Intermountain West Climate Summary

by The Western Water Assessment

Issued June 23, 2008
Vol. 4, Issue 5

June 2008 Climate Summary

Hydrological Conditions — Moderate to severe drought persists in southwestern Wyoming, but it has decreased in severity. Drought severity has increased in southeastern Colorado, up to the extreme category.

Temperature— Temperatures across most of the region were 2-4 ºF below average in May, but Salt Lake City and areas of eastern Colorado were 0-2 ºF above average.

Precipitation— Precipitation was over 120% of average across most of Wyoming, central Utah and central Colorado in May, but areas of eastern and northwestern Colorado and northeastern Utah were below average.

ENSO — La Niña conditions continue to weaker and most models project that SST anomalies will decrease to neutral conditions during the June - August season.

Climate forecasts — During the July-September season, there is an increased chance of above average temperatures across much of the Intermountain West an increased chance of below average precipitation across Wyoming and northern Utah.

In This Issue

Recent Conditions

Forecasts

Rivers are Rising!

Typically rivers across the Intermountain West rise between mid-May and mid-June, but this year we have seen some rivers rising more than usual. Warm temperatures, rapid snowmelt, and in Wyoming, spring storms have brought several rivers close to flood stage. Flood warnings were issued for the Provo and Green Rivers in northern Utah in May and for the Colorado River in western Colorado in June. In Wyoming, the rising rivers are bringing much needed water to reservoirs that have not filled in years. There is still a lot of snow in the mountains, especially in Colorado, so flooding is still possible if warm weather continues to quickly melt the snowpack.

Frying Pan River in central Colorado at high flow
(Source: Colorado River Water Conservation District).

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

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North American Monsoon Variability: Implications to Water Resources Management in the Southwestern US

By Balaji Rajagopalan, WWA and Katrina Grantz[1] , USBR Upper Colorado Region

The North American Monsoon (NAM) is responsible for 50-70% of annual precipitation in the arid southwestern U.S., particularly Arizona and New Mexico. Water managers in this region are dependent on the NAM seasonal precipitation and resulting streamflows, which typically occur between July and September. However, water managers and scientists alike have observed a shift towards later NAM precipitation and streamflows in the last 30 years. Engineers at WWA and University of Colorado have analyzed this shift and its causes, and they have developed a forecasting tool that water managers in the southwest can use to save both water and money. This article summarizes our research on the spatial and temporal variability of NAM precipitation and streamflow in Arizona and New Mexico. We also give an example of the utility of the research in water management for the Pecos River basin (in New Mexico).

NAM Background

The NAM is a large-scale atmospheric circulation system that drives the dramatic increase in rainfall experienced in the desert southwestern U.S. and northwestern Mexico during the summer. Summer thunderstorms typically begin in early July and last until mid-September, accounting for as much as 50-70% of the annual precipitation in the arid region (Carleton et al. 1990; Douglas et al. 1993; Higgins et al. 1997; Mitchell et al. 2002; Sheppard et al. 2002). The typical daily NAM precipitation pattern generally peaks in the afternoon and early evening (Dai et al. 1999; Berbery 2001; Trenberth et al. 2003; Anderson and Kanamaru 2004). The timing of the onset of NAM each year depends on both atmospheric and land surface conditions. The NAM begins when the winds shift from westerly in winter to southerly in summer. This brings moist air from the Gulf of California, the eastern Pacific Ocean and the Gulf of Mexico northward to the land during

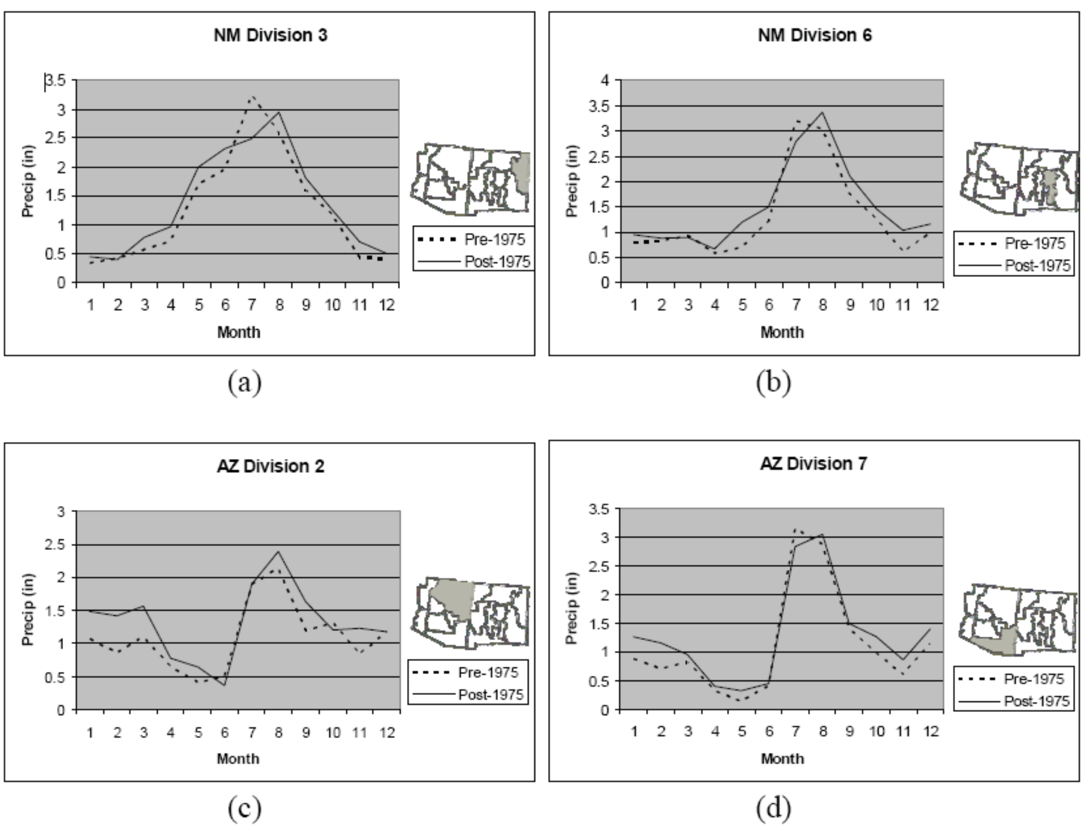

Figure 1a: Shows the shift in the annual cycle at couple of locations in the South Western US. Annual cycle of precipitation during 1948-1975 (dashed line) and 1976-2004 (solid line) at two climate divisions in New Mexico (a, b) and two climate divisions in Arizona (c, d)

[1]This research was part of Dr. Grantz's PhD dissertation in the Department of Civil, Environmental, and Architectural Engineering at the University of Colorado under the direction of Dr. Rajagopalan (http://cadswes.colorado.edu/PDF/Theses-PhD/GrantzPhD2007.pdf).

the summer months (Adams and Comrie 1997). As the moist air interacts with the rising air over the hot desert , there is an increase of convective instability, which causes frequent summer precipitation events (Adams and Comrie 1997; Barlow et al. 1998).

