

The Introduction of an In-depth Drought Monitoring Process in the Upper Colorado River Basin

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1. Introduction

Drought in the Upper Colorado River Basin (UCRB) can affect millions of people and many acres of farmland. The majority of water supplies in the western United States start as mountain snowfall. The snowfall in the UCRB eventually provides water for seven states. Therefore, it is essential to monitor the UCRB for climate and precipitation variability.

The U.S. Drought Monitor (USDM) has been the primary tool for tracking drought changes in the UCRB (and the rest of the country) since 2000. Before 2010, only a few experts would occasionally contribute to the weekly monitor for areas in the UCRB—however this was rarely coordinated with other experts in the region. Local users have said they use the USDM to assess large scale conditions, but don't find it useful on a local scale. Based on user needs though, it seems that the USDM could be the most comprehensive tool at their disposal, but improvements are needed.

In February 2010, an increased monitoring effort began as part of the National Integrated Drought Information System's (NIDIS) Upper Colorado River Basin Pilot project. This increased monitoring included the implementation of weekly summaries and webinars—both of which monitor all water variables in the UCRB and culminate in a “consensus” of recommended changes to the weekly USDM depiction based on input from local experts. The goals of this increased monitoring effort (and the NIDIS-UCRB pilot) are 1) to determine critical thresholds for when a drought begins and ends, 2) to evaluate drought indices, and 3) to develop a drought “early warning” system. With the accomplishment of these goals, it is the hope that local users' needs will be better met via the USDM weekly depictions.

This study focuses on three key drought indices (the standardized precipitation index, the Palmer drought severity index, and the surface water supply index) and compares them over time to the U.S. Drought Monitor drought categories. Ideally, the comparison will show a close relationship between the drought indices and the USDM, and hopefully the analysis will also show an improvement in that relationship after the introduction of the increased monitoring in February 2010.

2. Data and drought indicators

Because of the relatively short timespan of post-increased-monitoring, this study will focus on drought and precipitation data in Colorado (due to the lack of drought conditions in the UCRB and the prevalence of severe drought in southeast and southern Colorado since February 2010). For this study, 110 National Weather Service Cooperative Network Stations (COOP stations) are used to calculate the standardized precipitation index (SPI, McKee *et al.* [1993]) as one drought indicator. These stations contain daily precipitation data from 1981 – 2011. Missing daily data could be replaced with zeros if the three closest neighboring stations reported no precipitation for the day. The data in this study are only included when less than 5% of the data for a given month are missing. Weekly Palmer Drought Severity Index (PDSI) statistics were downloaded from the Climate Prediction Center (2011) for the Rio Grande climate division in southern Colorado as another drought indicator. Finally monthly surface water supply index (SWSI) values were obtained from the Natural Resources Conservation Service (2011) for the Rio Grande watershed as a third drought indicator.

Weekly USDM archive data were downloaded for Colorado statistics (2011). The USDM archive data simply provides the percent of the state (or county) that was currently in each drought category for every week since 1/1/2000 through 7/31/2011. Drought categories are drawn based partly on objective, quantitative analysis of many different drought indicators and water variables. Each category's threshold is determined by a specific percentile (e.g. a specific location could be in the D0 category [abnormally dry] if one of the drought indicators is at the 30th percentile—meaning a 3 out of 10 year occurrence). D4 droughts are the most rare and occur the least often in history (with indicators at the 0 – 2nd percentile, or a 1 in 50 year event). Other important factors for the USDM drought category determinations are more subjective and are based on user input and local impacts. This can make it more difficult to quantitatively assess how increased monitoring has improved the USDM depictions.

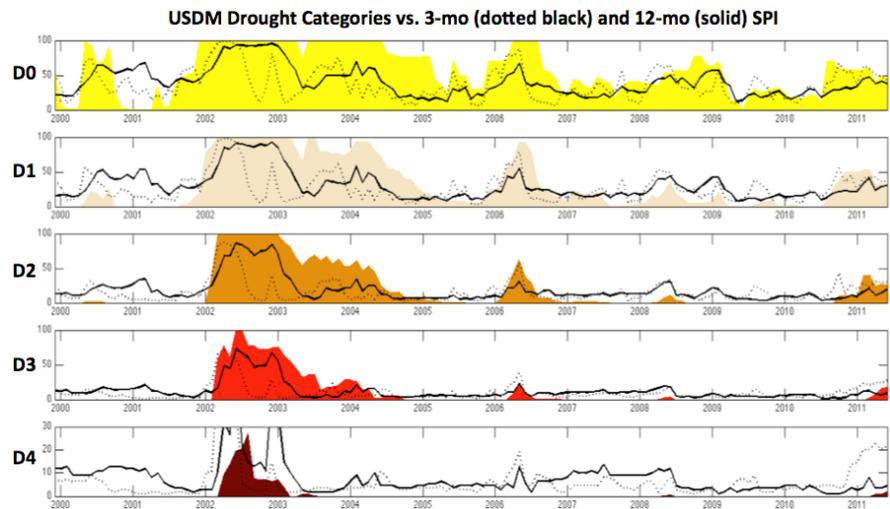


Fig. 1 Percent of Colorado in each drought category (colors) compared to the percent of COOP stations with an SPI percentile matching the associated drought category threshold.

The SPI (first introduced in 1993 by McKee *et al.*) transforms precipitation data from its typical gamma distribution to a Gaussian distribution. This allows for easier analysis and comparison to the USDM as it puts precipitation anomalies into percentiles. For this study, the 3-month SPI is calculated for short-term anomalies and the 12-month SPI is calculated for long-term anomalies at all 110 COOP stations in Colorado at a monthly timescale.

