Intermountain West Climate Summary

by The Western Water Assessment

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July 2007 Climate Summary

Hydrological Conditions – Drought is expected to persist over Utah, western Colorado, and most of Wyoming, but the southwest corner of Colorado may see some decrease in drought status from summer monsoons.

Temperature – Temperatures were 0 – 4˚F above average around most of the region in June. The warmest area was around Salt Lake City.

Precipitation/Snowpack – Precipitation was below average in most of the region in June, but northwest Utah and southwest Colorado had above average precipitation.

ENSO – ENSO-neutral conditions prevail in the Pacific, and there is about a 50% chance of La Niña conditions developing by the fall (Sep-Nov 2007).

Climate Forecasts – La Niña or El Niño is not a factor in climate forecasts for the region during the August - October 2007 season; La Niña may influence the fall.

Nolan Doesken receives Earth Day 2007 Environmental Hero Award

Colorado Climate Center's Nolan Doesken received the Earth Day 2007 Environmental Hero Award in April for his work in organizing a network of citizen volunteers to measure and report precipitation from their homes. Starting with a few volunteers in 1998, the Community Collaborative Rain, Hail and Snow (CoCoRaHS) network involves thousands of volunteers in 17 states, and enhances the forecasting and warning capabilities of the NOAA National Weather Service. See the Focus Page in the March 2006 IWCS for more information about CoCoRaHS. In the photo, Nolan is being given the award by retired Navy Vice Admiral Conrad Lautenbacher, Ph.D., undersecretary of commerce for oceans and atmosphere and NOAA administrator (photo courtesy of NOAA.) A description of the other 2007 Environmental Hero award recipients can be found at: http://www.noaanews.noaa.gov/stories2007/s2842.htm

Upcoming Conference: The U.S. Drought Monitor Forum will be held in Portland, OR, October 10-11, 2007. Authors and users of the U.S. Drought Monitor will convene to discuss user needs and modifications to the tool. Registration is free, but attendance is limited. For information and registration: http://snr.unl.edu/ndmcsurvey/usdmforum.html.

In This Issue

On the Web: http://wwa.colorado.edu

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Brad Udall – WWA Director
Andrea Ray, Jessica Lowrey – Editors/Writers
Eileen McKim, Christina Alvord – Writers
Barb DeLuisi - Graphic Designer
Klaus Wolter, Gary Bates – Asst. Editors

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Drought Indices

By Dr. Michael J. Hayes, Climate Impacts Specialist, National Drought Mitigation Center, with Christina Alvord and Jessica Lowrey, WWA

This article originally appeared in a longer form on the National Drought Mitigation Center (NDMC) webpage, http://drought.unl.edu/index.htm. The NDMC works to minimize impacts and vulnerabilities of drought by providing risk management strategies and recommendations.

Introduction

Drought indices assimilate data on rainfall, snowpack, streamflow, and other water supply indicators into a comprehensible big picture. A drought index value is typically a single number, far more useful for decision-making than raw data. Although none of the major indices is inherently superior, some indices are better suited for certain regions or uses than others. For example, the Palmer Drought Severity Index (PDSI) is useful for large areas of uniform topography and is widely used by the U.S. Department of Agriculture to determine when to grant emergency drought assistance. On the other hand, decision makers in western states, with mountainous terrain and complex regional microclimates, often supplement PDSI values with other indices such as the Surface Water Supply Index (SWSI), which takes snowpack and other unique conditions into account, and the Standardized Precipitation Index, (SPI) which identifies emerging droughts sooner than the PDSI and is computed on various timescales. The National Drought Mitigation Center (NMDC) now uses the SPI as its primary tool to monitor moisture supply conditions. This article provides an introduction to major drought indices used in the United States, however other indices do exist or are in development.

Percent of Normal Precipitation

Overview: The percent of normal is a simple calculation well suited to the needs of TV weathercasters and general audiences.
Pros: Quite effective for comparing a single region or season.
Cons: Easily misunderstood, because "normal" is a mathematical construct that does not necessarily correspond with expected weather patterns.

The percent of normal precipitation is one of the simplest measurements of rainfall for a location. Analyses using percent of normal are very effective when used for a single region or a single season. It is calculated by dividing actual precipitation by normal precipitation—typically considered to be a 30-year mean—and multiplying by 100%. This can be calculated for a variety of time scales, including monthly, seasonal, annual, or water year. Normal precipitation for a specific location is considered to be 100%.

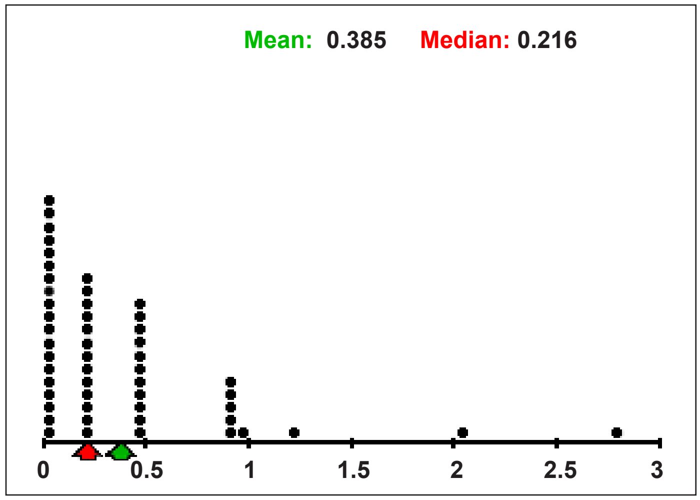

Figure 1a. Example of hypothetical data showing how the mean can be higher than the median. If the majority of data points are low, a few high data points skew the distribution, resulting in a higher mean value in comparison to the median.

A disadvantage of using the percent of normal precipitation is that the mean, or average precipitation is often not the same as the median precipitation. Median precipitation is the middle value of all the individual precipitation measurements; it is always the 50th percentile. Precipitation on monthly or seasonal scales is not normally distributed, so use of the percent of normal implies a normal distribution where the mean and median are considered to be the same. In the west, although precipitation amounts are often low, there also are some very wet days. The resulting distribution gives a mean (normal) that is higher than the median because the infrequent wet events skew the distribution (Figure 1a). The actual amount of precipitation tends to be closer to the median than the mean. Therefore, if one is expecting average (normal) precipitation on any given day, he will usually get a value that is below average.

Because the value of normal depends on time and location, one cannot compare the frequency of the departures from normal between time periods or locations. This makes it difficult to link a particular value of a departure with a specific impact occurring as a result. Therefore, mitigating the risks of drought based on the departures from normal is not a useful decision-making tool when used alone (Willeke et al., 1994).

The Palmer Drought Severity Index (PDSI) and other Palmer Indices

Overview: The PDSI is a soil moisture algorithm calibrated for relatively homogeneous regions.
Who uses it: Many U.S. government agencies and states rely on the Palmer to trigger drought relief programs.
Pros: It was the first comprehensive drought index developed in the U.S.
Cons: Palmer values may not identify droughts as early as the other indices; it is less well suited for mountainous land or areas of frequent climatic extremes; it is highly complex.

The Palmer Drought Severity Index (PDSI) is a meteorological drought index, which provides a standardized measurement of moisture conditions to compare between locations and over time (Palmer, 1965). The PDSI estimates duration and intensity of drought events by measuring departure of the moisture supply based on a supply-and-demand concept of the water balance equation. The PDSI incorporates precipitation and temperature data, and local Available Water Content of the soil from an unspecified period that best corresponds to past 9-12 months. Past conditions are incorporated because long-term drought is cumulative, so the intensity of drought at a particular time is dependent on the current conditions plus the cumulative patterns of previous months. From the inputs, all the basic terms of the water balance equation are determined, including evapotranspiration, soil recharge, runoff, and moisture loss from the surface layer. The equations are described in Palmer's original study (1965) and in the more recent analysis by Alley (1984). By accounting for moisture conditions in the past, the PDSI estimates when a drought (or wet spell) begins, ends, and the duration of the event (Palmer, 1965; Alley, 1984). The Palmer Hydrological Drought Index (PHDI) is a derivative of the PDSI. It is based on daily inflow (precipitation) and soil moisture storage (Karl and Knight, 1985).

The PDSI generally ranges from -4.0 to +4.0 and it is designed so that, an extreme drought (-4.0) in one climate division has the same meaning in terms of the moisture deficit as an extreme drought in any other climate division (Alley, 1984). The PDSI is typically calculated on a monthly basis, and a long-term archive of monthly PDSI values for every climate division in the United States is available from the National Climatic Data Center from 1895 through the present. In addition, weekly PDSI values are calculated for the climate divisions during every growing season and are available in the Weekly Weather and Crop Bulletin (see On the Web box).

Palmer Classifications	
4.0 or more	Extremely Wet
3.0 to 3.99	Very Wet
2.0 to 2.99	Moderately Wet
1.0 to 1.99	Slightly Wet
0.5 to 0.99	Incipient Wet Spell
0.49 to - .49	Near Normal
-0.5 to -0.99	Incipient Dry Spell
-1.0 to -1.99	Mild Drought
-2.0 to -2.99	Moderate Drought
-3.0 to -3.99	Severe Drought
-4.0 or less	Extreme Drought

Figure 1b. The PDSI classification ranges from -4.0 or less (extreme drought) to 4.0 or more (extremely wet).

Alley (1984) identified three primary benefits of the PDSI. The PDSI provides decision makers with a measurement of the abnormality of recent weather events for a region and places current conditions in a historical perspective. It also provides spatial and temporal representations of historical droughts. The PDSI has been widely used for a variety of applications across the U.S. It is most effective at measuring impacts sensitive to soil moisture conditions, such as agriculture (Willeke et al., 1994). It has also been useful as a drought-monitoring tool and been used to trigger actions associated with drought contingency plans (Willeke et al., 1994). Finally, water managers find it useful to supplement PDSI values with PHDI values as a way to analyze additional hydrological information important to water management decisions in the West.

The limitations of the PDSI involve its inability to fully characterize hydrologic, climatic, and geographical parameters and variance in such parameters within river basins, in the US or in other countries (Alley, 1984; Karl and Knight, 1985). Drawbacks include:

- The values quantifying the intensity of drought and signaling the beginning and end of a drought or wet spell were arbitrarily selected based on Palmer's study of central Iowa and western Kansas and have little scientific meaning.
- The PDSI is sensitive to the Available Water Content of a soil type. The two soil layers within the water balance computations are simplified and may not be accurately representative of a location. Thus, applying the index for a climate division may be too general.
- Snowfall, snow cover, and frozen ground are not included

in the index. All precipitation is treated as rain, so that the timing of PDSI values may be inaccurate in the winter and spring months in regions where snow occurs.

- The natural lag between when precipitation falls and the resulting runoff is not considered. In addition, no runoff is allowed to take place in the model until the water capacity of the surface and subsurface soil layers is full, leading to an underestimation of runoff.
- The PDSI does not account for streamflow, lake and reservoir levels, and other longer-term hydrologic impacts of drought (Karl and Knight, 1985).
- Human impacts on the water balance, such as irrigation, are not considered.
- The PDSI is applied within the United States but has little acceptance elsewhere (Kogan, 1995).
- The "extreme" and "severe" classifications of drought occur with a greater frequency in some parts of the country than in others (Willeke et al., 1994). "Extreme" droughts in the Great Plains occur with a frequency greater than 10%. This limits the accuracy of comparing the intensity of droughts between two regions and makes planning response actions more difficult.

Crop Moisture Index (CMI)

Overview: A Palmer derivative, the CMI reflects moisture supply in the short term across major crop-producing regions.
Pros: Identifies potential agricultural droughts.
Cons: Not useful in long-term drought monitoring.

The Crop Moisture Index (CMI) uses a meteorological approach developed by Palmer (1968) to monitor week-to-week crop conditions. In comparison to the PDSI, which monitors long-term meteorological wet and dry spells, the CMI was designed to evaluate short-term moisture conditions across major crop-producing regions. It is based on weekly mean temperature and total precipitation within a climate division, and incorporates the CMI value from the previous week. The CMI responds rapidly to changing conditions, and it is weighted by location and time, so weekly maps of the U.S. can be used to compare moisture conditions at different locations. The CMI is part of the USDA/JAWF Weekly Weather and Crop Bulletin (see On the Web box).

Because the CMI is designed to monitor short-term moisture conditions for a developing crop, it is not a good long-term drought-monitoring tool Its rapid response to changing short-term conditions may provide misleading information about long-term conditions. For example, a beneficial rainfall during a drought may allow the CMI value to indicate adequate moisture conditions, while the long-term drought at that location persists. Another limiting characteristic is that the CMI typically begins and ends each growing season near zero. This prevents the CMI from being used to monitor moisture conditions outside the general growing season, especially in droughts that extend over several years. In addition, the CMI may not be applicable during seed germination at the beginning of the growing season.

Surface Water Supply Index (SWSI)

Overview: The SWSI is designed to complement the Palmer Indices in western states where mountain snowpack is a key element of water supply. The SWSI is calculated by river basin, based on snowpack, streamflow, precipitation, and reservoir storage.
Pros: It represents water supply conditions unique to each basin.
Cons: Changing a data collection station or water management policies requires that new algorithms be calculated; the index is unique to each basin, which limits interbasin comparisons.