Shift in NAM precipitation and streamflows

After analyzing the precipitation and streamflow trends in the southwestern U.S. (Arizona and New Mexico) between 1948 and 1999, we attributed the shift toward a later onset of the NAM to a chain of large and small-scale atmospheric patterns.

We observed a trend toward NAM precipitation beginning late and extending beyond the typical end time. Through an analysis of daily precipitation for the summer season (Jul – Sep), they found a significant delay (approximately 10-20 days) in the entire summer rainfall cycle. The delay resulted in a decrease in rainfall during the early monsoon (July) and an increase in rainfall during the late monsoon (August and September; Figure 1d).

During this same period, the authors observed a trend of increased antecedent (winter/spring) rainfall and resulting soil moisture. We observed nterestingly, this antecedent rainfall affects climate conditions that help bring on the start of the monsoon. Several recent studies have demonstrated an inverse relationship between winter precipitation, particularly snowfall, and subsequent summer monsoon precipitation (Higgins et al. 1998; Gutzler 2000; Higgins and Shi 2000; Lo and Clark 2002; Zhu et al. 2005). Researchers theorize that above average winter precipitation results in above average spring and summer soil moisture, which continues to evaporate well into the summer months. Greater amounts of snowfall in winter require more energy to melt and evaporate the moisture by summer. This delays the land surface warming and the formation of the land-ocean temperature contrast necessary for monsoonal circulation patterns, thus delaying the onset of the NAM.

We attribute the increased antecedent rainfall, resulting soil moisture, and delayed onset of NAM precipitation with large-scale ocean-atmosphere conditions, in particular the El Niño Southern Oscillation (ENSO). The El Niño phase is associated with above average precipitation in the southwestern U.S. during winter months, and this phase has been more active in recent decades. Combining these observations completes the delayed NAM onset causal chain of events (Grantz et al. 2007):

* A more active ENSO cycle leads to more frequent El Niño phases, which causes increased winter precipitation in the southwestern U.S., resulting in increased spring and summer soil moisture.
* This moisture takes longer to evaporate and as a result, the land surface takes longer to heat up. This delays the onset of convection and NAM precipitation.
* The delayed onset of NAM shifts the timing of precipitation, causing below average precipitation in July and above average precipitation in September and October (Figure 1b).

Consequently, a delayed NAM onset affects streamflow timing, as well. During the study period, the authors observed an increase in winter and spring streamflows and a trend toward a later seasonal peak in summer streamflows. This change was especially pronounced in southern areas of Arizona and New Mexico, where up to 80% of annual precipitation occurs during the monsoon season (Grantz 2006).

Potential use for water resources management: Pecos River Basin, NM

The links between antecedent rainfall, NAM precipitation, and land/ocean interactions offer hope for long-lead forecasts of the summer monsoon. In addition, the relationship between winter precipitation and summer NAM precipitation is very important for streamflow prediction. Our understanding of the variability of summer monsoon precipitation and related was used streamflows to generate ensemble streamflow forecasts in the Pecos River basin.

Like most river basins in the western U.S., the Pecos River basin in central New Mexico (Figure 1c), has multiple competing demands for its limited water resources. The reservoirs of the Pecos River system are operated primarily to optimize water delivery to farmers of the Carlsbad Irrigation District (CID) and to protect the habitat of the endangered Pecos Bluntnose Shiner fish. In addition, Pecos River water is managed for inter-state flow deliveries to Texas (Boroughs and Stockton 2005).

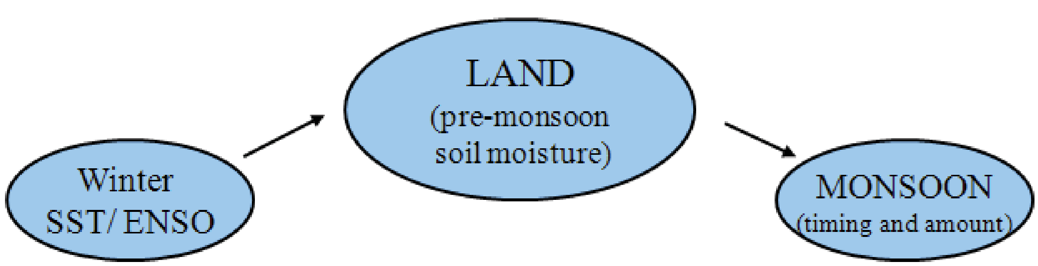

Figure 1b: Schematic of land-ocean-atmospheric processes that interact to cause the onset of the NAM.

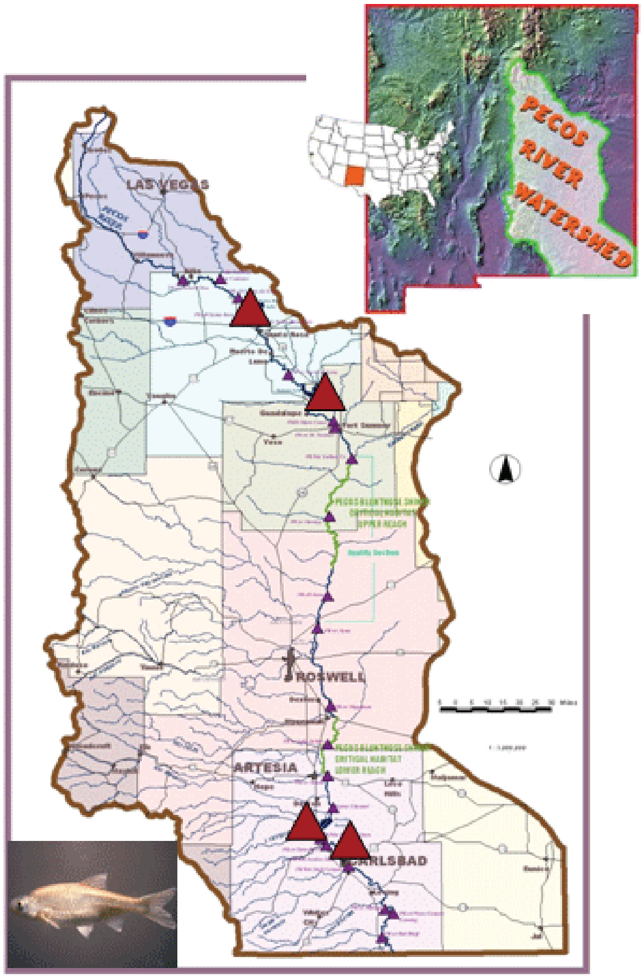

Figure 1c: Pecos River study area. Triangles represent reservoirs, which are primarily managed for irrigation by the Carlsbad Irrigation District. Streamflows are also managed for the protection of the endangered Pecos Bluntnose Shiner (lower left). (Source: Craig Boroughs and New Mexico Interstate Stream Commission (NMISC).