The PDSI was developed by Wayne Palmer in the 1960s and uses temperature and precipitation data in a formula to determine dryness. It is best used to depict long-term moisture deficiency or excess for all the major climate divisions in the U.S. An index value near 0 indicates near normal conditions, and the more negative the index, the more severe the drought in that location is.

The SWSI, developed in the 1980s, is an algorithm that combines water supply (from reservoirs) and streamflow forecasts into one index for a given watershed. Negative values of the SWSI indicate that the watershed is short in water supplies.

3. Comparing the U.S. drought monitor with drought indicators

In Figure 1, it can be seen that there is good correlation between the USDM drought categories and the SPI timeseries. Overall, the drought categories are better correlated with the long-term SPI than the short-term SPI. Also of note, there is almost always D0 somewhere in CO throughout time, and in general, there is a higher percentage of D0 in CO than the percentage of stations meeting the D0 threshold in terms of SPI. This is also true many times for D1 and D2. This is not the case for the more severe D-categories—there is almost always a higher percentage of stations with SPIs meeting the D4 threshold than there is D4 in the state.

After February 2010, increased monitoring began. When comparing before and after, there is little change in the D0 – D2 panels. However, the D3 – D4 panels tend to show spikes in the SPI timeseries without corresponding spikes in the D-category timeseries before the increased monitoring period. After the increased monitoring, spikes in the SPIs are better correlated with increases in the D3 – D4 percentages.

In the USDM timeseries in Figure 2 (top), there are two instances that D4 has been introduced in the Rio Grande basin—first during the drought of 2002 and also during the summer of 2011. The weekly PDSI

timeseries (Fig. 2, bottom) shows both of these times were indeed at D4 intensity. The weekly PDSI also shows that three other periods would have qualified for D4 intensity—all of these times were before increased monitoring began. For example, in 2006 the PDSI indicated that D4 could be introduced into the basin, but the USDM timeseries only shows a D2 intensity.

There is not as strong of a relationship when comparing the end-of-month USDM percentages in the Rio Grande basin with the monthly SWSI index for the basin (not shown). In general, when the USDM timeseries indicates D2 or greater drought through much of the basin, the SWSI tends to be negative. However, there are periods when the SWSI is negative but this is not captured in the USDM timeseries or the other drought indicators. Therefore, the SWSI does not appear to be as good of an indicator for the Rio Grande basin.

4. Conclusions

The SPI has been and continues to be a good indicator for drought conditions throughout Colorado. At this time, it appears to be the best drought index to use for the USDM, as percentiles for the SPIs match up well with thresholds for the drought categories. It is also a better matrix for the USDM as it is higher resolution than the PDSI—while the PDSI gives an index for an entire basin (which can be useful for larger scale assessment) the SPIs are station specific and can therefore give a more accurate picture of conditions within a basin.

Both the SPI and the PDSI show that the D4 category (the 0 – 2nd percentile) occurs more often in the data than in the USDM depictions. The SPI shows that the D0 category occurs less often in the data than in the USDM depictions. Both of these results could be based on a variety of different factors. First, both indices rely on precipitation and don't take into account soil moisture, streamflow, vegetation or evapotranspiration. These other water variables also weigh heavily on the USDM depiction. Also, impacts and local user input are two qualitative variables that can have an effect on the USDM.

More time will be needed to better assess how the increased monitoring has modified the depiction of drought in the USDM. A longer timeseries (and more data points) could reveal more useful information. Also, an objective way to compare impacts over time with the USDM would also be beneficial. Use of crop data or river calls could probably shed more light on the relationship between impacts and the USDM, and whether or not that relationship has changed since the introduction of increased monitoring. Even so, it is evident with just this study that increased monitoring has helped improve local depictions in the USDM.

References

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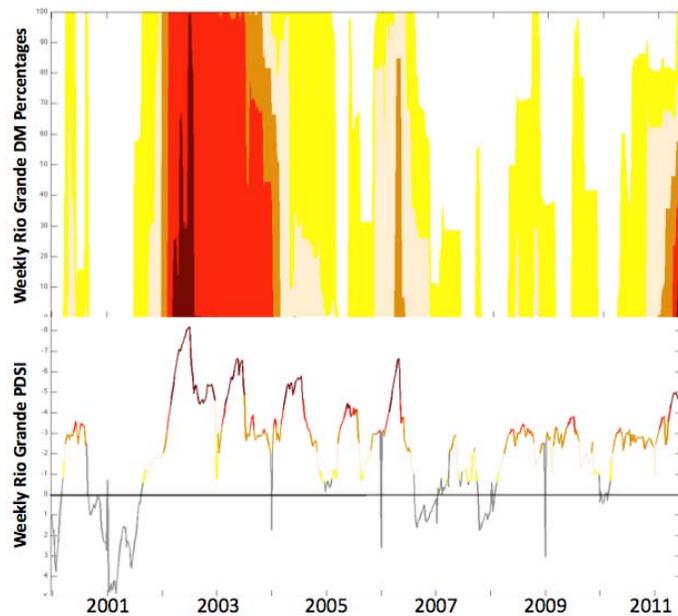


Fig. 2 Percent of Rio Grande basin in each drought category (top) compared to the PDSI value for the basin (bottom) color-coded for its associated drought category threshold.