The Surface Water Supply Index (SWSI) was designed to complement the Palmer Indices for moisture conditions across the state of Colorado (Shafer and Dezman, 1982), however, now most western starts calculate their own SWSI (see page 12 for the current Colorado SWSI). The Palmer Indices are not designed for large topographic variations across a region, and do not account for snow accumulation and subsequent runoff. In contrast, SWSI incorporates mountain snowpack levels and was designed specifically to asses surface water conditions. The objective of the SWSI is to incorporate both hydrological and climatological features into a single index value for each major river basin in the west (Shafer and Dezman 1982). These values are standardized to allow comparisons between basins. Four inputs are used to calculate SWSI: snowpack, streamflow, precipitation, and reservoir storage. Because water supply is dependent on the season, snowpack, precipitation, and reservoir storage are used to compute SWSI during the winter (November-April). During the summer months, (May-October) streamflow replaces the snowpack component in the SWSI equation.

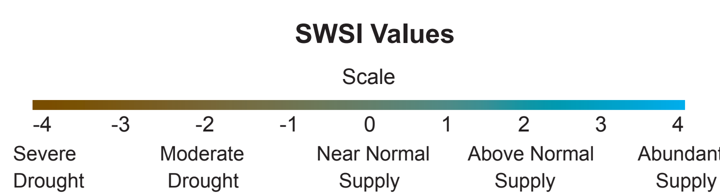

Figure 1c. SWSI scale ranges from -4, (severe drought) to +4 (abundant water supply).

The SWSI has been used, along with the PDSI, to trigger the activation and deactivation of the Colorado Drought Plan. It has been modified and applied in other western states as well, such as Wyoming and Utah. One of its advantages is that it is simple to calculate and gives a representative measurement of surface water supplies across the state. In addition, each input component (streamflow, reservoir storage, snowpack, etc.) is given a weight depending on its typical contribution to the surface water within each basin. Therefore it gives a more accurate picture of water supplies than the other indices that primarily focus on precipitation inputs.

The SWSI has several limitations. Because the SWSI calculation is unique to each basin or region, it is difficult to compare SWSI values between basins or regions (Doesken et al., 1991). If any existing stations are discontinued within a basin or region, new stations must be added with new frequency distributions for each input component to ensure SWSI is calculated the same each month. Extreme events also cause a problem if the events are beyond the historical time series, so the index must be reevaluated to include these events within the frequency distribution of a basin component. Changes in water management within a basin, such as flow diversions or new reservoirs, mean that the entire SWSI algorithm for that basin needs to be redeveloped to account for changes in the weight of each component. Thus, it is difficult to maintain a homogeneous time series of the index (Heddinghaus and Sabol, 1991).

Standardized Precipitation Index (SPI)

Overview: The SPI is an index based on the probability of precipitation for any time scale.

Pros: The SPI can be computed for different time scales, can provide early warning of drought and help assess drought severity, and is less complex than the Palmer. Many drought planners appreciate the SPI's versatility.

Cons: SPI values based on preliminary data may change.

The Standardized Precipitation Index (SPI) reflects the impact of drought on the availability of different water resources. It is designed to quantify the impacts of precipitation deficit on groundwater, reservoir storage, soil moisture, snowpack, and streamflow for multiple time scales. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow, and reservoir storage reflect the longer-term precipitation anomalies. Therefore, SPI was originally calculated for 3, 6, 12, 24, and 48–month time scales. The SPI is used operationally to monitor conditions across Colorado since 1994 (McKee et al., 1995), and is being monitored at the climate division level for the contiguous United States by the NDMC and the Western Regional Climate Center (WRCC). The NDMC and High Plains Regional Climate Center also provides daily SPI maps broken down by region and for the United States (see On the Web box; see page 11 for current SPI maps of the IMW region).

SPI Values	
2.0+	Extremely Wet
1.5 to 1.99	Very Wet
1.0 to 1.49	Moderately Wet
-.99 to .99	Near Normal
-1.0 to -1.49	Moderately Dry
-1.5 to -1.99	Severely Dry
-2 and less	Extremely Dry

Figure 1d. SPI values range from -2 (extremely dry) to +2.0 (extremely wet). The IWCS SPI page is 11.

The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997). Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation (Figure 1d). Because the SPI is normalized, wetter and drier climates can be represented in the same way.

While the SPI can monitor wet periods, it is typically used to assess the length and magnitude of drought events. A drought event occurs when the SPI is continuously reaches an intensity of -1.0 or less (Figure 1d). The event ends when the SPI becomes positive. Each drought event, therefore, has a duration defined by its beginning and end, and an intensity for each month that the event continues. Drought magnitude is the positive sum of the SPI for each month during the drought event.

Based on an analysis of stations across Colorado, the SPI is in the mild drought category 34% of the time, in moderate drought 9.2% of the time, in severe drought 4.4% of the time, and in extreme drought 2.3% of the time (McKee et al., 1993). Because the SPI is standardized, these percentages are expected from a normal distribution of the SPI. The 2.3% of SPI values within the "Extreme Drought" category is a percentage that is typically expected for a very unlikely event (Wilhite 1995). In contrast, the Palmer Index reaches its "extreme" category more than 10% of the time across portions of the central Great Plains. This standardization allows the SPI to determine the rarity of a current drought, as well as the probability of the precipitation necessary to end the current drought (McKee et al., 1993).

Conclusion

While the PDSI is the oldest and most well known, the SPI is the most widely used index for understanding the magnitude and duration of drought events. Most water supply planners like the SWSI, but they find it useful to consult one or more other indices before making a decision. It is important to know the benefits and limitations of each index in order to decide which one is the most useful for any particular application. Users should consult agencies such as the NDMC, the WWA, and State Climatologists for additional information and insight on strengths and weaknesses of each index.

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On the Web

- Weekly updated Palmer Drought Severity Index (PDSI): http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/palmer.gif.
- NOAA Weekly Crop Moisture Index (CSI) maps: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/cmi.gif.
- USDA/JAWF Weekly Weather and Crop Bulletin: http://www.usda.gov/oce/weather/pubs/Weekly/Wwcb/index.htm.
- SWSI information can be found on the NRCS website for each western state.
- Monthly Surface Precipitation Index (SPI) maps: http://drought.unl.edu/monitor/spi.htm; http://www.wrcc.dri.edu/spi/spi.html.
- SPI program files: http://drought.unl.edu/monitor/spi/program/spi_program.htm.

Temperature 6/1/07 - 6/30/07

Monthly average temperatures for June 2007 for the Intermountain West region ranged from 45 – 80°F (Figure 2a). The warmest areas (above 70°F) were across most of **Utah**. Temperatures across most of the region were 0-4°F above average, but areas in south-central and eastern **Colorado** were 0-4°F below average. **Utah** had the highest temperature anomalies recording temperatures 4-8° F above average in the northwest near Salt Lake City (Figure 2b). The NWS Salt Lake City reported that **Utah** had the 12th warmest June in 113 years.

According to the NWS Denver-Boulder, five records were set or tied in Denver during June. Temperatures ranged from a record high of 100°F on the 24th to a record low of 31°F on the 8th. This is the latest spring freeze date in Denver weather history; the previous record was June 2, 1951. The NWS Salt Lake City reported that **Utah** set numerous record high and low temperatures in June as well. On June 7, two record cold minimums and ten record cold maximum temperatures were reported. A record low minimum of 30°F was set in Cedar City (previous record 35°F in 1995) and a record low maximum of 30°F was set at Alta (previous record 34°F in 1993).

Temperatures in June 2006 were higher than temperatures in June 2007 throughout much of the IMW region (Figure 2c). In June 2006, most of the region was 2 – 6°F above average, whereas it was mostly 0 – 4°F above average in June 2007.

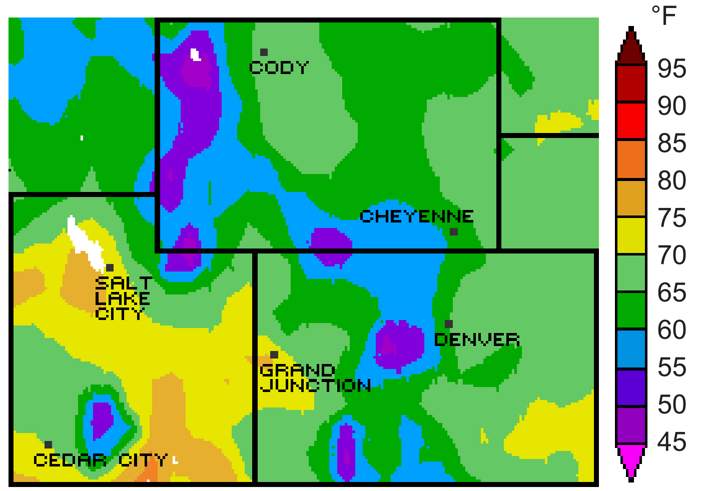


Figure 2a. Average temperature for the month of June 2007 in °F.

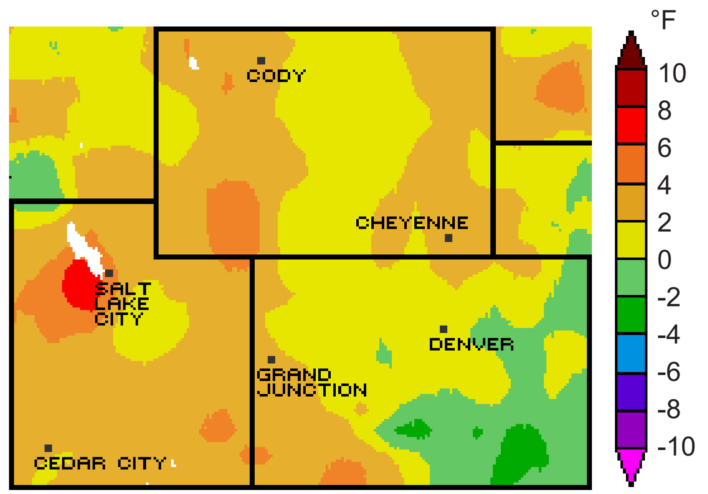


Figure 2b. Departure from average temperature for the month of June 2007 in °F.

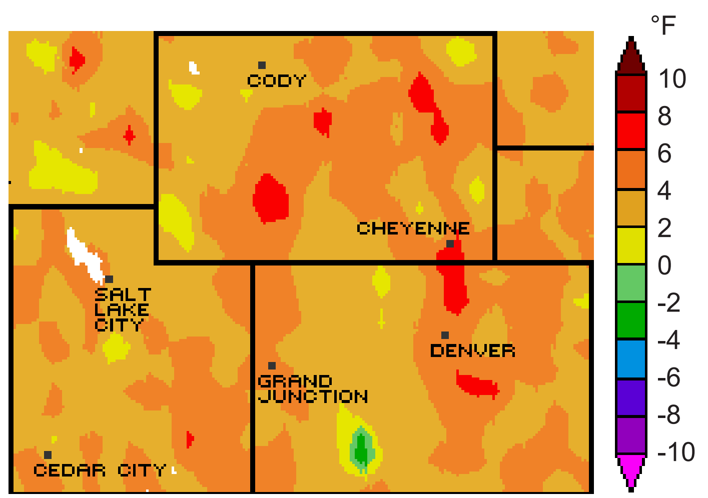


Figure 2c. Departure from average temperature in °F for last year, June 2006.

Notes

Figures 2a-c are experimental products from the High Plains Regional Climate Center. These data are considered experimental because they utilize the most recent data available, which have been subject to minimal quality control. These maps are derived by taking measurements at individual meteorological stations and interpolating (estimating) values between known points to produce continuous categories. Interpolation procedures can cause incorrect values in data-sparse regions. For maps with individual station data, please see web sites listed below. *Average* refers to the arithmetic mean of annual data from 1971- 2000. Departure from average temperature is calculated by subtracting current data from the average. The result can be positive or negative.

On the Web

- For the most recent versions of these and maps of other climate variables including individual station data, visit: http://www.hprcc.unl.edu/products/current.html.
- For information on temperature and precipitation trends, visit: http://www.cpc.ncep.noaa.gov/trndtext.htm.
- For a list of weather stations in Colorado, Utah, and Wyoming, visit: http://www.wrcc.dri.edu/summary.

Precipitation 6/1/07 - 6/30/07

Total precipitation for June 2007 in the Intermountain West regions ranged from 0 – 3+ inches (Figure 3a). Central and northern **Wyoming** and northeast and southeast **Colorado** received the highest totals (1.5 – 3+ inches). Southern and eastern **Utah** and parts of western **Colorado** received the least precipitation (< 0 – 0.25 inch). However, according to NWS Salt Lake City, five locations set 24-hour rainfall records on June 6. The greatest precipitation fell in the northern Wasatch mountains, with heavy snow above 7000 ft.

Most of the region had below average precipitation in June (Figure 3b). Southern and eastern **Utah**, southwest and southeast **Wyoming**, and western and northern **Colorado** received the lowest percent of average (0 – 60%) last month. Above average precipitation was recorded in parts of northwest **Utah** (120 – 150 % of average), and southeast **Colorado** (120 – 200% of average). According to NWS Denver-Boulder, precipitation in June was 0.52 inches or 1.04 inches below average (1.56 inches). Most of the rain (0.46 inches) fell in one 24-hr. period on June 12th.

Precipitation since the start of the water year is near average to above average for most of **Colorado**, southeast **Utah**, and eastern **Wyoming** (Figure 3c). Southeast **Utah** and eastern **Colorado** have received 110-200% of average precipitation. The driest areas were in the western half of **Wyoming** and northern and western **Utah** (50-90% of average).