We used a suite of large-scale land-ocean-atmosphere predictors in a statistical forecasting method to generate ensemble streamflows. The forecast of the seasonal streamflows are very skillful, especially when forecasting wet years (Figure 1d). Pecos River Basin water management operates under the conservative assumption that each year will be a dry year (below average NAM precipitation), so the high forecast skill in wet years has important implications for capitalizing on this “extra” water. For example, under the dry year assumption, extra water not allotted to irrigation spills out of reservoirs, but it does not count toward the inter-state compact with Texas. Water managers could take advantage of the wet year forecast by alloting more water to irrigation and not overfilling their reservoirs.

We compared hypothetical operations decisions based on forecasts with operations using existing criteria (e.g. assuming a dry year) in order to evaluate potential benefits to Pecos River water managers. Two scenarios were tested: (i) the inclusion of streamflow forecasts in the calculation of irrigation allotments to provide a better estimate of the season’s available water, and (ii) the reduction of block releases in forecasted wet years to better capture monsoon runoff in the lower Pecos basin and reduce spill to Texas. The results of scenario (i) show that water managers could allot 14% more water to irrigators using the forecasts (Figure 1e). The results for scenario (ii) show insignificant improvements due to the relative size of block releases in comparison with large monsoon events. The coupling of streamflow forecasts with a decision tool in the Pecos River Basin demonstrates that using large-scale climate information to predict NAM streamflow can have significant positive impacts on water management in the region.

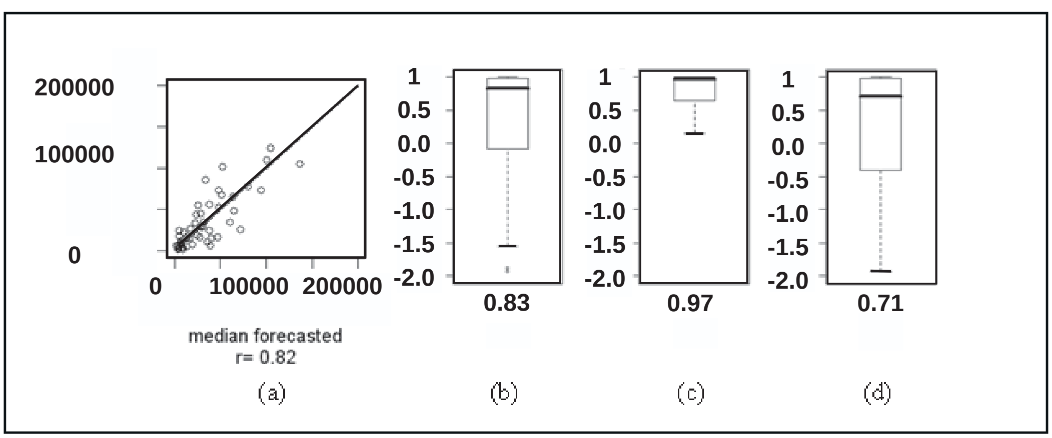

Figure 1d. Skill scores for the May 1st forecast of May - June upper Pecos River streamflow. The median of the ensemble forecast versus the observed streamflow is shown in (a). The RPSS (a categorical skill score) is shown broken into three categories: all years (b), wet years (c) and dry years (d). Median RPSS values are listed below the boxplots, and forecasts for wet years have the highest skill.

Conclusion

The North American Monsoon is responsible for a large portion of annual precipitation and resulting streamflows in the arid southwestern U.S. Scientists have observed changes in the monsoonal pattern, specifically a shift towards a later onset of the monsoon. By attributing these changes to large-scale atmospheric circulation patterns, we were able to develop a streamflow forecasting tool that could potentially help water managers increase the efficiency of annual water supply operations.

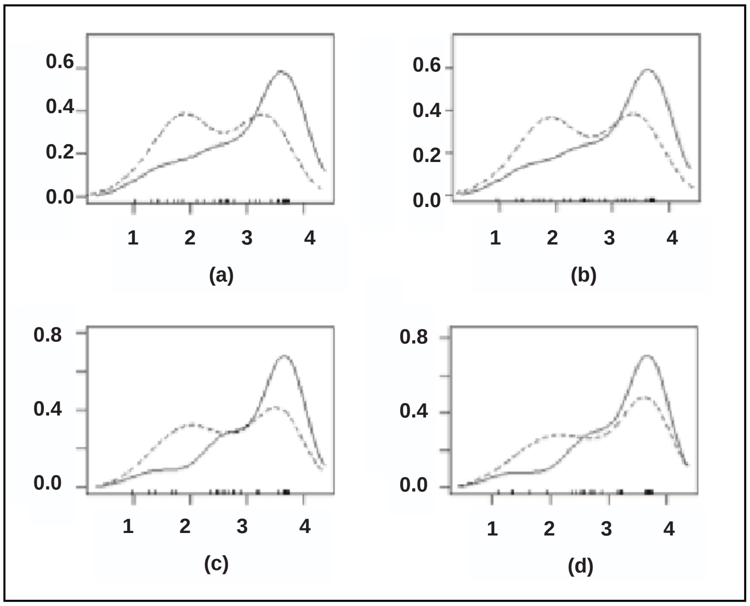

Figure 1e. Probability density functions (PDFs) of allotments (acre-ft/acre) for March 1st (a), May 1st (b), June 1st (c) and July 15th (d). The solid lines represent allotments based on the forecasts and the dashed lines represent baseline scenarios. Management decision based on forecasts would allow higher allotments at all time periods.

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Temperature 05/01/08 – 05/31/08

The NOAA National Climatic Data Center just released a summary of temperature and precipitation for May 2008, and found that Utah, Wyoming and Colorado each had the 25th, 21st, and 26th respectively coolest spring period (March – May) in the 114 year record back to 1895 (http://www.ncdc.noaa.gov/oa/climate/research/2008/may/may08.html).

Monthly average temperature for May 2008 in the Intermountain West region ranged from 40-65°F (Figure 2a). The warmest areas (60-65°F) were across southern **Utah** and southeastern **Colorado**. Temperatures were 1-2°F above average in southeastern and parts of central **Colorado**, 2-3°F above average near Salt Lake City, **Utah**, and near or below average for the remainder of the region (Figure 2b). Central, eastern, southwestern and northwestern **Utah**, central, eastern and western **Wyoming**, and central **Colorado** all had areas between 2 - 4°F below average.

