A Meteorological Perspective on Drought

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How did we get into our current situation?

In much of Colorado, the 1980s and 90s were climatologically benign. Dry years were rare, and some of the wettest years on record were observed in the Front Range in particular. If you moved into our state during this period, you might have gotten a misleading impression about typical conditions around here, – just as someone investing in the stock market might have expected to see returns continue at a 1990s clip.

Beginning in September 1999, Colorado experienced severe drought conditions, part of a global drought regime that covered a large fraction of the U.S., the Mediterranean, and Southwest Asia for the following three years. It resulted in two of the worst wildfire seasons ever recorded in the Western U.S., 2000 and 2002. With reservoirs being drawn down from preceding wet years, it was easy to ignore the initial signs of drought. However, the third and worst drought year (2001-02), resulted in record-low streamflows, and record-high wildfire coverage. Statewide, it was one of the the driest years ever observed for much of Colorado, including the foothills southwest of Denver that suffered through the Hayman fire in June 2002. Nevertheless, the drought periods of the 1950s and '30s were longer lasting, and had probably more severe impacts.

Near-normal moisture returned during the subsequent water year (2002-03) over northern Colorado, while much of southern Colorado suffered through a fourth drought year. With local exceptions, statewide snowpack tallies remained below normal both in early 2003 and 2004. These deficiencies continued to strain reservoir management, despite abundant summer moisture in 2004 in much of eastern Colorado. Since September 2004, southwestern Colorado has benefited