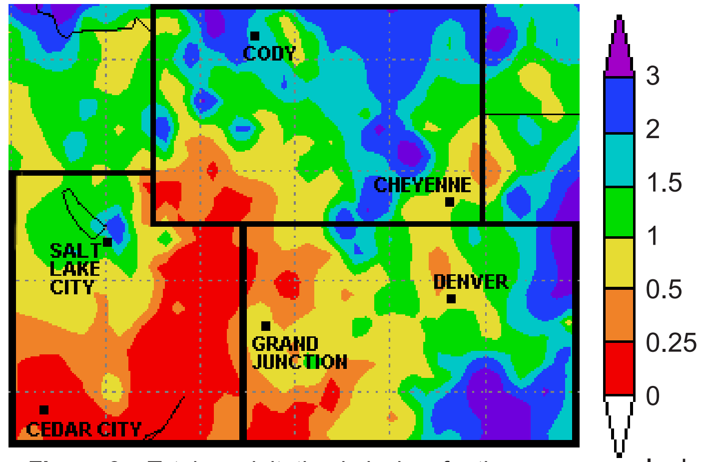


Figure 3a. Total precipitation in inches for the month of June 2007.

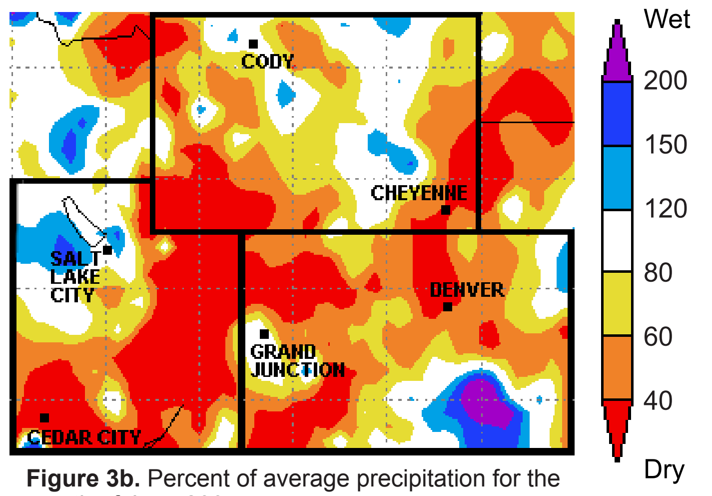


Figure 3b. Percent of average precipitation for the month of June 2007.

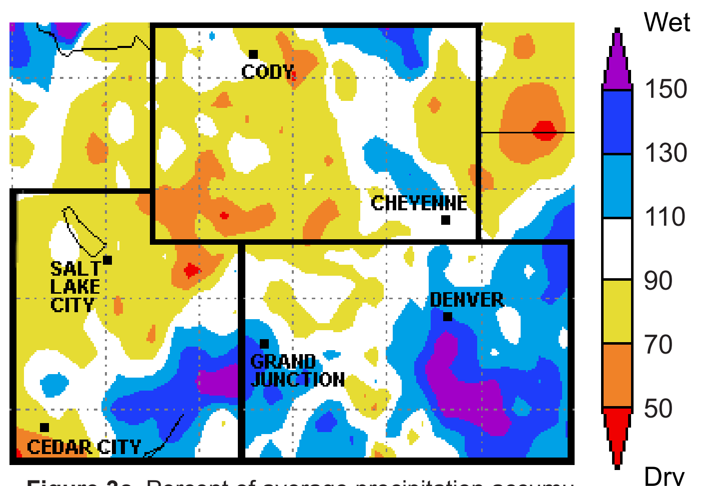


Figure 3c. Percent of average precipitation accumulation since the start of the water year 2007 (Oct. 1, 2006 – June 30, 2007).

Notes

The data in Figs. 3 a-c come from NOAA's Climate Prediction Center. The maps are created and updated daily by NOAA's Earth System Research Laboratory (see website below). These maps are derived by taking measurements at individual meteorological stations and interpolating (estimating) values between known data points to produce continuous categories. The water year runs from October 1 to September 30 of the following year. The 2007 water year began October 1, 2006 (Figure 3c). The water year better reflects the natural cycle of accumulation of snow in the winter and run-off and use of water in the spring and summer. It is a better period of analysis for presenting climate and hydrologic conditions. *Average* refers to the arithmetic mean of annual data from 1996-2005. This period of record is only ten years long because it includes SNOTEL data, which have a continuous record beginning in 1996. Percent of average precipitation is calculated by taking the ratio of current to average precipitation and multiplying by 100.

On the Web

- For the most recent versions of these and maps of other climate variables including individual station data, visit: http://www.hprcc.unl.edu/products/current.html.
- For precipitation maps like these and those in the previous summaries, which are updated daily visit: http://www.cdc.noaa.gov/Drought/.
- For National Climatic Data Center monthly and weekly precipitation and drought reports for Colorado, Utah, Wyoming, and the whole U. S., visit: http://lwf.ncdc.noaa.gov/oa/climate/research/monitoring.html.
- For a list of weather stations in Colorado, Utah, and Wyoming, visit: http://www.wrcc.dri.edu/index.html.

U.S. Drought Monitor conditions as of 7/17/07

The Drought Monitor (DM) has slight changes since last month, with small increases in each state (Figure 4). Southwestern **Wyoming** remains in severe drought status (D3), and that area now extends slightly more westward than last month. Areas of abnormally dry (D0) and moderate drought (D1) now includes more of central Wyoming. Drought status in northwest **Utah** moved from the moderate (D1) to severe (D2) category. Northern **Colorado** moved into the abnormally dry (D0) status.

According to the Drought Impact Reporter, Park City, **Utah** is in a stage one drought, and residents must reduce outdoor water use. In **Wyoming**, Seminoe, Pathfinder and Grayrocks reservoirs are critically low and the governor asked residents to reduce water use. A succession of dry years has adversely impacted the forage in the Pawnee National Grassland, in eastern **Colorado**. In addition, wells in the South Platte River Basin have been shut down due to drought, new water laws, and contention over the area's water. Large agricultural areas have had to stop irrigating, which is decreasing property values. Wildfires, aggravated by drought conditions are reported in **Utah**, **Wyoming**, and **Colorado**.

Upcoming Conference: The U.S. Drought Monitor Forum will be held in Portland, OR, October 10-11, 2007. Authors and users of the U.S. Drought Monitor will convene to discuss user needs and modifications to the tool. Registration is free, but attendance is limited. For information and registration: http://snr.unl.edu/ndmcsurvey/usdmforum.html.

Notes

The U. S. Drought Monitor (Figure 4) is released weekly (every Thursday) and represents data collected through the previous Tuesday. The inset (lower left) shows the western United States from the previous month's map.

The U. S. Drought Monitor maps are based on expert assessment of variables including (but not limited to) the Palmer Drought Severity Index, soil moisture, streamflow, precipitation, and measures of vegetation stress, as well as reports of drought impacts. It is a joint effort of several agencies.

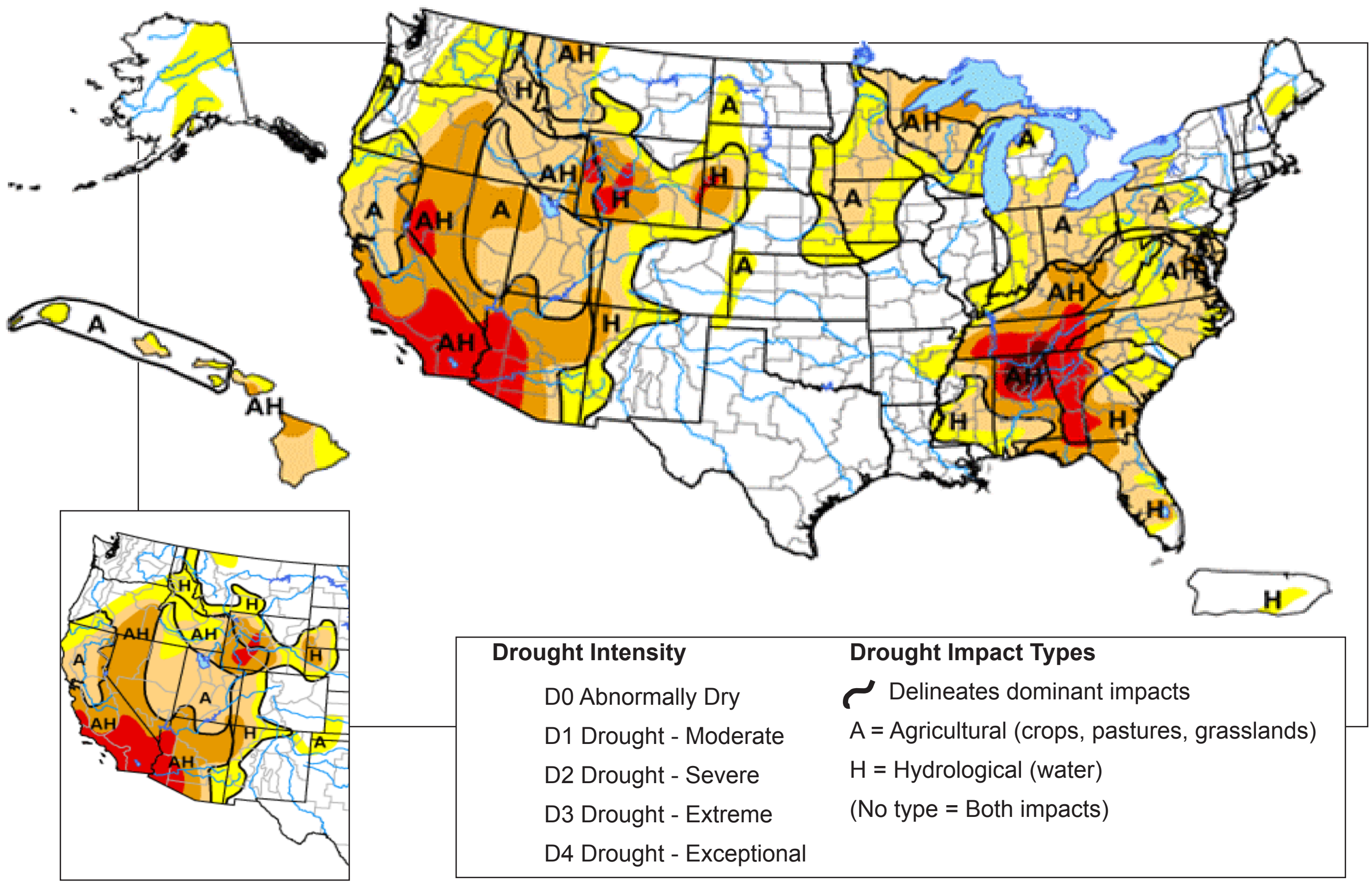


Figure 4. Drought Monitor from July 17, 2007 (full size) and last month, June 19, 2007 (inset, lower left) for comparison.

On the Web

- For the most recent Drought Monitor, visit: http://www.drought.unl.edu/dm/monitor/html. This site also includes archives of past drought monitors.
- Drought Impact Reporter (National Drought Mitigation Center): http://droughtreporter.unl.edu/.

Reservoir Supply Conditions

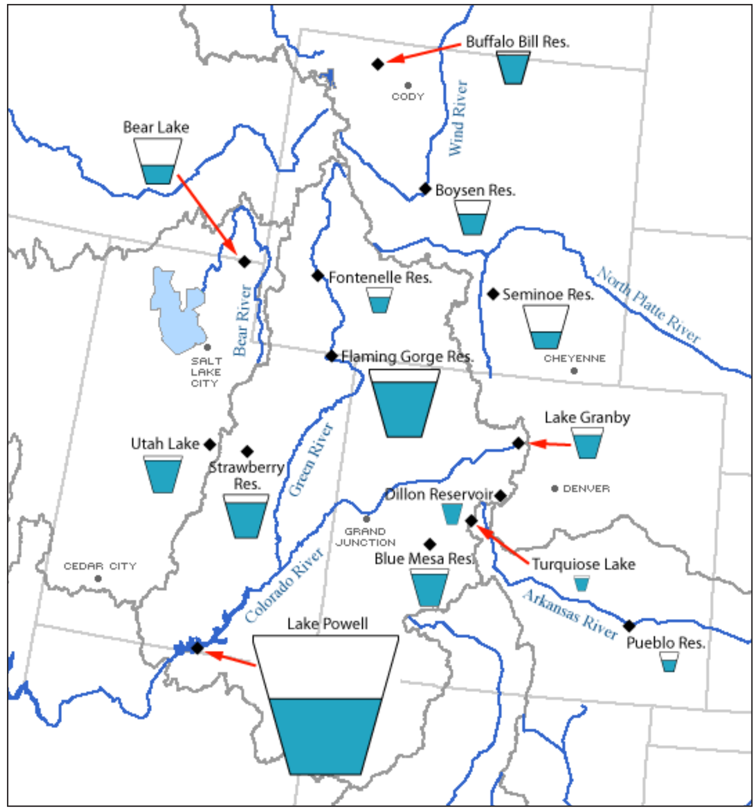
In July, reservoirs are at peak storage levels because the majority of snowpack has melted and streamflow volumes are past their annual peak (Figure 5). In addition, spring flood risk has passed, so storage previously reserved for flood control purposes is allowed to fill. Throughout **Colorado**, storage levels have all increased from June levels, and are all above average. Turquoise Lake and Blue Mesa Reservoir have experienced the highest gains in storage, reporting an increase of 19 and 14 percentage points from last month, respectively. The USBR did not anticipate Blue Mesa Reservoir filling to this level, but conservative releases during the winter months contributed to higher storage levels than originally projected in January.