Numerous high and low temperature records were broken in May 2008, especially in **Utah**. First, a record low minimum temperature of 46°F on May 1 in Bountiful Val Verda, **Utah**, breaking the previous record of 51°F set in 1983. Then two record high temperatures were set in **Utah**: on May 18 it was 95°F in Delta, beating the previous high of 92°F from 2006, and on May 20 it was 93°F at the Salt Lake City airport, beating the previous record of 92°F set in 1958. The next day temperatures dropped, and the high in Salt Lake City on May 21 was 52 ºF, which is 21 degrees below the average of 73 ºF. Finally, on May 27 at Bryce Canyon Airport, the low was 23°F, breaking the previous record low of 25°F from 1978. These temperature fluctuations have had a major impact on the snowpack and snowmelt streamflows throughout **Utah** (see **Utah** water availability page, p. 14).

In 2007, May temperatures were higher than in 2008 throughout most of the IMW region (0-5°above average; Figure 2c). The exceptions were a few areas in southern **Colorado** which were around 0-5°F below average in May 2007.

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.

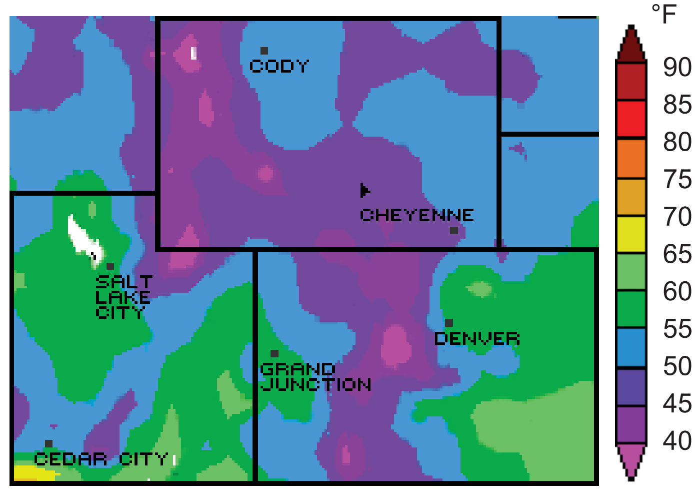


Figure 2a. Average temperature for the month of May 2008 in °F.

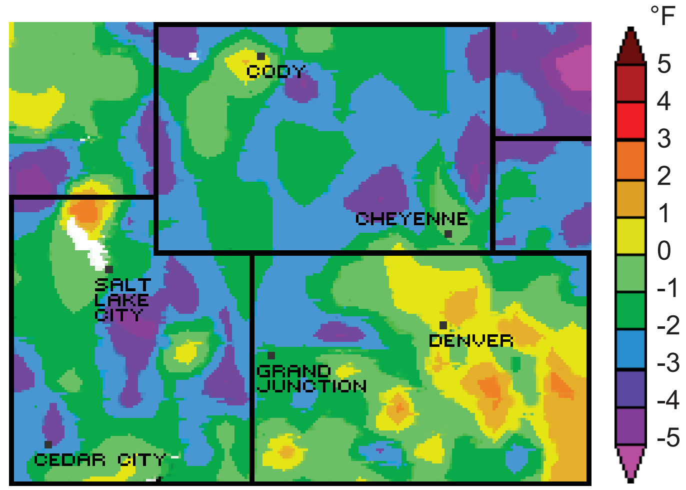


Figure 2b. Departure from average temperature for the month of May 2008 in °F.

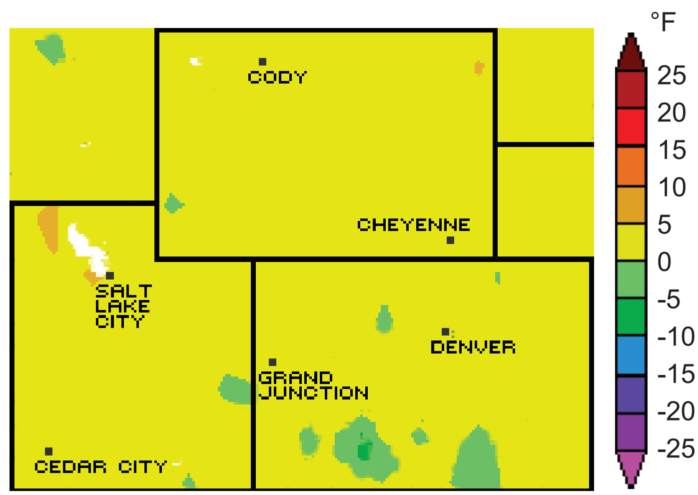


Figure 2c. Departure from average temperature in °F for last year, May 2007.

On the Web

- For maps like Figures 2 a-c 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 05/01/08 – 05/31/08

Total precipitation for May 2008 in the Intermountain West region ranged from 0.25 - 3+ inches (Figure 3a). Most of **Wyoming** and north-central **Colorado** received the highest totals (3+ inches). South-central **Utah** and small pockets scattered throughout **Utah** and **Colorado** received the least amount of precipitation (0.25-0.5 inches).

Most of the region had near or above average precipitation for May (Figure 3b). Most of **Wyoming**, southern **Utah**, and southwestern **Colorado** had 150-200+% of average precipitation. A record daily maximum rainfall of .55 inches was recorded on May 24 in Rock Springs, **Wyoming**, breaking the previous record of .50 inches set in 1996. A record daily maximum snowfall of .4 inches was set at Grand Junction, **Colorado** on May 1. This is the first measurable snow on record to fall in Grand Junction on the first of May, and only the tenth time measurable snow has fallen in Grand Junction during the month of May. Eastern **Colorado**, however, had well below average precipitation in May (<40-80% of average). Portions of northeastern and northwestern **Utah** also had below average precipitation (40-80% of average).

The IMW region generally had near-average or above average precipitation since the start of the water year (Figure 3c). The highest precipitation as a percent of average has been along the **Colorado/Utah** border, central **Colorado**, central **Utah**, and scattered throughout **Wyoming** (110-150+% of average). Areas with below average precipitation are eastern **Colorado**, with southeastern **Colorado** receiving less than 50% of average during the water year. Other relatively dry areas include southwestern **Wyoming** and south central **Utah** (70-90% of average).

