenheit in Arizona a) and 1.8 degrees Fahrenheit in New Mexico b), or 0.8 degrees and 0.6 degrees Fahrenheit a decade, respectively. Data was averaged from the respective states' climate divisions by Ben Crawford, CLIMAS.

Floods

A more northerly jet stream in summer theoretically might make it easier for the monsoon to reach the Southwest, on the other hand. The jet stream can present a barrier to the monsoon's northward progression from its origin in tropical Mexico (see the two chapters starting on page 20 of GWS).

The monsoon operates at a scale smaller than that modeled by global climate models, making its future difficult to predict. No trend toward increased rainfall during the Southwest's monsoon season shows up in records for 1950–2001, but there are a few reasons to suspect the monsoonal rainfall tallies could increase as land and sea temperatures rise (see GWS, page 20). The projected shift in the jet stream could strengthen that case. A strong monsoon can increase the potential for flooding during this annual summer event. However, even a strong monsoon generally does little to break long-term drought in the Southwest.

The stronger hydrological cycle that comes with global warming can produce seemingly paradoxical effects, including more drought and more floods. Southwestern springs, for instance, have been featuring both heavier rains and drier soils, based on a trend analysis of data from the past half century (*Journal of Hydrometeorology*, February 2004). Higher temperatures increase the atmosphere's ability to hold air moisture, as described in the climate regimes section of GWS. Evidence indicates this projected increase in air moisture and extreme precipitation events already is occurring globally, as noted in the 2007 *IPCC Summary for Policymakers*.

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The IPCC summary also acknowledges a correlation since the 1970s between rising sea surface temperatures and an increase in intense hurricanes in the Atlantic, and possibly in other regions, although it notes the data is less reliable for other parts of the world (see GWS, page 26). Remnants of hurricanes from the East Pacific affect the Southwest, as described on page 29 of GWS. These tropical storms can blanket the region with days of rain, increasing the risk of large-scale floods compared to the smaller scale monsoon thunderstorms.

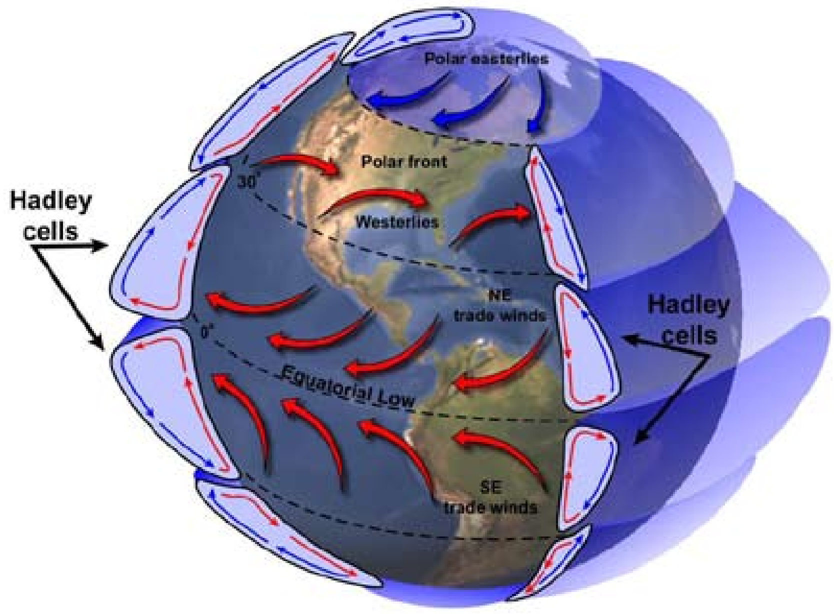

Figure 2. Hadley Cell circulation, above, illustrates how the rising air in the superheated tropics descends in the subtropics, which include the U.S. Southwest. The descending air creates high pressure zones that increase evaporation rates while restricting the development of clouds and rain. This circulation pattern is projected to intensify with global warming. Credit: Barbara Summey, NASA Goddard Visualization Analysis Lab

Impacts on water supply

The growing consensus that the Southwest faces extensive drought in coming years leads to an increasing conviction that the region's water resources will be strained. The GWS chapters on water resources generally reflect that concern. However, two relevant publications worth noting have surfaced since then.

Researchers Martin Hoerling and Jon Eischeid of the National Oceanic and Atmospheric Administration (NOAA) paint a dire picture of future Colorado River flow (*Southwest Hydrology*, January/February 2007). The authors note that the Palmer Drought Severity Index (PDSI) explains nearly two-thirds of the variability in the Colorado's reconstructed natural flow near Lee's Ferry. They used the average of 18 global climate models to model future PDSI values, then applied these estimates to predict future river flow. They conclude the Colorado's annual flow could drop by half, on average, by about mid-century—dire news, especially considering that almost every drop of the river's current flow is already promised to somebody.

On a brighter note, two of the lead researchers whose 2004 paper had suggested the runoff trickling and streaming into the Colorado River might decline by an average of 16 percent in the coming century updated their results (see GWS, page 36). Their 2006 analysis has a somewhat more positive conclusion.