In **Utah**, storage levels range from a low of 49% of average for Bear Lake to 134% of average for Strawberry Reservoir. Minimal storage gains of 1 and 3 percentage points were made for Strawberry reservoir and Lake Powell respectively, while Utah Lake and Bear Lake storage levels decreased in comparison to last month. Lake Powell reached a spring peak of 53% of capacity in June, and unregulated inflow into Lake Powell was 42% of average.

In **Wyoming**, reservoir storage levels are all lower than storage levels at this time last year due to persistent below average snowpack during the winter. However, all have increased in storage from last month, except Flaming Gorge. June was the third driest on record in the Upper Green Basin, impacting inflow for Fontenelle and Flaming Gorge Reservoirs. Flaming Gorge storage remains near 85% capacity due to below average unregulated inflow (54% of average or lower) since April. June inflows were 19% of average and the USBR projects this inflow rate for July as well. Fontenelle reservoir storage levels peaked even lower than Flaming Gorge at 66% capacity.

Notes

The size of each "tea-cup" is proportional to the size of the reservoir, as is the amount the tea-cup is filled, Figure 5. The first percentage shown in the table is the current contents divided by the total capacity. The second percentage shown is the percent of average water in the reservoir for this time of year. Reservoir status is updated at different times for individual reservoirs.



Reservoir	Current Water (KAF)	Total Capacity (KAF)	% Full	% of Average
Colorado				
Blue Mesa Res.	783.2	829.5	94%	113%
Lake Dillon	258.7	254.0	102%	104%
Lake Granby	434.4	539.7	80%	104%
Pueblo	196.6	354.0	56%	110%
Turquiose Lake	122.6	129.4	95%	107%
Utah				
Bear Lake	539.5	1,302.0	41%	49%
Lake Powell	12,894.1	24,322.0	53%	61%
Strawberry Res.	952.1	1,106.5	86%	134%
Utah Lake	819.0	870.9	94%	94%
Wyoming				
Boysen Res.	476.9	741.6	64%	67%
Buffalo Bill Res.	621.1	644.1	96%	113%
Flaming Gorge Res.	3,123.1	3,749.0	83%	97%
Fontenelle Res.	226.7	344.8	66%	84%
Seminoe Res.	458.2	1,017.3	45%	64%

KAF = Thousands of Acre Feet

Figure 5. Tea-cup diagram of several large reservoirs in the Intermountain West Region. All reservoir content data is from July 1-3, 2007.

On the Web

- Individual reservoir information including management agency, operations, and storage content, visit the WWA website at: http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/links.html, and click on individual links.

Regional Standardized Precipitation Index data through 6/30/07

The Standardized Precipitation Index is used to monitor moisture supply conditions. The distinguishing traits of this index are that it identifies emerging droughts months sooner than the Palmer Index and that it is computed on various time scales (see Feature Article on page 2 for more information). This month we feature Regional SPI maps at two time scales: 3-months and the 12-month map that we have shown in the past. 3- and 6-month SPIs are useful in short-term agricultural applications, while longer-term SPIs (12 months and longer) are useful in hydrological applications. By comparing the two SPI maps one can see how the precipitation over the last 3-months compares to the precipitation over the previous year. For example, the 12-month SPI shows two climate divisions in eastern **Colorado** (Platte and Arkansas) in the very wet category (Figure 6a), while the 3-month SPI shows two divisions in northern **Wyoming** (Yellowstone and Powder/Little Missouri/Tongue) (Figure 6b) in the same category. That means that northern Wyoming has had more above average precipitation in the last three months (April– June) than the rest of the Intermountain West Region. Eastern **Colorado** has had more anomalously high precipitation that the rest of the region for the last year, but in the last three months it has not had as much as northern **Wyoming**. The Rio Grande climate division in south-central **Colorado** is in the moderately wet category in both maps.

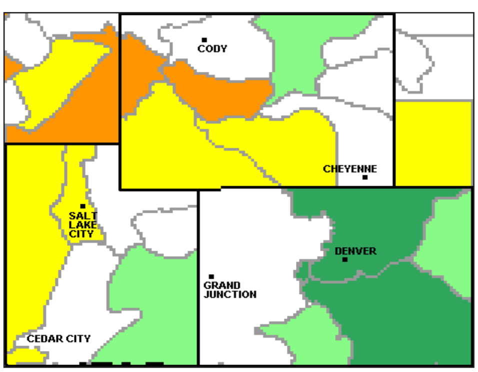
On the other hand, the driest climate divisions in the 12-month SPI are also some of the driest in the 3-month SPI. The Snake and Wind River divisions in western and central **Wyoming** are in the very dry category for both SPIs. That means that those areas of Wyoming have had more months with below average precipitation than the rest of the region for most of last year. Other parts of southern Wyoming and western **Utah** are in the moderately dry category in both the 3- and 12-month SPIs as well.

For most climate divisions in the region, this month's 12-month SPI is similar to last month. However, several divisions moved to a wetter category: Platte and Kansas divisions in northeastern **Colorado** and Big Horn and Powder/Little Missouri/Tongue in north-central **Wyoming**. The only division that moved into a drier category was the Snake in western Wyoming. Despite below average precipitation in northern and western **Utah** and above average precipitation in southeastern Utah, all divisions in the state stayed the same. That means that the dry precipitation anomalies in June were not high enough to off-set the SPI pattern that had been established over the past 12 months.

Notes

The SPI is an index based on the probability of recording a given amount of precipitation, and the probabilities are standardized so that an index of zero indicates the median precipitation amount (half of the historical precipitation amounts are below the median, and half are above the median). The index is negative for drought, and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive. The SPI is computed by the NOAA National Climatic Data Center (NCDC) for several time scales, ranging from one month to 24 months, to capture the various scales of both short-term and long-term drought. The Colorado Climate Center describes the SPI as valuable in monitoring both wet and dry periods, and it can be applied to other types of data (e.g. streamflow, reservoir levels, etc.). Near normal SPI means that the total precipitation for the past 12 months is near the long-term average for one year. An index value of -1 indicates moderate drought severity and means that only 15% would be expected to be drier. An index value of -2 means severe drought with only 2.5% of years expected to be drier.

A 12-month SPI is used for the Intermountain West region (Figure 6a) and compares precipitation patterns for 12 consecutive months with the same 12 consecutive months during all the previous years of available data. The SPI at these time scales reflect long-term precipitation patterns. The 3-month SPI uses data for the last three months and represents short-term precipitation patterns (Figure 6b). The graphics in Figures 6a and b comes from the Western Regional Climate Center, which uses data from the NCDC and the NOAA Climate Prediction Center.



+3.00 and above	Exceptionally Wet
+2.00 to +2.99	Extremely Wet
+1.25 to +1.99	Very Wet
+0.75 to +1.24	Moderately Wet
-0.74 to +0.74	Near Normal
-1.24 to -0.75	Moderately Dry
-1.99 to -1.25	Very Dry
-2.99 to -2.00	Extremely Dry
-3.00 and below	Exceptionally Dry

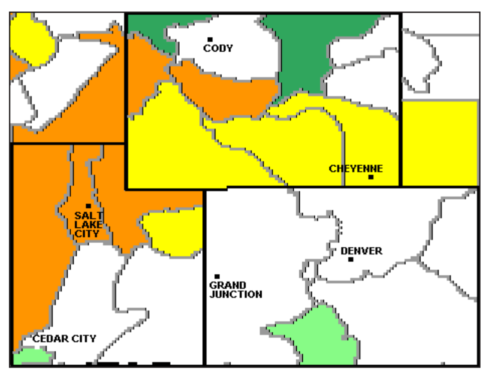


Figure 6a. 12-month Intermountain West regional Standardized Precipitation Index (data from 7/1/06 - 6/30/07).

Figure 6b. 3-month Intermountain West regional Standardized Precipitation Index (data from 4/1/06 - 6/30/07).

On the Web

- For a discussion of Drought Indices, see: *What is Drought?* by Dr. Michael Hayes, National Drought Mitigation Center, http://drought.unl.edu/whatis/indices.htm, or see the Feature Article on page 2.
- For information on the SPI, how it is calculated, and other similar products for the entire country, visit http://www.wrcc.dri.edu/spi/spi.html.
- For information on past precipitation trends, visit: http://www.hprcc.unl.edu/products/current.html.
- For SPI products directly form the NCDC, visit: http://lwf.ncdc.noaa.gov/oa/climate/research/prelim/drought/spi.html. These maps use the same data as Figure 6a and 6b, but the categories are defined slightly differently.

Colorado Water Availability

In July, snowpack is near or at complete melt-out, reservoirs are at peak levels, and streamflow volumes have dropped. Water supply conditions for the rest of the summer are based on precipitation, temperature, streamflow volumes, and reservoir storage.

Streamflow volumes across Colorado are in the normal category (25th -75th percentile) for this time of year, according to the 7-day average streamflow observations from the USGS (Figure 7a). Several stations east of the Continental Divide on the Arkansas and South Platte rivers are in the above normal category (75th - >90th percentile), while many stations across the West Slope in the Yampa, Gunnison, and Upper Colorado basins are in the below normal category (24th - <10th percentile). According to an article published in the Pueblo Chiefton, boaters have enjoyed higher flows on the Arkansas River this summer due to enhanced releases from Clear Creek reservoir near the headwaters. Clear Creek reservoir is lowered for maintenance and repairs starting in the fall.

Statewide SWSI values have all dropped at least one point since last month, and only the South Platte, Arkansas, and Rio Grande basins have positive SWSI values of +1.3, +0.6, and +0.5, respectively (Figure 7b). SWSI values range from a high of +1.3 in the South Platte basin to a low of -3.7 in the Yampa and White Basins. Although reservoir storage across the state is near average, below average precipitation contributed to losses in SWSI values. Current annual precipitation for July 1 as a percent of average ranges from a 101% of average for the Rio Grande basin, to 89% of average for the Upper Colorado and Gunnison basins, and a low of 69% of average for the Yampa and White River basins. As a result of persistent dry conditions, fire restrictions are in place for many West Slope counties.

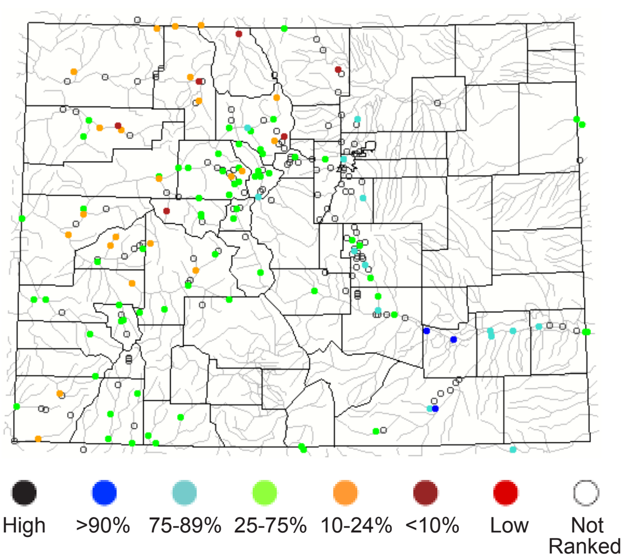


Figure 7a. Seven-day average streamflow conditions for points in Colorado as of July 1, 2007, computed at USGS gauging stations. The colors represent 7-day average streamflow compared to percentiles of 7-day average streamflow.

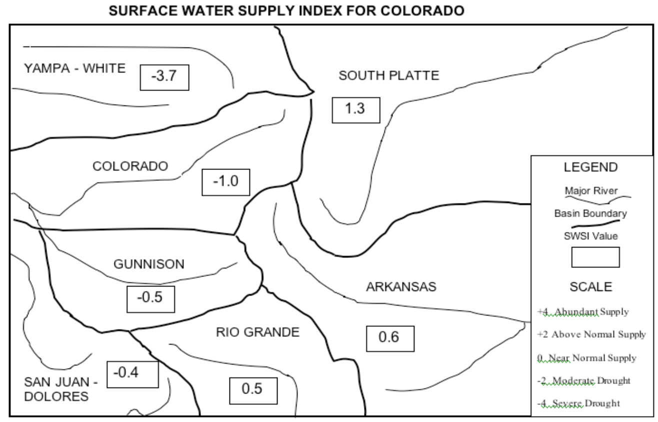


Figure 7b. Colorado Surface Water Supply Index is an indicator of mountain-based water supply conditions in the major river basins of the state as of July 1, 2007.

Notes

The "7-day average streamflow" map shows the average streamflow conditions for the past 7 days compared to the same period in past years (Figure 7a). By averaging over the past 7 days, the values on the map are more indicative of longer-term streamflow conditions than either the "Real-time streamflow" or the "Daily streamflow" maps.

If a station is categorized in "near normal" or 25th – 75th percentile class, it means that the streamflows are in the same range as 25-75% of past years. Note that this "normal" category represents a wide range of flows. Only stations having at least 30 years of record are used. Areas containing no dots indicate locations where flow data for the current day are temporarily unavailable. The data used to produce this map are provisional and have not been reviewed or edited; they may be subject to significant change.