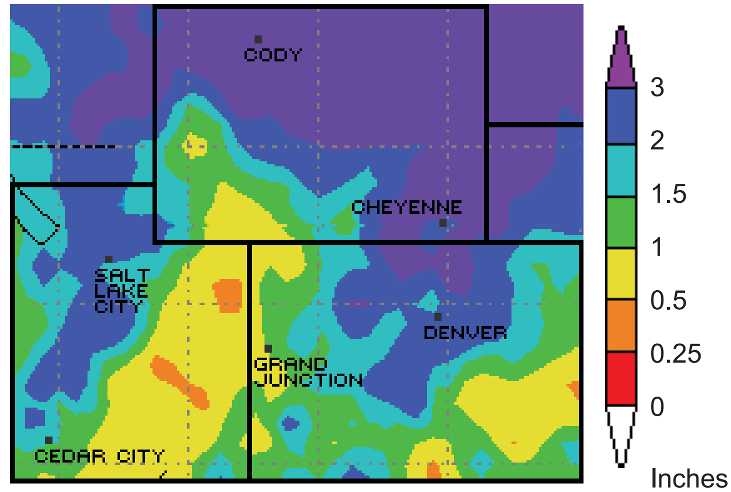


Figure 3a. Total precipitation in inches for the month of May 2008.

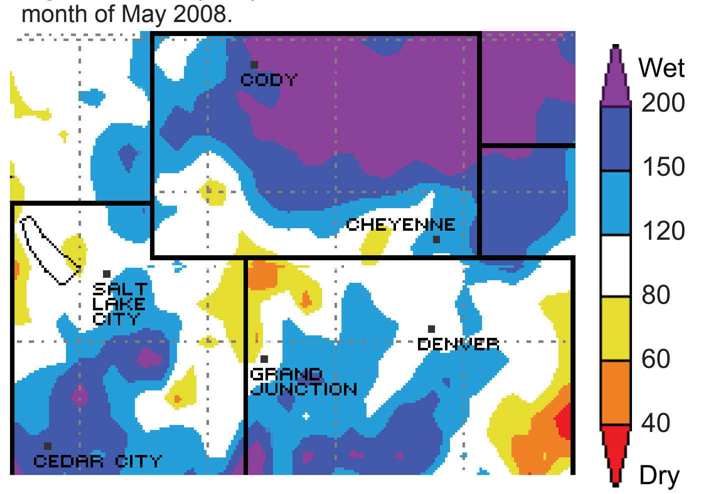


Figure 3b. Percent of average precipitation for the month of May 2008.

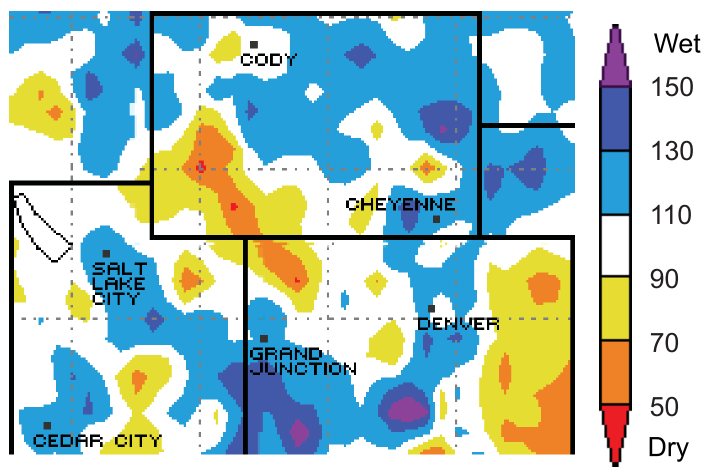


Figure 3c. Percent of average precipitation accumulation since the start of the water year 2008 (Oct. 1, 2007 – May 31, 2008).

Notes

The data in Figs. 3 a-c come 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. The water year runs from October 1 to September 30 of the following year. The 2008 water year began October 1, 2007 (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 1971- 2000. Percent of average precipitation is calculated by taking the ratio of current to average precipitation and multiplying by 100.

On the Web

- For precipitation maps like Figures 3 a-c, which are updated daily visit: http://www.cdc.noaa.gov/Drought/.
- For other precipitation maps including individual station data, visit: http://www.hprcc.unl.edu/maps/current/
- 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.

Regional Standardized Precipitation Index data through 04/30/08

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. 3- and 6-month SPIs are useful in short-term agricultural applications. Longer-term SPIs (12 months and longer) are useful in hydrological applications.

Due to below average precipitation in May in the eastern portion of **Colorado**, all climate divisions (except the Colorado Drainage division in the west) moved into drier categories in the 3-month SPI (Figure 4a). The driest climate division in **Colorado** remains the Arkansas Drainage division in the southeast, which is now in the very dry category. Western **Utah** also had below average precipitation in May, and the Western Division moved into the very dry from the moderately dry category. Only northern **Wyoming** had a change to wetter categories this month. Above average precipitation throughout the state in May led to two climate divisions (Powder/Little Missouri/Tongue and Belle Fouche Drainage divisions in the northeast) moving from near normal to the very wet category. The Big Horn division in north-central **Wyoming** moved from the near normal to the moderately wet division (See page 8 for recent precipitation conditions).

Changes in the 12-month SPI for May 2008 were similar to changes in the 3-month SPI. The Arkansas Drainage division in **Colorado** moved into a drier category and three divisions in northern **Wyoming** moved into wetter categories (Figure 4b). There were no changes in **Utah**.

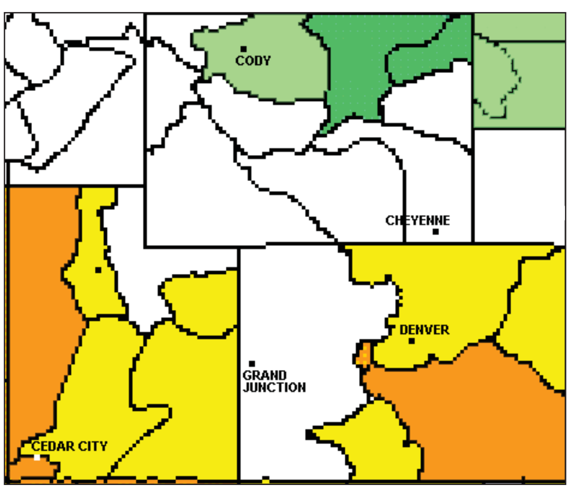


Figure 4a. 3-month Intermountain West regional Standardized Precipitation Index (data from 03/1/08 - 05 /31/08).

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.

The 3-month SPI uses data for the last three months and represents short-term precipitation patterns (Figure 4a). The 12-month SPI (Figure 4b) 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. Figures 4a and b come from the Western Regional Climate Center, which uses data from the NCDC and the NOAA Climate Prediction Center.

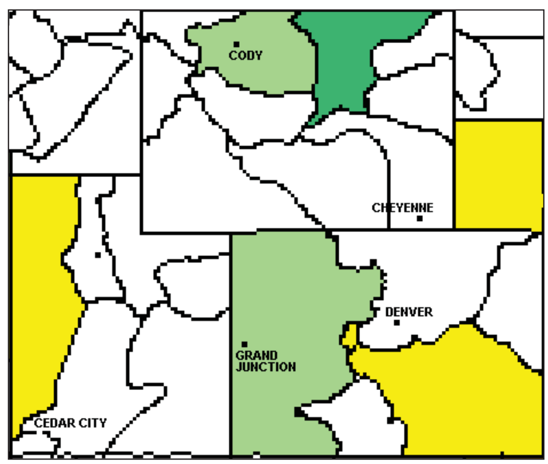


Figure 4b. 12-month Intermountain West regional Standardized Precipitation Index (data from 06/1/07 - 05/31/08).