The paper by Niklas Christensen and Dennis Lettenmaier projected modest declines in Colorado runoff for the near future, through about 2040. By the end of the century, they projected the Colorado's flow would drop by 8 to 11 percent, depending on the IPCC emissions scenario used (*Hydrology and Earth Systems Sciences*, 2006).

"Everybody is consistent that there will be a downward trend, it's just a matter of how much," Lettenmaier elaborated in April, referring to theirs and others' latest projections.

The differences from the 2004 paper relate mainly to differences in seasonal precipitation in the Upper Colorado River Basin as projected by the climate models they employed, which they selected from the IPCC archive as appropriate models became available. While the 2004 climate model they used projected a slight shift from winter to summer precipitation, the 2006 models projected a slight shift in the opposite direction, from summer to winter. Such seemingly minor differences have a major impact because the fraction of precipitation that ends up in streams and rivers is much higher in winter than in summer, Lettenmaier noted.

Impacts of warming temperatures on groundwater resources remain even more difficult to model or project than those on surface water supplies, but researchers worry about ongoing trends linked to snow cover decline (see GWS, page 39).

The earlier snowmelt that had been projected already has been observed at many western sites, as described in a 2005 article that documents how this change has been shifting the timing of rivers' peak flows forward in time throughout much of the West (*Journal of Climate*, April 2005). The fraction of precipitation falling as rain rather than

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snow also has increased, although some peaks in northeastern New Mexico have managed to evade this overall trend (*Journal of Climate*, September 2006). A January 2007 review article in the *Intermountain West Climate Summary* goes into more detail about recent research regarding western snow cover and water resources (for link, see box at right).

Landscape impacts

The telltale signs of spring, including melting snow, have been arriving earlier in time around the world (see GWS, page 56). The earlier arrival of spring could disrupt life cycles between paired species, such as plants and their pollinators, or birds and their prey. The premature snowmelt can allow soils to dry out sooner, increasing the risk of drought, insect invasions, and large wildfires.

Temperature has the potential to spur on wildfires for many reasons, some of which are described in the chapter starting on page 62 of GWS. In 2006, researchers reported that the number of large western wildfires tends to move up and down with spring and summer temperatures based on U.S. Forest Service and National Park Services data from 1970–2003 (*ScienceExpress*, July 6, 2006). The ground-breaking paper by Anthony Westerling and colleagues, including the UA's Thomas Swetnam, linked the earlier snowmelt during warmer-than-average springs and summers to an increase in large, western wildfires especially since the mid-1980s.

Researchers had also suspected high temperatures were linked to bark-beetle outbreaks that damaged more than 3.5 million acres of southwestern ponderosa and pinyon pines from 2001 to 2003 (see GWS, page 49). In 2005, UA researcher David Breshears and colleagues documented how high temperatures served as an underlying cause behind an extensive piñon die-off event in the Southwest (*Proceedings of the National Academy of Sciences*, October 18, 2005).

Striving for sustainability

And now for the good news. As the evidence grows that the Southwest and the rest of the world face dire disruptions from global warming, politicians have joined scientists and activists to push for policy changes to reduce the greenhouse gas emissions behind the temperature rise and other chaotic climate changes.

Governments from local to state levels, including Arizona and New Mexico, are setting goals for reducing greenhouse gases emissions. The last section of the compilation describes some of these efforts, (as well as some things individuals can do to reduce their own contributions to global warming). Employing wind energy, solar power, energy and water conservation, water harvesting, and forest mitigation all can increase the odds that society will be able to weather global warming.

The move to renewable forms of energy can even help the economy, as the chapter in GWS on solar and wind energy illustrates. Regional efforts to tap into alternative energy markets might help restore some of the U.S. presence in the solar and wind markets. Currently, these forms of renewable energy are so popular around the world that production is not keeping up with demand.

The world market is gearing up for alternative energy production and other "green" business ventures. Also, companies have been reaping savings by pursuing conservation efforts. Recently Wal-Mart has found that putting sky lights in some of its stores not only saved money on energy bills, it also improved profits. Judging from reports in publications from *The New York Times* to *The Economist*, businesses are increasingly finding that going greener speaks to the bottom line as well as the greater good.

Between the efforts of governments, individuals, and businesses, the U.S. public is starting to embrace the wisdom of reducing its collective greenhouse gas emissions. Increasingly, people are recognizing that stabilizing the global climate amounts to stabilizing the global economy. Americans release among the highest levels of greenhouse gases in the world, on both the per-capita and country level. So this country's efforts really can make a difference in how much the world warms in years to come.

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Related Links

Global Warming in the Southwest
http://www.ispe.arizona.edu/climas/pubs.html

Intermountain West Climate Summary
http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/January_2007.pdf

Southwest Hydrology
http://www.swhydro.arizona.edu/archive/V6_N1/

Hydrological Earth Systems Science paper by Christensen and Lettenmaier
http://www.copernicus.org/EGU/hess/hessd/3/3727/hessd-3-3727.pdf

"More Large Forest Fires Linked to Climate Change"
http://uanews.org/spots/sci-12868.html

"Underlying Cause of Massive Pinyon Pine Die-Off Revealed"
http://uanews.org/spots/sci-11731.html