Each state calculates their SWSI a little differently. The Surface Water Supply Index (SWSI) (Figure 7b), developed by the Colorado Office of the State Engineer and the USDA Natural Resources Conservation Service, is used as an indicator of mountain-based water supply conditions in the major river basins of the state. The Colorado SWSI is based on streamflow, reservoir storage, and precipitation for the summer period (May - October). This differs from winter calculations that use snowpack as well. During the summer period, streamflow is the primary component in all basins except the South Platte Basin, where reservoir storage is given the most weight.

On the Web

- Pueblo Chieftion, "Flows mean more fun on Arkansas River," July 13, 2007, available at: http://www.chieftain.com/metro/-1184309470/6.
- For current streamflow information from USGS, Figure xa, visit: http://water.usgs.gov/waterwatch/.
- The Colorado SWSI, Figure xb, along with more data about current water supply conditions for the state can be found at: http://www.co.nrcs.usda.gov/snow/index.html.
- For monthly reports on water supply conditions & forecasts for major CO river basins, visit: http://www.wcc.nrcs.usda.gov/cgibin/bor.pl.
- Water Supply Outlook information for the Upper Colorado River Basin, produced by the Colorado Basin River Forecast Center, is available at: http://www.cbrfc.noaa.gov/wsup/wsup.cgi.

Wyoming Water Availability

The Wyoming State Climatologist, Steve Gray, reports in the July "Wyoming Drought Watch" that above average temperatures in March and April caused earlier snowmelt and runoff this spring, especially in western Wyoming. SNOTEL sites throughout the state recorded that much of the snowpack was melted by mid to late May – 4 to 6 weeks earlier than historical averages (Figure 8a). The early runoff and below average precipitation in May and June are now contributing to below average streamflows (Figure 8b). As of July 1, 2007, the USGS streamflow gauges indicate that most flows in western Wyoming are in the driest categories, corresponding to the 10th percentile or lower. Streamflow gauges in the eastern half of the state indicate flows that are closer to average, in the 25th – 75th percentile range.

Gray says high temperatures and a very dry June have exacerbated long-term moisture deficits, especially in the west. The final two weeks of June were especially dry, with much of the state receiving a trace of precipitation. The extended dry spells in the last six months negated many of the gains in moisture status following late-spring storms. The cumulative effects of the 7-8 years of drought are also having an impact on water supplies in other parts of the state. The Pathfinder Reservoir in the North Platte Basin is now down to 27% of capacity, and inflow to several of the state's reservoirs is forecast to be less than 50% of average (USBR). See page 10 for more information on Wyoming reservoirs.

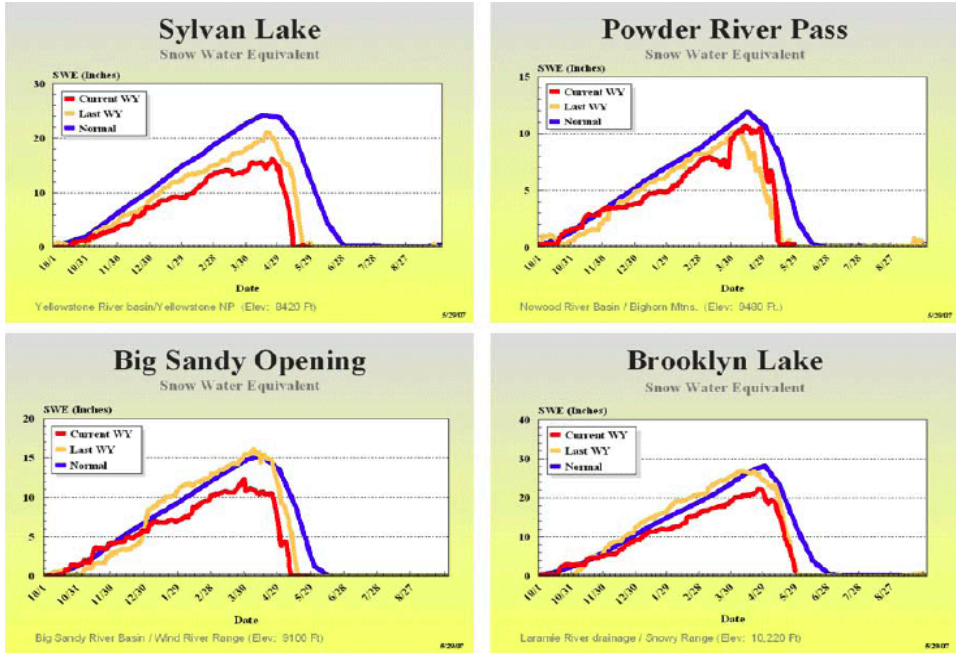


Figure 8a. Graphs comparing snowpack for the 2006-07 season (red) against historical averages (blue) and the 2005-06 season (yellow). Throughout much of the state high country snows melted off 4-6 weeks earlier than the historical average. See notes for locations of SNOTEL sites.

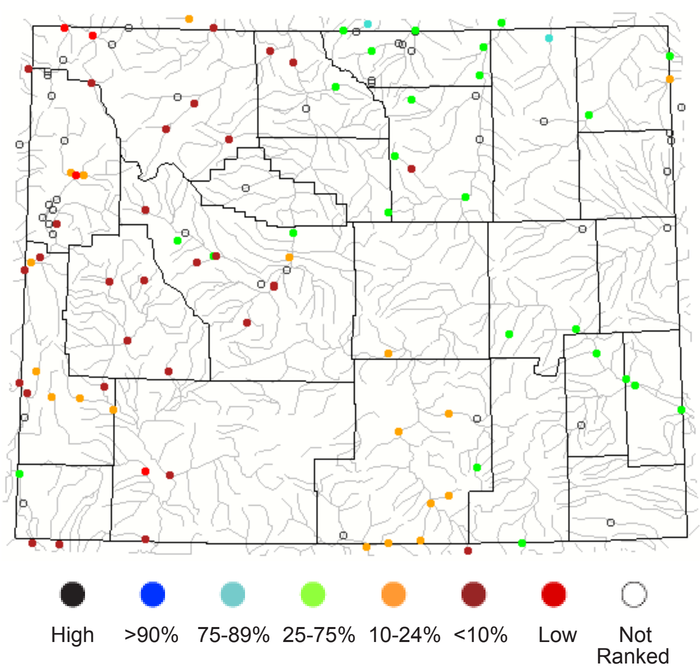


Figure 8b. Seven-day average streamflow conditions for points in Wyoming as of July 1, 2007, computed at USGS gauging stations. The colors represent 7-day average streamflow compared to percentiles of 7-day average streamflow.

Notes

Figure 8a is a graph of SWE measurements from four NRCS SNOTEL sites using data from the current water year (2007), last year (2005), and normal, which is an average of 1971-2000. Figure 8a came from the July "Wyoming Drought Watch", a product of the University of Wyoming's Water Resource Data System. The "7-day average streamflow' map (Figure 8b) shows the average streamflow conditions for the past 7 days compared to the same period in past years. For a more detailed description of Figure 8b, see the Notes on page 12 or 14.

On the Web

- Wyoming Drought Watch: http://www.wrds.uwyo.edu/wrds/wsc/dtf/droughtupdate.pdf.
- For current streamflow information from USGS as in Figure 8b, visit: http://water.usgs.gov/waterwatch/.
- For monthly State Basin Outlook Reports on water supply conditions and forecasts for WY river basins, visit: http://www.wcc.nrcs.usda.gov/cgibin/bor.pl.

Utah Water Availability

Below average winter snowfall and an early melt-out are the primary causes for below average streamflow across Utah on July 1. The majority of streamflow across Utah are running in the below average category (<10th-24th percentile) (Figure 9a). Some gauges in the northern and central parts of the state are in the normal category (25th to 75th percentiles).

A new Utah SNOTEL Basin snowpack time series summary is available statewide or for individual basins from NRCS (Figure 9b). The time-series compares SWE values for the last four water years (2004-2007). In 2007, both the dates of peak snowpack and complete melt out occurred about 4 weeks earlier than average. In addition, peak SWE estimates of 11 inches were well below the average of 17 inches. This pattern of a lower and earlier than average snowpack peak with an earlier melt-out occurred in all basins in Utah this year, contributing to below average water supplies. In 2006, parts of Utah had above average water supplies because of above average snowpack, despite an early melt-out. 2005 had above average snowpack and an average melt-out date across the state.

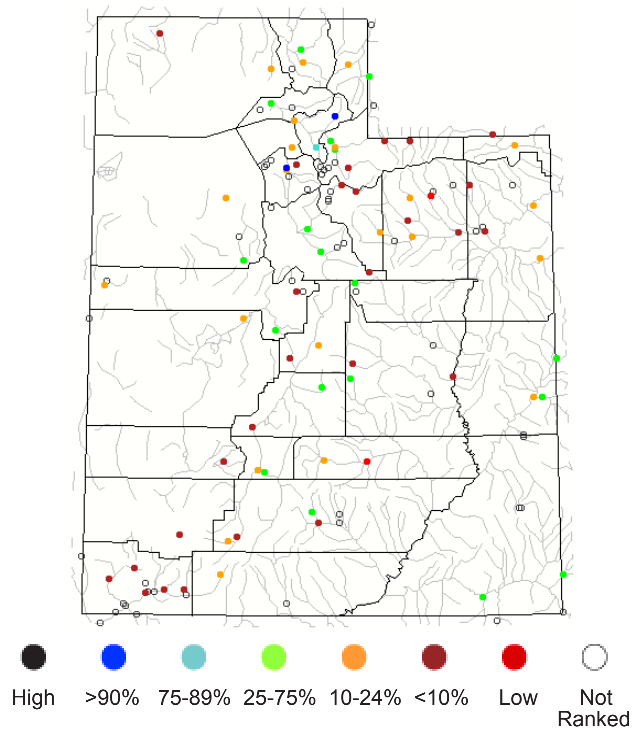
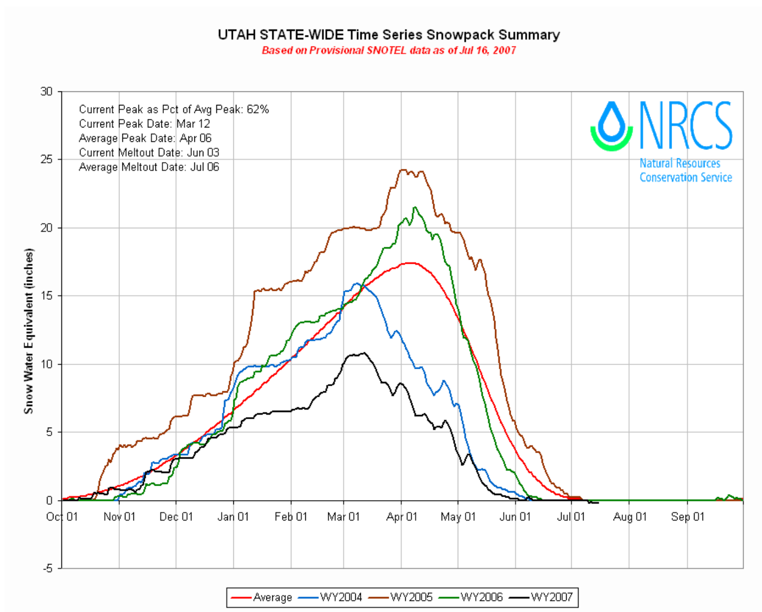


Figure 9a. Seven-day average streamflow conditions for points in Utah as of July 1, 2007, computed at USGS gauging stations. The colors represent 7-day average streamflow compared to percentiles of 7-day average streamflow.



Figures 9b. Utah state-wide time series snowpack summary. Based on provisional SNOTEL data as of July 11, 2007. Courtesy of Utah NRCS

Notes

The "7-day average streamflow' map (Figure 9a) shows the average streamflow conditions for the past 7 days compared to the same period in past years. By averaging over the past 7 days, the values on the map are more indicative of longer-term streamflow conditions than either the "Real-time streamflow" or the "Daily streamflow" maps. If a station is categorized in "near normal" or 25th – 75th percentile class, it means that the stream flows are in the same range as 25 – 75 % of past years. Note that this "normal" category represents a wide range of flows. Only stations having at least 30 years of record are used. Areas containing no dots indicate locations where flow data for the current day are temporarily unavailable. The data used to produce this map are provisional and have not been reviewed or edited. They may be subject to significant change.

The Utah SNOTEL Basin time series snowpack summary graph (Figure 9b) compiled by NRCS is based on averages of SWE measurements for all SNOTEL sites in the state or individual basins, depending on the graph. This product uses the daily measurements to calculate the SWE totals for each basin. SWE "average" (red line) is based on historical record averages from 1971-2000. Date of melt out is determined when the last SNOTEL station in the state, typically Big Flat or Snowbird, reads "zero," i.e. no snow. Once a SNOTEL site reads "zero", it is excluded in SWE calculations.

On the Web

- For current streamflow information from USGS as in Figure 9a, visit: http://water.usgs.gov/waterwatch/.
- Utah NRCS SNOTEL Basin time-series summary graphics like Figure 9b for the state or individual basins are at: http://www.ut.nrcs.usda.gov/snow/data/current/basin_charts.htm.
- For monthly reports on water supply conditions & forecasts for major UT river basins, visit: http://www.wcc.nrcs.usda.gov/cgibin/bor.pl.
- Water Supply Outlook information for the Upper Colorado River Basin, produced by the Colorado Basin River Forecast Center, is available at: http://www.cbrfc.noaa.gov/wsup/wsup.cgi.