+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

On the Web

- 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 Figures 4a and b, but the categories are defined slightly differently.

U.S. Drought Monitor conditions as of 6/17/08

The U.S. Drought Monitor (Figure 5) shows a decrease in drought severity in **Utah** and **Wyoming** and an increase in drought severity in **Colorado** since last month (see inset). Due to continued below average precipitation, the highest drought intensity in the IMW region is now in southeastern **Colorado** (D3-extreme drought), and the whole eastern half of the state is between abnormally dry (D0) and severe drought (D2).

The Drought Impact Reporter shows several problems or potential problems related to ongoing drought in parts of the Intermountain West. There is a fire ban in Prowers County in southeast **Colorado** and in Converse County in eastern **Wyoming**. As of June 17, 2008 a fire in southern **Utah** west of Escalante was burning 2,250 acres. Drought is also affecting the economy and the environment. In **Colorado**, Prowers County declared a state of emergency because five years of drought created economic hardships for farmers, ranchers, and other businesses. In southwest **Utah**, a study shows that the population of endangered desert tortoises in the Red Cliff Desert Reserve declined by nearly 50% since 2000 (from over 3,200 to 1,700), according to the Utah Division of Wildlife Resources. Drought decreases the tortoises' food supply and makes them weaker and more susceptible to disease.

Notes

The U. S. Drought Monitor (Figure 5) 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 summary'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.

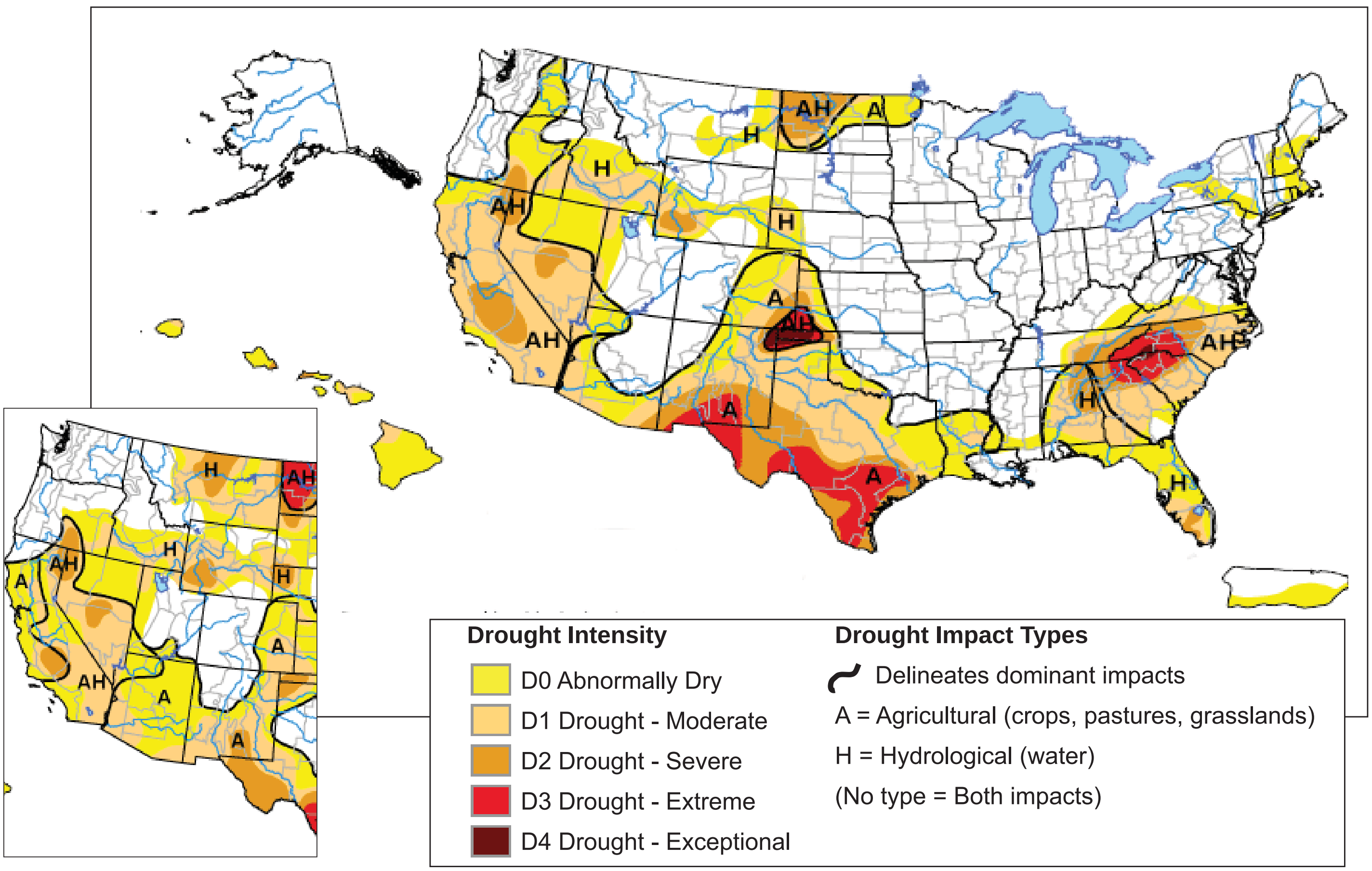


Figure 5. Drought Monitor from June 17, 2008 (full size) and May 13, 2008 (inset, lower left) for comparison.

On the Web

- For the most recent Drought Monitor, released every Thursday, 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/.
- NIDIS Drought Portal: http://www.drought.gov.

Reservoir Supply Conditions

Reservoirs began to fill in May for the 2008 season. Due to above average snowpack, water managers in **Colorado** are expecting above average reservoir inflows in most basins. Most Colorado reservoirs in Figure 6 are near or above average, except for Turquoise Lake, which went from 57% of average on May 1 to 65% of average on June 1. Reservoir storage declined as a percent of average in some places because water managers released water from some reservoirs to ensure room for above average streamflows. Storage in Dillon Reservoir, Pueblo Reservoir, and Blue Mesa Reservoir declined since last month, but the reservoir with the highest storage as a percent of average is still Pueblo reservoir on the Arkansas River (141% of average). The headwaters of the Arkansas and Gunnison Rivers had some of the highest snowfall in several decades, and streamflows are expected to be 140% to 160% of average this year in those basins.