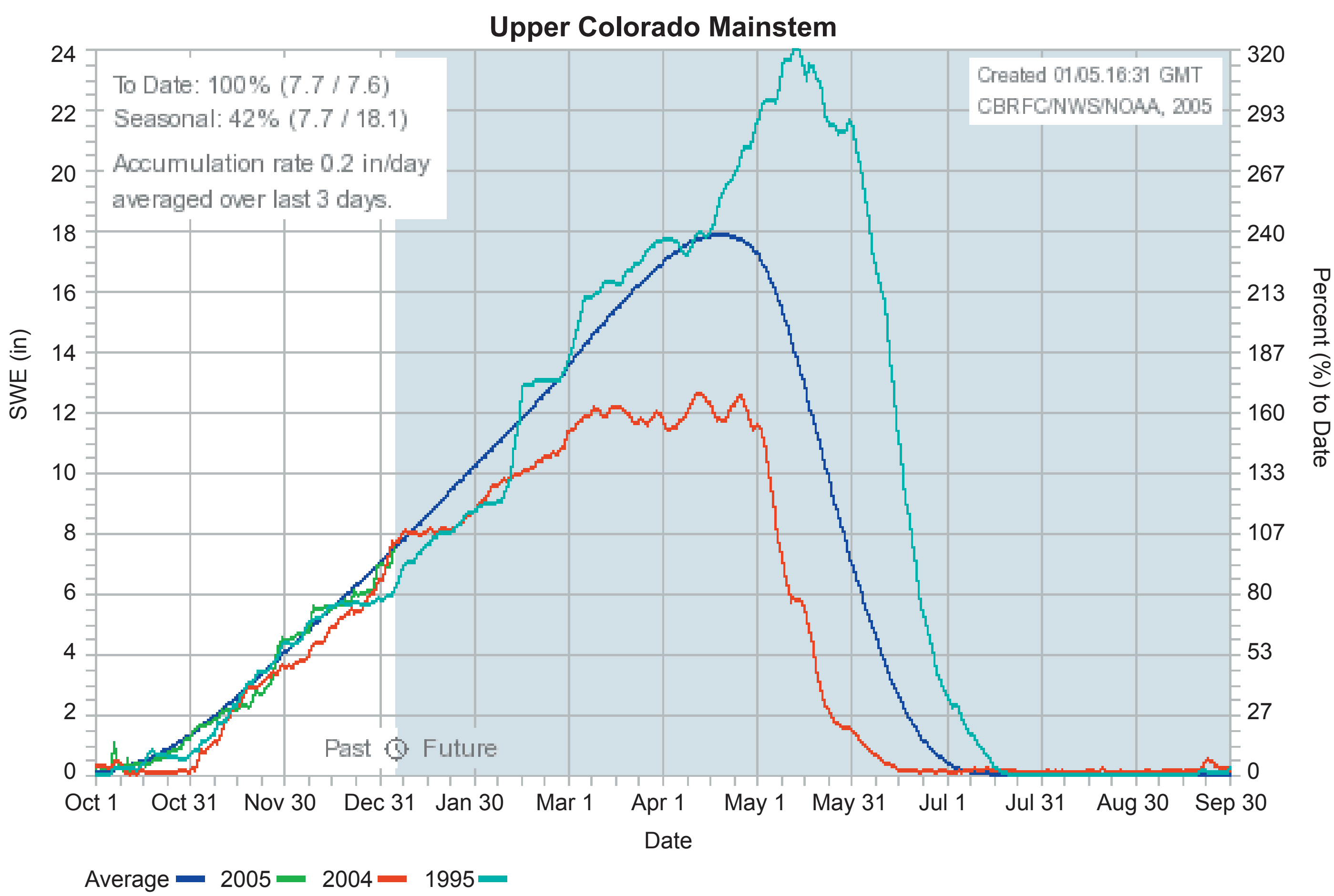

Figure 1: Snowpack levels converted into snow water equivalent (SWE) for selected SNOTEL stations in the Upper Colorado watershed in Colorado. Note the long persistence of the snowpack into the spring in 1995 compared to the average, as well as to 2004 when a low snowpack melted out fairly early.

from an exceptionally active early season that has created above-normal snowpack conditions, while the northern mountains continue to experience just below normal moisture until recent weeks.

What do we know about droughts?

Do droughts come in 'cycles'? Despite a tendency for Western U.S. droughts to occur about once every two decades – most notably during the 1930s and 50s -, careful analysis reveals more complex behavior, especially over northern Colorado. The duration of droughts can vary from a brief, so-called 'flash' drought like last July's heatwave to a seven-year drought like the 'dustbowl' period of the 1930s, and even longer droughts in the tree-ring record. Therefore, the length of a recent dry spell should not be used to predict the duration of a drought.

How do droughts get 'broken'? In much of Colorado, especially along the Front Range, and towards the San Juans, long-lasting 'La Niña' events have been associated with drought, while a switch to 'El Niño' is one of the more reliable indicators for a possible recovery. Here, the term El Niño refers to warmer-than-normal sea surface temperatures in the eastern tropical Pacific basin, while La Niña refers to the opposite phase. For example, the 1930s drought was replaced by wet conditions during the long-lasting El Niño of the early 1940s, and the 1950s drought came to an abrupt end with the emergence of the 1957-8 El Niño event. Last year's March 'Storm of the Century' over the Front Range was consistent with impacts expected from the El Niño of 2002-3.

Aside from La Niña, there are many other influences that contribute to widespread and prolonged drought conditions. Several important ones involve land surface feedback mechanisms: The longer a region stays dry, the more the soil dries out, and the sun's energy goes into heating up the atmosphere instead of evaporating moisture. During the warmer half of the year, this results in heat waves that tend to dry the soil out even further. Thus, moisture has to be imported rather than recycled to make it rain, and with growing spatial extent, this mechanism may perpetuate a drought over the interior of continents. The 1930s dustbowl years are a prime example for this. In September 2002, it took the land-falling hurricane 'Hernan' from the Pacific Ocean to reintroduce moisture to Colorado after a failed monsoon season.

During extreme wildfire seasons, drought gets reinforced by large-scale forest fires. They release huge amounts of soot into the atmosphere that may 'overseed' clouds, thus resulting in drizzle rather than regular raindrops. Suspended haze high above the ground tends to anchor temperature inversions, and reduces the sunshine reaching the ground, thus hindering thunderstorm development. Much of the Western U.S. was affected by this during the 2000 and 2002 fire seasons.

As a third feedback mechanism, late season snowpack may have an influence on the monsoon: if snow lingers into the summer, as in 1995, it appears to inhibit the development of a surface heat low, one of the key ingredients of the monsoon system. On the other hand, if an anemic snowpack melts out early, it opens the door for an early onset of the monsoon season - to the extent that it can overcome the soil moisture and forest fire impacts described above. Therefore, this mechanism may provide for an escape hatch out of prolonged drought conditions.

Other factors play a role, and are the subject of ongoing research. Oceans have been called the flywheels of the climate system by maintaining long-lasting sea surface temperature anomalies that influence the atmosphere above them. Aside from the Pacific, with its El Niño and La Niña events, anomalously warm Indian and Atlantic Oceans may be detrimental by diverting the storm track away from us. Solar influences like the 11-and 22-year sunspot cycles have been correlated with precipitation anomalies around the world, including Colorado, but as yet there is no ready physical explanation for these apparent relationships. Again, much research remains to be done.

What will the Future bring?

While there is broad scientific consensus that global warming is likely to occur over the next century, it is much less clear how this will affect the climate of any given region, including Colorado. Our climate is shaped by occasional storms that cross our region, followed by dry spells that can last for weeks. **Are the dry spells going to be more intense due to higher temperatures, while the stormy periods drop more moisture on us, as has been suggested by scientific reports?** While confidence with regard to precipitation prospects is low, most climate models suggest that Colorado's climate will become warmer. Global warming could lead to earlier snowmelt in the mountains, and longer growing (and irrigation) seasons in the plains, translating into higher water demand. Even if we receive as much moisture as we have in the past, this may pose a challenge for Colorado's future.

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Dr. Wolter's regional climate forecasts come out every month on the web at: http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/.