Temperature Outlook August – December 2007

The August 2007 temperature outlook indicates an increased risk of above average temperatures across **Utah**, **Wyoming**, and most of **Colorado** (Figure 10a). The highest chance (up to 50%) of above average temperatures occurs across most of Utah. Further east, over the southern Great Plains, the forecast is for an increased chance of below average temperatures. The forecast is based on wet soil conditions (http://www.cpc.ncep.noaa.gov/soilmst/img/curr.w.anom.daily.gif) and cooler than average temperatures over the last two months, which will help to persist the temperatures anomalies into August. Climate forecasts that take advantage of regional soil moisture anomalies show skill during the summer. The August temperature forecast will be updated on July 31st on the CPC web page. Because of the shorter lead-time, the "zero-lead" forecast (i.e. on the last day of the previous month) often have increased skill over the half-month lead forecasts.

During the Aug.-Oct forecast period, the western U.S., including Utah, western Colorado, and the southwest corner of Wyoming, show increased risk of above average temperatures (Figure 10b). Compared to the August forecast, the 50% chance of above normal temperatures shifts into just the southwest corner of Utah. CPC notes that most models indicate an increased chance for above normal temperatures throughout the country during the Aug. – Oct. period, but high soil moisture anomalies in the Great Plains will keep temperatures closer to normal. During the Sept.-Nov. forecast period most of the Intermountain West has equal chances (EC) of below- near- or above normal temperatures (Figure 10c), however, during the Oct.-Dec. period, most of the Intermountain West shows slightly increased chanced for above average temperatures (Figure 10d).

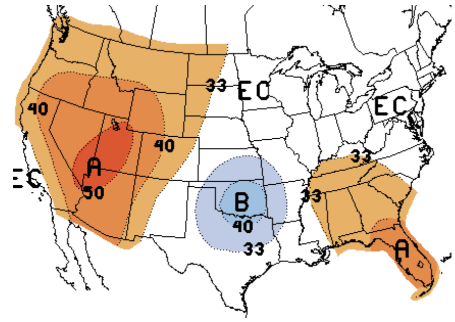


Figure 10a. Long-lead national temperature forecast for August 2007 (released July 19, 2007).

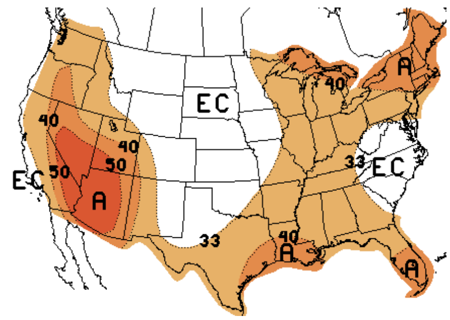


Figure 10b. Long-lead national temperature forecast for Aug. – Oct. 2007 (released July 19, 2007).

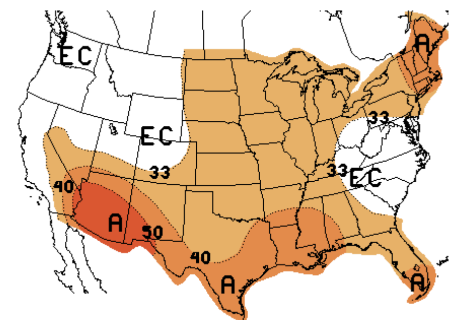


Figure 10c. Long-lead national temperature forecast for Sep. – Nov. 2007 (released July 19, 2007).

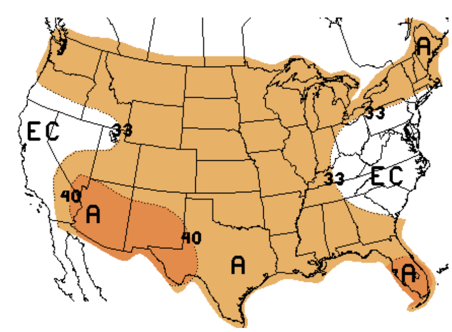


Figure 10d. Long-lead national temperature forecast for Oct. – Dec. 2007 (released July 19, 2007).

Notes

The seasonal temperature outlooks predict the likelihood (chance) of temperatures occurring in the *above-average*, *near-average*, and *below-average* categories. The numbers on the maps do not refer to actual temperature values, but to the probability in percent that temperatures will be in one of these three categories.

The CPC outlooks are 3-category forecasts based on climate models in which the skill largely comes from the status of ENSO and recent trends. The categories are defined based on the 1971-2000 climate record; each 1- or 3-month period is divided into 3 categories (terciles), indicating the probabilities that the temperature in the period will fall into the upper third of the years (upper tercile, the middle third of the years (middle tercile, or around average), or the lowest third of the years (lower tercile). The forecast indicates the likelihood of the temperature being in the *above-average* (A, orange shading) or *below-average* (B) tercile--with a corresponding decrease in the opposite category. The *near-average* category is preserved at 33.3% likelihood, unless the anomaly forecast probability is very high. Equal Chances (EC) indicates areas for which the models do not have sufficient skill to predict the temperature with any confidence, representing equal chances or a 33.3% probability for each tercile. For a detailed description, see notes on the precipitation outlook page.

A = Above
- 60.0–69.9%
- 50.0–59.9%
- 40.0–49.9%
- 33.3–39.9%

B = Below
- 40.0–49.9%
- 33.3–39.9%

EC = Equal Chances

On the Web

- For more information and the most recent forecast images, visit: http://www.cpc.ncep.noaa.gov/products/predictions/90day/. Please note that this website has many graphics and may load slowly on your computer.
- The CPC "discussion for non-technical users" is at: http://www.cpc.noaa.gov/products/predictions/90day/fxus05.html.
- For IRI forecasts, visit: http://iri.columbia.edu/climate/forecast/net_asmt/.
- More information about temperature distributions at specific stations in Colorado, Utah, Wyoming, and across the West can be found at the Western Regional Climate Center, http://www.wrcc.dri.edu/CLIMATEDATA.html.

Precipitation Outlook August – December 2007

The August 2007 CPC precipitation forecast is based on unusually good agreement among traditional forecast tools and strong soil moisture anomalies over large areas of the country. Soil moisture anomalies are a major contributor to predictive skill of the regional climate during the summer season. The forecast indicates an increased chance for below average precipitation in most of **Wyoming**, **Utah**, and in northwestern **Colorado** (Figure 11a). CPC notes that, for some time, there has been a pattern of cool and wet in the Great Plains and warm and dry in the West. This general pattern is likely to continue through August 2007. The August precipitation forecast will be updated on July 31st on the CPC web page. Because of the shorter lead-time, the "zero-lead" forecasts (i.e. on the last day of the previous month) often have increased skill over the half-month lead forecasts.

The forecasts for subsequent seasons indicate "EC" or "equal chances" of above-average, near-normal or below-average precipitation for much of the region (Figures 11b-c). However, there is an increased chance of below average precipitation in northwest Utah during the Aug. – Oct. forecast period (Figure 11b). These areas are on the edge of drier than normal conditions forecasted for the region centered over the Great Basin and Pacific Northwest.

CPC does not expect any influence from El Niño or La Niña on the climate of the United States during the Aug. – Oct. 2007 season because neutral ENSO conditions are expected through that time, with the possible development of La Niña in the fall.

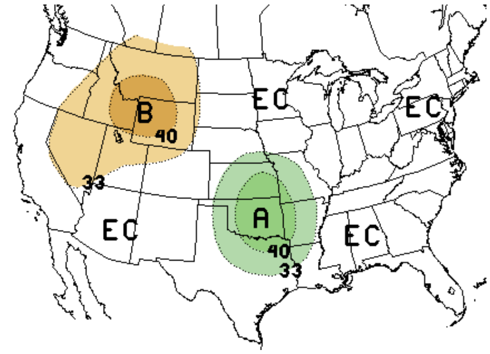


Figure 11a. Long-lead national precipitation forecast for August 2007 (released July 19, 2007).

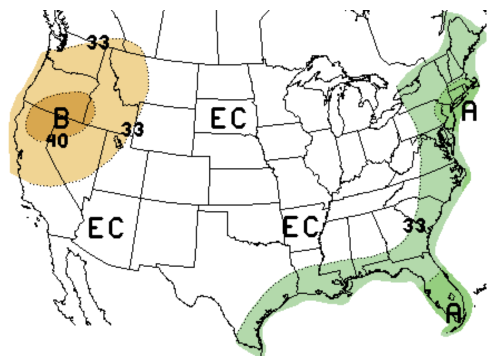


Figure 11b. Long-lead national precipitation forecast for Aug. – Oct. 2007 (released July 19, 2007).

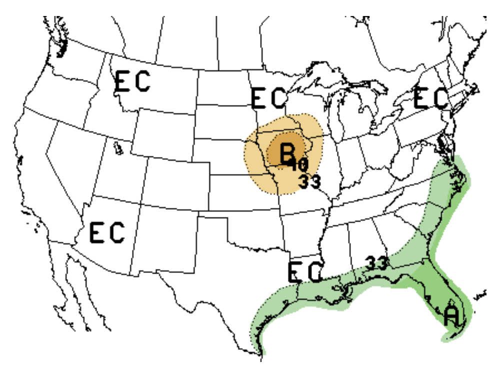


Figure 11c. Long-lead national precipitation forecast for Sep. – Nov. 2007 (released July 19, 2007).

A = Above	B = Below	EC = Equal Chances
40.0–49.9%	40.0–49.9%	
33.3–39.9%	33.3–39.9%	

Notes

The seasonal temperature outlooks predict the likelihood (chance) of temperatures occurring in the *above-average*, *near-average*, and *below-average* categories. The numbers on the maps do not refer to actual temperature values, but to the probability in percent that temperatures will be in one of these three categories.

The CPC outlooks are 3-category forecasts based on climate models in which the skill largely comes from the status of ENSO and recent trends. The categories are defined based on the 1971-2000 climate record; each 1- or 3-month period is divided into 3 categories (terciles), indicating the probabilities that the temperature in the period will fall into the upper third of the years (upper tercile, the middle third of the years (middle tercile, or around average), or the lowest third of the years (lower tercile). each with a 33.3% chance of occurring. The middle tercile is considered the *near-average* (or normal) precipitation range. The forecast indicates the likelihood of the precipitation occurring in the *below-average* (B, brown shading) or *above-average* (A, green shading) --with a corresponding decrease in the opposite category, The *near-average* category is preserved at 33.3% likelihood, unless the anomaly forecast probability is very high.

Thus, areas with dark brown shading indicate a 40.0-50.0% chance of below-average, a 33.3% chance of *near-average*, and a 16.7-26.6% chance of *above-average* precipitation. Light brown shading displays a 33.3-39.9% chance of *below-average,* a 33.3% chance of *near-average*, and a 26.7-33.3% chance of *above-average* precipitation and so on. Green shading indicate areas with a greater chance of *above-average* precipitation. Equal Chances (EC) indicates areas for which the models cannot predict the precipitation with any confidence, representing equal chances or a 33.3% probability for each tercile, indicating areas where the reliability (i.e., 'skill') of the forecast is poor. "N" indicates an increased chance of near-average conditions, but is not forecasted very often.

On the Web

- For more information and the most recent CPC forecast images, visit: http://www.cpc.ncep.noaa.gov/products/predictions/90day/. Please note that this website has many graphics and may load slowly on your computer.
- The CPC "discussion for non-technical users" is at: http://www.cpc.ncep.noaa.gov/products/predictions/90day/fxus05.html.
- For IRI forecasts, visit: http://iri.columbia.edu/climate/forecast/net_asmt/.
- More information about temperature distributions at specific stations in Colorado, Utah, Wyoming, and across the West can be found at the Western Regional Climate Center, http://www.wrcc.dri.edu/CLIMATEDATA.html.

Seasonal Drought Outlook through October 2007

The Drought Outlook (DO) depicts general, large-scale trends and change in drought status through the end of October 2007 (3.5 months, Figure 12). This product includes input from the U.S. Drought Monitor, which designates drought for most of the western U.S. The western drought area includes **Utah**, most of **Wyoming**, and western **Colorado** (see page 9). Over the western states, record low precipitation totals for the 2006-07 water year in some areas has resulted in the development of severe drought across the Southwest. In the northern Rockies, recent heat and dry weather have resulted in drought development. Drought conditions will persist through the period, with possible expansion into the Pacific Northwest, central Montana, and north-central Wyoming. Some decrease in drought conditions is expected in Arizona, the southeast corner of Utah and the southwest corner of Colorado due to the summer monsoons.

Upcoming Conference: The 4th Symposium on Southwest Hydrometeorology will be held in Tucson, AZ on Sept. 20-21, 2007. The meeting is a forum on research issues associated with mid-latitude, subtropical, and tropical weather systems that affect the Southwestern U.S., and to discuss the impact of these systems on hydrometeorological phenomenon, including drought. For more information and registration: http://www.atmo.arizona.edu/swhs.

Notes

The Seasonal Drought Outlook (DO) depicts general, large-scale trends from that date through the end of the forecast period (3 to 3.5 months, depending on the date of issue). The delineated areas in the (Figure 12) are defined subjectively based on expert assessment of numerous indicators, including outputs of short- and long-term forecasting models. Areas of continuing drought are schematically approximated from the Drought Monitor (D1 to D4). For weekly drought updates, see the latest Drought Monitor text on the website: http://www.drought.unl.edu/dm/monitor.html. NOTE: The green improvement areas imply at least a 1-category improvement in the Drought Monitor intensity levels, but do not necessarily imply drought elimination.