In **Utah**, reservoir storage ranges from a low of 38% of average in Bear Lake, to a high of 133% of average in Strawberry Reservoir. The USBR expects that Lake Powell will be at 64% of capacity by late July, which is 50 feet above the lowest elevation in 2008 (on March 11).

Most reservoirs in **Wyoming** have above average storage in the Green River basin (e.g. Fontenelle and Flaming Gorge), and the lowest reservoir storage is in the North Platte River basin (e.g. Seminoe). This is the opposite of reservoir inflow projections, which are above average in the North Platte and below average in the Green River basin. Of the reservoirs in Figure 6, the lowest storage is in still Seminoe Reservoir (68% of average), but this is 19 percentage points higher than last month. The highest is still in Buffalo Bill Reservoir (137% of average). Despite below average inflow projections, the USBR projects that Fontenelle Reservoir will fill by late July.

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 6). The first percentage shown in the table is the current contents divided by the total capacity. The second percentage shown is the current contents divided by the average storage for this time of year (not shown). Reservoir status is updated at different times for individual reservoirs.

Reservoir	Current Storage (KAF)	Total Capacity (KAF)	% Full	% of Average
Colorado				
Dillon Reservoir	221.9	254.0	87%	97%
Turquiose Lake	54.5	129.4	42%	65%
Lake Granby	344.7	539.7	64%	102%
Blue Mesa Res.	475	829.5	57%	92%
Pueblo	225.8	354.0	64%	141%
Utah				
Strawberry Res.	931.5	1,106.5	84%	133%
Utah Lake	810.0	870.9	93%	94%
Bear Lake	355.3	1302.0	27%	38%
Lake Powell	12898.1	24322.0	53%	69%
Wyoming				
Fontenelle Res.	111.8	344.8	51%	98%
Flaming Gorge Res.	3043.3	3749.0	81%	100%
Seminoe Res.	404	1017.2	40%	68%
Boysen Res.	514.4	741.6	69%	101%
Buffalo Bill Res.	479	644.1	74%	137%

KAF = Thousands of Acre Feet

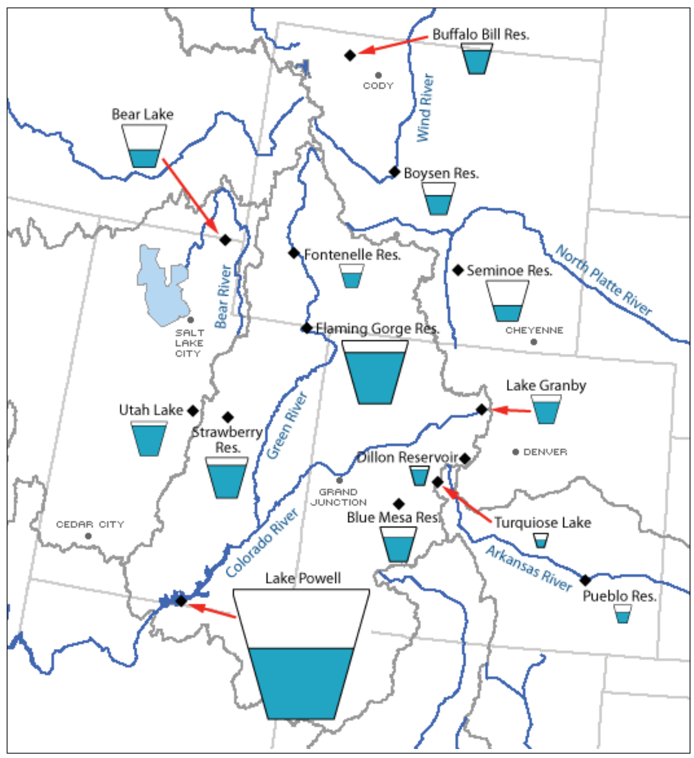


Figure 6. Tea-cup diagram and table of several large reservoirs in the Intermountain West Region. All reservoir content data is from May 31 and June 1, 2008.

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. The NOAA/NWS Seasonal Runoff Volume Forecast website is: http://www.cbrfc.noaa.gov/westernwater.
- For individual site-specific streamflow forecasting information, click on desired region and drag mouse over square box.
- For individual forecast point plot graphs click on the desired square box.
- Monthly reports from NRCS on water supply conditions & forecasts for major CO river basins, visit: http://www.wcc.nrcs.usda.gov/cgibin/bor.pl.
- Water Supply Outlook for the Upper Colorado River Basin, produced by the CBRFC at: http://www.cbrfc.noaa.gov/wsup/wsup.cgi.

Colorado Water Availability

Snowmelt began in May in Colorado, especially in the south. This led to high streamflows, and SWE values are below average in the south and the Yampa/White basins in the north, according to the NRCS. As of June 3, 2008, the majority of the USGS streamflow sites in western Colorado had values in the above average (75th – 90th percentile) to much above average (above the 90th percentile) categories (Figure 9a). The eastern slope had lower streamflows. The Arkansas River and its tributaries had streamflows in the average (25th – 75th percentile) or below average (10th – 24th percentile) categories.

Due to above average seasonal snowfall, water supply forecasts are still above average for most of the state. Many water managers are releasing water to make room for above average inflows, which resulted in storage percentages decreasing slightly in most basins (see reservoir page 11). As snowmelt continues during the next few months, storage volumes are expected to recover these losses. The highest volumes are expected to occur throughout the Gunnison and Arkansas River basins (140% to 160% of average). Throughout portions of the Yampa, Colorado, San Juan, and Rio Grande basins, forecasts range from 110% to 140% of average. For example, the inflow forecast for Dillon Reservoir is 156% of normal as of June 1 (Figure 9b). Below average streamflows are expected in the lower elevations of the South Platte and Arkansas Rivers. These areas depend on spring precipitation to contribute to streamflows, but they have had below average precipitation for the past few months.

Notes

The average streamflow conditions for the past 7 days are compared to streamflows during the same time period in past years (Figure 7a). The “near normal” or 25th – 75th percentile class indicates 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. This data is provisional and may be subject to significant change.

Site-specific forecast graphs (Figure 7b), feature observed and forecasted streamflow information from the NWS Western Water Supply Forecast website (see On the Web box). Users click on a region of the map and then on specific forecast points to load forecast information displayed as a graph. The most probable forecasts (50% exceedence probability) for the current water year are displayed as red circles. Streamflow forecasts are based on NRCS monthly forecasts and other NOAA/NWS RFC forecast points. See May 2007 Intermountain West Climate Summary (IWCS) focus page (see On the Web for URL) for detailed description of the graph.