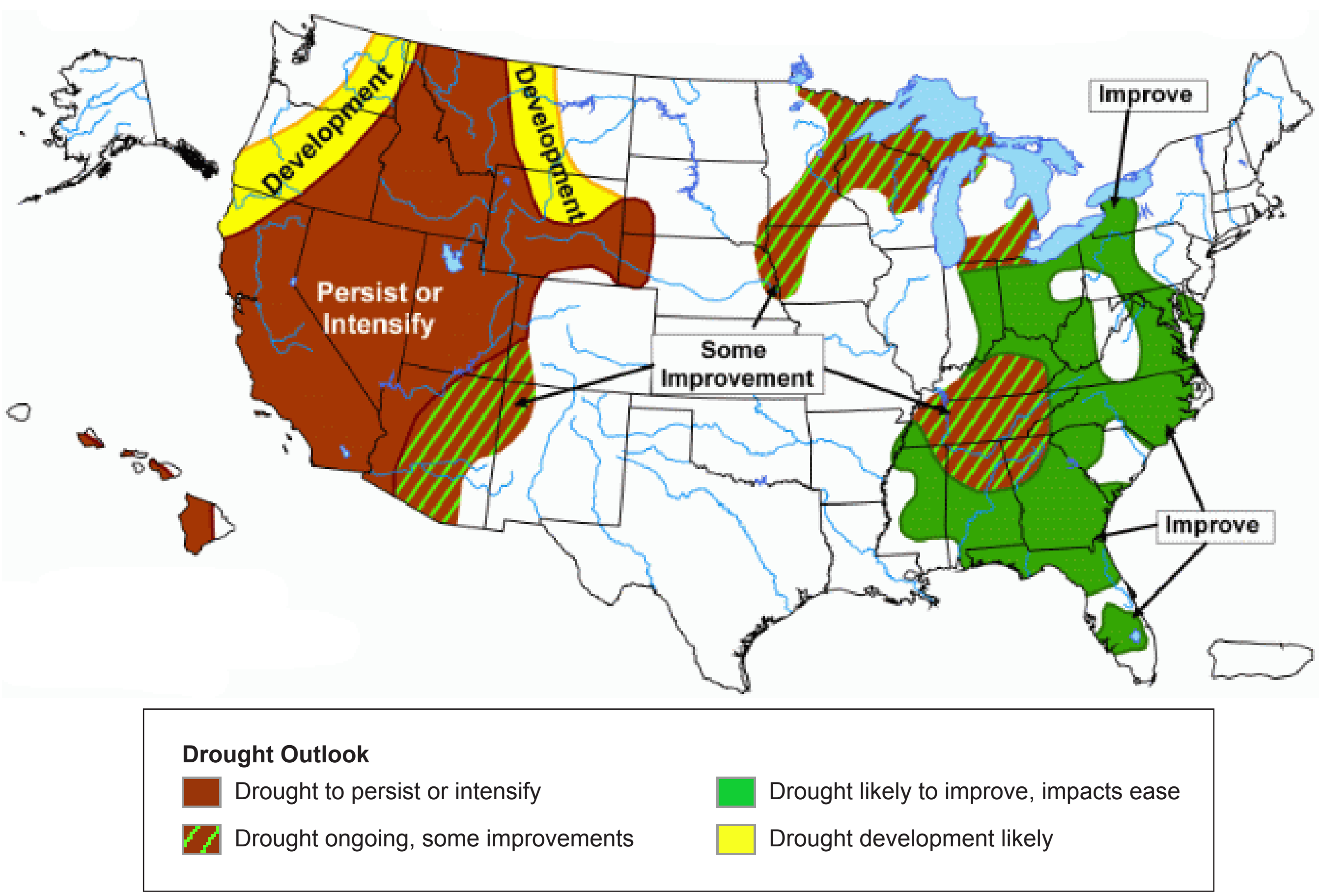


Figure 12. Seasonal Drought Outlook through October 2007 (release date July 19, 2007).

On the Web

- For more information, visit: http://www.drought.noaa.gov/.
- Drought termination probabilities: http://www.ncdc.noaa.gov/oa/climate/research/drought/current.html

El Niño Status and Forecast

According to the NOAA Climate Prediction Center, conditions in the equatorial Pacific during the first part of 2007 indicated the possible development of La Niña by mid-2007. This statement was based on model forecasts and the sudden decrease of sea surface temperature (SST) anomalies in the east-central equatorial Pacific to the South American coast. However, the trend toward cooler SSTs has not continued at the same speed, and sub-surface ocean temperatures in the east-central Pacific became less negative in June. Currently, SSTs in the eastern Pacific are between 0.5 – 1.5ºC below average (Figure 13a). About half of the models predict ENSO neutral conditions for the 10-month forecast period, and half predict a weak to moderate La Niña. These indicators suggest ENSO-neutral conditions for the next few months with equal chances of ENSO-neutral or La Niña conditions thereafter. Thus, there is a large amount of uncertainty in this prediction. Thus ENSO has a limited impact on the forecasts made for August for the U.S. The CPC ENSO Diagnostic Discussion will be updated on August 9th and the IRI ENSO "Quick Look" on August 16th.

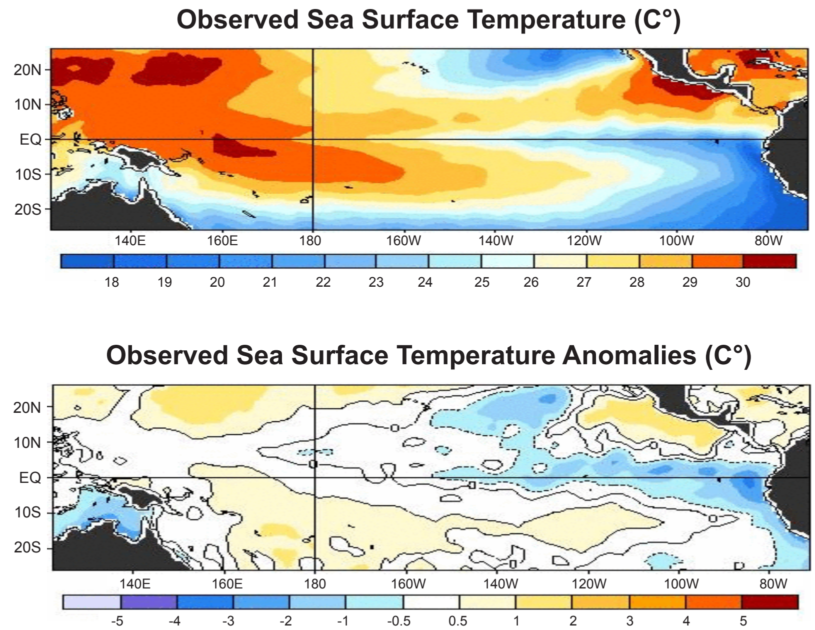


Figure 13a. Observed SST (upper) and the observed SST anomalies (lower) in the Pacific Ocean. The Niño 3.4 region encompasses the area between 120˚W-170˚W and 5˚N-5˚S. The graphics represent the 7-day average centered on July 11, 2007.

Notes

Two NOAA graphics in Figure 13a show observed SST (upper) and SST anomalies (lower) in the Pacific Ocean, averaged over a recent 5-day period. Data are from satellite observations and the NOAA TAO array of 70 moored buoys spread out over the Pacific Ocean, centered on the equator. The buoys measure temperature, currents, and winds and transmit data in real-time. NOAA uses these observations to predict short-term (a few months to one year) climate variations.

Figure 13b shows forecasts for SST in the Niño 3.4 region for nine overlapping 3-month periods from September 2005 to July 2006. "Niño 3.4" refers to the region of the equatorial Pacific from 120˚W to 170˚W and 5˚N to 5˚S, which is used as an SST-based index for defining ENSO. Abbreviations represent groups of three months (e.g. SON = Sept-Nov). The expected skills of the models, based on historical performance, vary among the models, and skill generally decreases with lead-time. Forecast skill also varies over the year because of seasonal differences in predictability of the system, e.g., forecasts made between June and December are generally better than those made between February and May. Differences among forecasts reflect both differences in model design and actual uncertainty in the forecast of the possible future SST scenario.

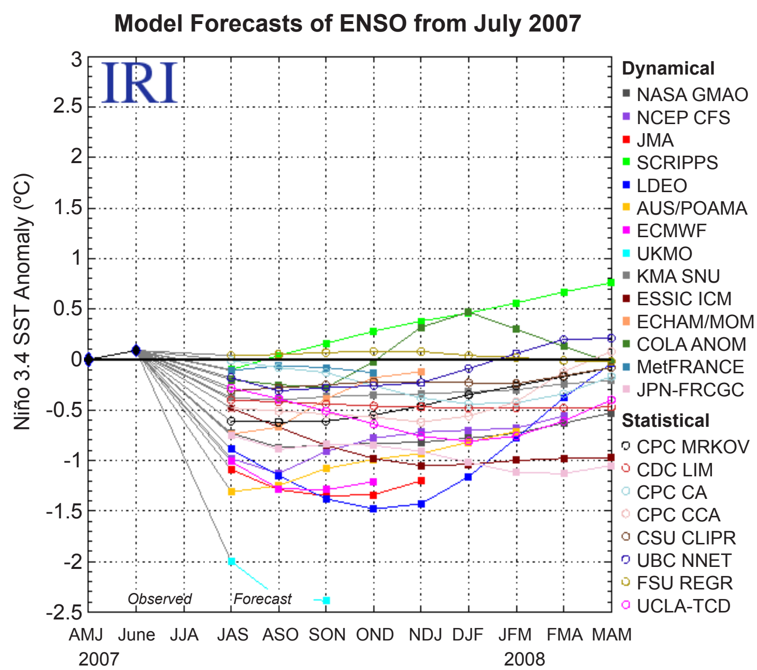


Figure 13b. Forecasts made by dynamical and statistical models for sea surface temperatures (SST) in the Niño 3.4 region for nine overlapping 3-month periods from July 2007 through May 2008 (released July 19, 2007). Forecast graphic is from the International Research Institute (IRI) for Climate and Society.

On the Web

- For a technical discussion of current El Niño conditions, visit: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/.
- For updated graphics of SST and SST anomalies, visit this site and click on "Weekly SST Anomalies": http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml#current.
- For more information about El Niño, including the most recent forecasts, visit: http://portal.iri.columbia.edu/climate/ENSO/.

Climate Prediction Center Soil Moisture Products

By Jessica Lowrey, WWA

Soil moisture is the amount of water contained in the soil pores above the saturated groundwater zone that is available for plants to use or for evaporation into the atmosphere. Soil moisture affects runoff because snowmelt fills soil pores first, then it either flows through the soil (interflow) or over the soil (surface runoff) and eventually into streams. Once the soil pores are saturated with moisture, the water percolates down into the groundwater. Soil moisture can be measured directly by sensors in the ground at specific locations, or indirectly using radio waves to observe the amount of moisture in the ground. Neither one of these methods is trivial. Direct measurements are expensive to set up and do not provide data for a continuous area. Remote sensing with radio waves requires airplane or satellite flyovers, and while this provides continuous measurements, these are expensive and time consuming. National Weather Service (NWS) River Forecast Centers and the Natural Resources Conservation Service (NRCS), who produce water supply forecasts, have developed sophisticated methods for modeling the influence of soil moisture on water supplies based on variables like temperature, precipitation, and evapotranspiration (see text box, page 22). In addition, forecasters at the NOAA Climate Prediction Center (CPC) calculate soil moisture because it is an important factor in monthly and seasonal temperature and precipitation outlooks. This page focuses on the soil moisture calculations and outlooks produced by CPC.

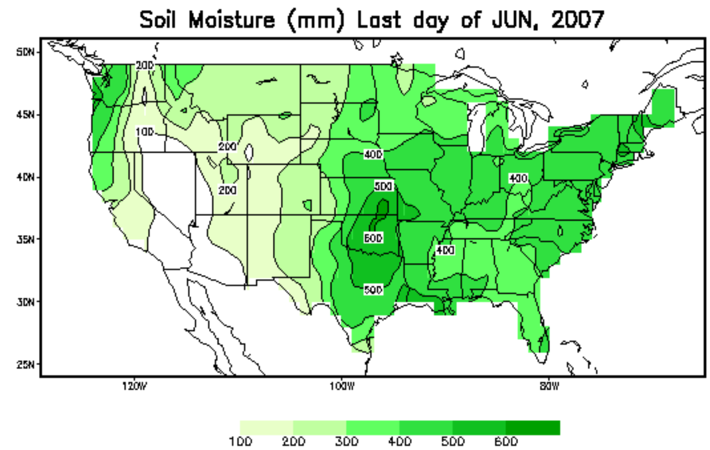


Figure 14a: Current soil moisture conditions as of June 30, 2007. The scale is in mm, which represents the amount of water the soil is holding with a possible total of 760mm. If you divide the soil moisture number in these figures by 760, you will get the % water by volume.

Why does CPC calculate soil moisture?
CPC uses soil moisture outlooks as a predictor in monthly and seasonal temperature and precipitation outlooks. Forecasters at CPC have noticed that precipitation one month has a large impact on the temperature the next month in the summer due to its contribution to soil moisture. Soil moisture is more predictive in temperature forecasts than precipitation alone, and the correlation between soil moisture and temperature is highest in warm months when evaporation is the highest. It works like this: solar radiation is used either to evaporate soil moisture or to warm the air. If it is evaporating the soil moisture, then the solar radiation cannot raise the air temperature. Therefore, higher soil moisture will effectively lower air temperature below what it would normally be. Researchers also found that soil moisture is a good predictor for future precipitation because increased evaporation from the soil and resulting humidity increases the likelihood of future precipitation. However, using soil moisture adds more skill to temperature forecasts than to precipitation forecasts.

How can water managers use CPC soil moisture products?
Soil moisture in late winter and early spring (February-April) may be used to make qualitative projections about how much snowpack may become runoff. This qualitative assessment is possible because soil moisture changes little during the winter. In the spring, melting snow first fills the soil moisture "reservoir" before it becomes spring and summer streamflow. Therefore, higher soil moisture in the fall means more snowmelt will become streamflow rather than infiltrate into the soil.

How does CPC calculate soil moisture?
The CPC began calculating soil moisture because there is not a spatially complete soil moisture monitoring network in the U.S., with the exception of a few states (Illinois, Iowa, and Nebraska). Observed precipitation and temperature[1] and estimated evapotranspiration, runoff, and groundwater loss are the parameters used in soil moisture calculations. The CPC soil moisture model can be represented by this equation[2]:

Change in soil moisture over time =
Precipitation – Evapotranspiration – Surface Runoff – Groundwater loss

Precipitation (and temperature) comes from observations, but the other variables in the soil moisture equation are calculated based on current weather conditions and constants that represent the water retention properties of soil. Evaporation estimates come from Thornthwaite's expression for potential evaporation, which uses temperature as an input. Soil properties, such as the capacity of soil pores to hold water and the infiltration rate, affect the runoff and groundwater loss by influencing the way water flows through the soil. The runoff estimate is based on a simple hydrologic model that includes soil conditions: a surface

[1] Precipitation and temperature observations come from COOP station data.
[2] See Huang, van den Dool, and Georgakakos et. al., 1996 or http://www.cpc.noaa.gov/products/soilmst/paper.html for a more detailed description of the soil moisture model. CPC now uses a high resolution and physically comprehensive four-layer Noah model (Fan, et al., 2006) alongside the simple Huang, et al. (1996) model.

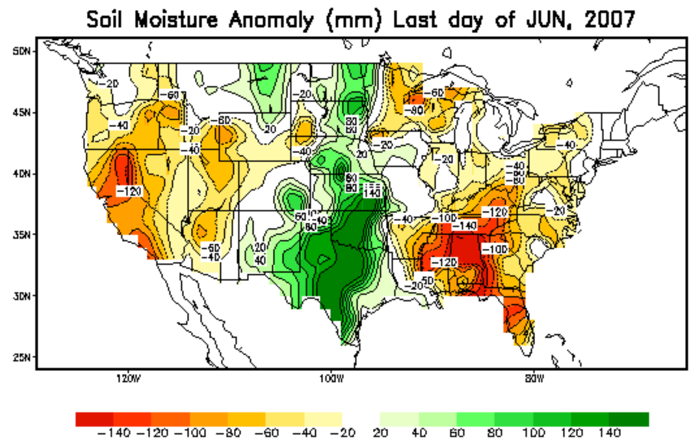


Figure 14b: Soil moisture anomalies as of June 30, 2007, relative to 1971-200- climatology. (CPC also shows maps of anomalies in terms of percentiles.)

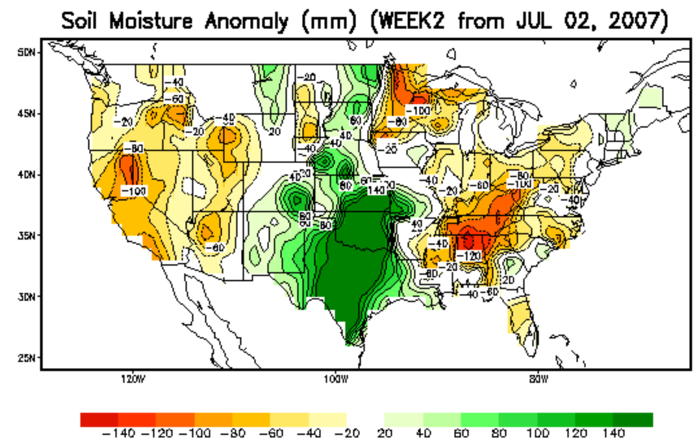


Figure 14c: Soil moisture anomalies forecasted for two weeks ahead (starting July 2, 2007) using temperature and precipitation forecasts from the GFS atmospheric model. CPC also produces maps of week 1 soil moisture outlooks and soil moisture anomaly change in the next two weeks.

runoff component and a subsurface (base flow) runoff component[3]. However, the model does not differentiate for different soil types in different locations because there is not an extensive soil moisture monitoring network across the country[4]. Instead, the model was calibrated with data from two small watersheds in Oklahoma using 1961-1990 data, and keeps these parameters constant across the entire US. Therefore, all of the variables in the soil moisture equation, except precipitation, come from data about soils in Oklahoma.

CPC's Soil Moisture Products

Current Conditions

CPC uses the soil moisture equation to create daily and monthly maps of current soil moisture conditions across the country[5] (Figure 14a). CPC found that the *spatial pattern* of soil moisture is largely determined by precipitation, but the *annual cycle* of soil moisture is largely determined by evaporation. Also, *anomalies* in soil moisture are driven by precipitation anomalies, but the *timescales* of soil moisture anomalies are determined by mean precipitation and mean evaporation (Huang, et al.1996). CPC used calculations of soil moisture from 1931 – present to establish a climatology of soil moisture, which they use to establish and interpret anomalies (Figure 14b).

Outlooks

Forecasters have developed two methods for creating soil moisture outlooks from forecasts of temperature and precipitation. While both methods use forecasts of temperature and precipitation in the soil moisture calculation explained above, they differ in forecast methodology and how far into the future they forecast soil moisture. One method uses an atmospheric model and the other uses a statistical model. The first method uses temperature and precipitation forecasts 1-2 weeks ahead from the GFS (Global Forecast System) atmospheric model as input for soil moisture outlooks for 1-2 weeks in the future (Figure 14c).

The second method, the Constructed Analogue Outlook for Soil Moisture (CAS), uses a statistical relationship between current soil moisture and future temperature and precipitation to generate temperature and precipitation outlooks 1-3 months ahead. CPC forecasters then use these temperature and precipitation outlooks to calculate soil moisture outlooks (Figure 14d). CPC found that they have about a 0.6 correlation in forecasting monthly soil moisture with a lead of one month (i.e. forecast for the month of July made at the end of May), and that the correlation is somewhat higher in early spring and lower in early fall (Van den Dool, et al. 2003).

Comparing CPC Soil moisture Calculations to Soil Moisture Observations

CPC verified their calculations with a long record of soil moisture observations in Illinois (19 sites with observations since 1981). The correlation was about 0.7 (Huang, et al.1996). However, it is difficult to compare CPC calculations to observations at NRCS SNOTEL and SCAN sites in the West. First, there is not a complete network of soil moisture sensors at all SNOTEL sites: only Utah and Nevada have soil moisture sensors at all sites. The SCAN network of soil moisture sensors is also incomplete across the West. Second, the soil moisture sensors at SNOTEL sites are relatively new and the network in Utah has a complete data set only back to April 2004, so there are not enough years of obser-

[3] CPC soil moisture calculations are also affected by runoff. Huug van den Dool of CPC says, "runoff depends on precipitation as well as soil moisture (the wetter the soil the more runoff). But soil moisture is depleted by the runoff obviously [soil moisture infiltrates and becomes subsurface flow, which moves laterally through the soil towards the stream, and eventually becomes baseflow]. This is commonplace in numerical modeling and taken care of in certain time stepping schemes."

[4] The NRCS is installing soil moisture sensors at some SNOTEL sites and other climate monitoring locations around the country, but the spatial coverage is still limited (see On the Web box).

[5] CPC uses daily COOP station data of temperature and precipitation for daily soil moisture maps and monthly climate division data for monthly soil moisture maps and climatology.

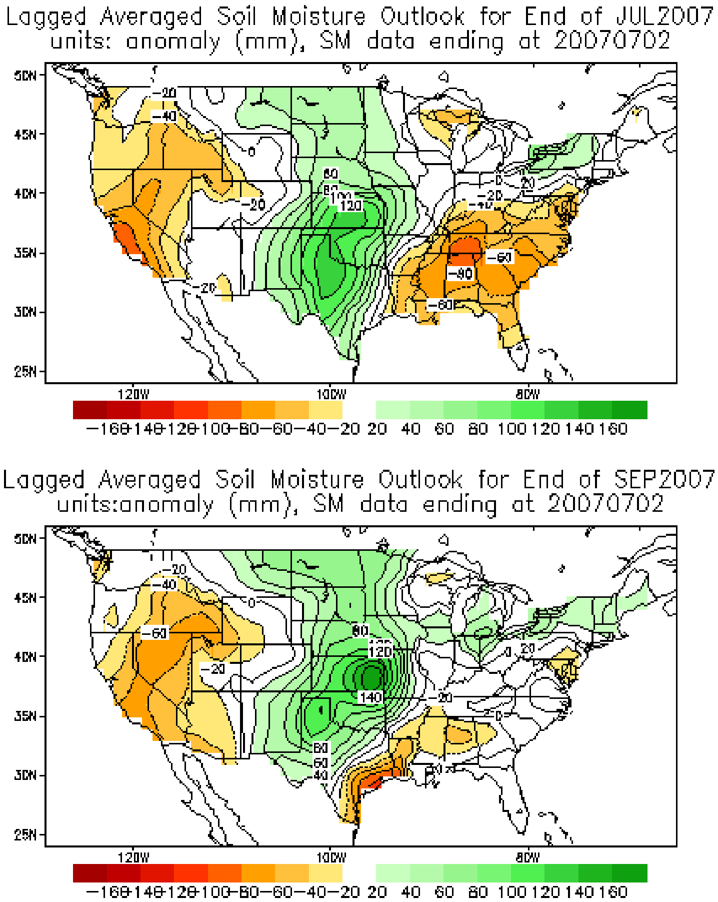


Figure 14d: Soil moisture anomalies forecasted for the end of the current month (July) and the current 3-month season (July-September) from the CAS model. The CAS model uses a statistical relationship to create temperature and precipitation forecasts from calculations of current soil moisture, and then it uses the forecasted temperature and precipitation values to calculate future soil moisture values.

vations to compare to the calculations. Finally, the biggest problem is that the SNOTEL sites are not co-located with the COOP weather stations where CPC gets the temperature and precipitation data for their soil moisture calculation. The weather data is likely to be very different at SNOTEL stations located at higher elevations compared to COOP stations located mostly at lower elevations. Therefore, the CPC soil moisture calculations might not be accurate for the higher elevation locations. SNOTEL stations also record temperature and precipitation, so in the future it is possible to include SNOTEL data in the CPC soil moisture calculations. Also, as the soil moisture observation network grows, and there is a longer record of observations, it will be possible to compare calculations to observations across the west. See On the Web box for websites with more information about soil moisture observations at NRCS SNOTEL and SCAN sites.

Sacramento Soil Moisture Accounting Model

The NWS River Forecast Centers, along with the NRCS, use a soil moisture model in their water supply forecasts of April-July streamflows. Like the CPC calculations, the Sacramento Soil Moisture Accounting Model (SAC) uses temperature, precipitation, and evapotranspiration inputs to model soil moisture, but the SAC goes a step further and models the effect of soil moisture on runoff. The SAC also has a much more complex mathematical description of the soil layers and the movement of water through these layers (Burnash and Ferral, 1996). Streamflow forecasters at NWS and NRCS are working on adding observations of soil moisture into their streamflow models as the data set becomes longer and more complete.

The author thanks the following people for their information and guidance in the research for this article: Huug van den Dool (NWS Climate Prediction Center), Randy Julander (NRCS), Tom Pagano (NRCS Water and Climate Center), Kevin Werner (NWS Western Region Office), and Seann Reed (NWS Office of Hydrology).

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Huang, J., H. M. van den Dool and K. G. Georgakakos, 1996: "Analysis of model-calculated soil moisture over the US (1931-1993) and applications to long-range temperature forecasts." *J. Climate*, **9**:1350-1362.

van den Dool, H., J. Huang, and Y. Fan, 2003: "Performance and analysis of the constructed analogue method applied to U.S. soil moisture over 1981-2001." *J. Geophys. Res*, **108**: 8617.

On the Web

CPC

- Soil moisture monitoring main page, including links to maps of current runoff, evaporation, precipitation and temperature: http://www.cpc.noaa.gov/products/soilmst/.
- Soil moisture maps: http://www.cpc.noaa.gov/products/soilmst/w.shtml.
- Detailed description of soil moisture model: http://www.cpc.noaa.gov/products/soilmst/paper.html.

Soil Moisture observations:

- NRCS Snotel: http://www.wcc.nrcs.usda.gov/snotel/.
- NRCS Utah soil moisture data: http://www.ut.nrcs.usda.gov/snow/climate/ or see the Focus Page in the June 2006 IWCS.
- NRCS SCAN: http://www.wcc.nrcs.usda.gov/scan/.