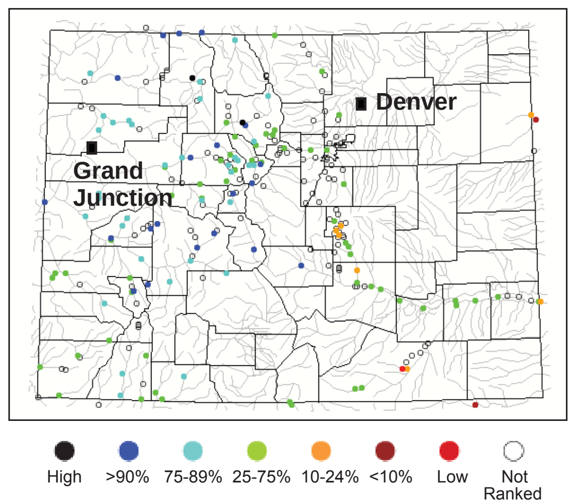


Figure 7a. 7-day average streamflow conditions for points in Colorado as of June 3, 2008 recorded at USGS gauging stations.

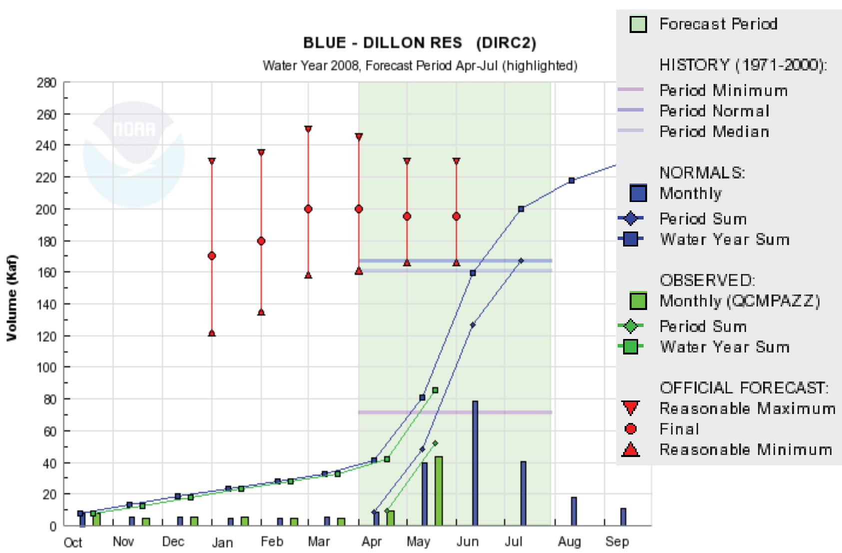


Figure 7b. Streamflow volume (kaf) forecast graph for inflow into Dillon Reservoir on the Blue River, a tributary of the Colorado River. Forecasts generated by the NOAA/NWS (data through June 1, 2008), The forecast is for 195 kaf, compared to average of 167 kaf. Above average snowpack through out the winter has resulted in an increase in April-July streamflow volume forecasts since the first forecast was issued in January.

On the Web

- For current streamflow information from USGS, Figure 7a, visit: http://water.usgs.gov/waterwatch/
- The NOAA/NWS Seasonal Runoff Volume Forecast (Figure 7b) website is: http://www.cbrfc.noaa.gov/westernwater. For individual site-specific streamflow forecasting information, click on desired region and drag mouse over square box. For individual forecast point plot graphs click on the desired square box.
- For monthly reports on water supply conditions & forecasts for major CO river basins, visit: http://www.co.nrcs.usda.gov/snow/snow/snow_all.html and click on “Basin Outlook Reports.”
- The Colorado SWSI along with more data about current water supply conditions for the state can be found at: http://www.co.nrcs.usda.gov/snow/fcst/watershed/current/monthly/maps_graphs/index.html
- The Colorado Water Availability Task Force information, including agenda & minutes of upcoming & previous meetings is available at: http://www.cwcb.state.co.us/Conservation/Drought/taskForceAgendaMinPres.htm.

Wyoming Water Availability

A cool spring and above average precipitation across the state in May have maintained SWE values above average. Runoff is below average in the Green River and Little Bear River basins (70-90% of average), but above average everywhere else. As of June 3, 2008, the majority of the USGS streamflow sites in Wyoming had values in the average category (25th - 75th percentile; Figure 8a), especially in the west. Some stations in the North Platte River in the south and in the Powder and Tongue rivers in the north reported flows in the much above average category (above the 90th percentile).

Reservoir inflow forecasts range from much above average in the North Platte River basin (110-130+% of average) to near average in the Snake River basin (90-110% of average) and much below average in the Green river basin (<70% of average). However, the reservoir storage is the opposite at this point: below average at Seminoe Reservoir on the North Platte River and above average on the Green River (see reservoir page 11). The reservoir inflow forecast for Fontenelle on the Green River is 69% of average, according to the USBR (Figure 8b). Even with this low forecast, Fontenelle Reservoir will still likely fill this year by late July.

Notes

The average streamflow conditions for the past 7 days are compared to streamflows during the same time period in past years (Figure 8a). The "near normal" or 25th – 75th percentile class indicates 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. This data is provisional and may be subject to significant change.

Site-specific forecast graphs (Figure 8b), feature observed and forecasted streamflow information from the NWS Western Water Supply Forecast website (see On the Web box). Users click on a region of the map and then on specific forecast points to load forecast information displayed as a graph. The most probable forecasts (50% exceedence probability) for the current water year are displayed as red circles. Streamflow forecasts are based on NRCS monthly forecasts and other NOAA/NWS RFC forecast points. See May 2007 Intermountain West Climate Summary (IWCS) focus page (see On the Web for URL) for detailed description of the graph.

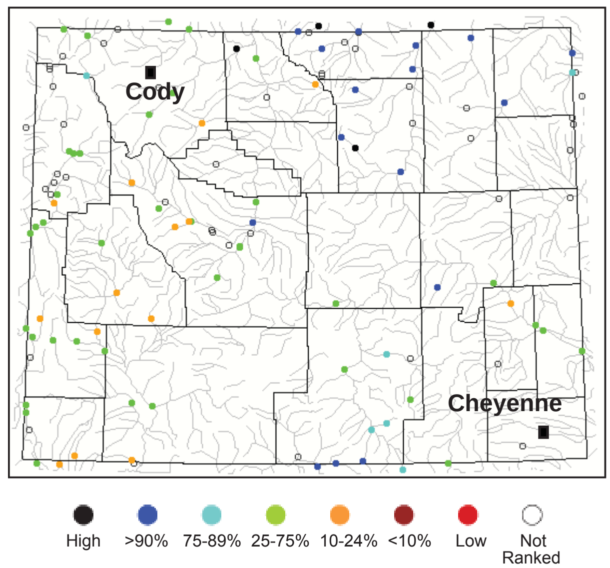


Figure 8a. 7-day average streamflow conditions for points in Wyoming as of June 3, 2008 recorded at USGS gauging stations.

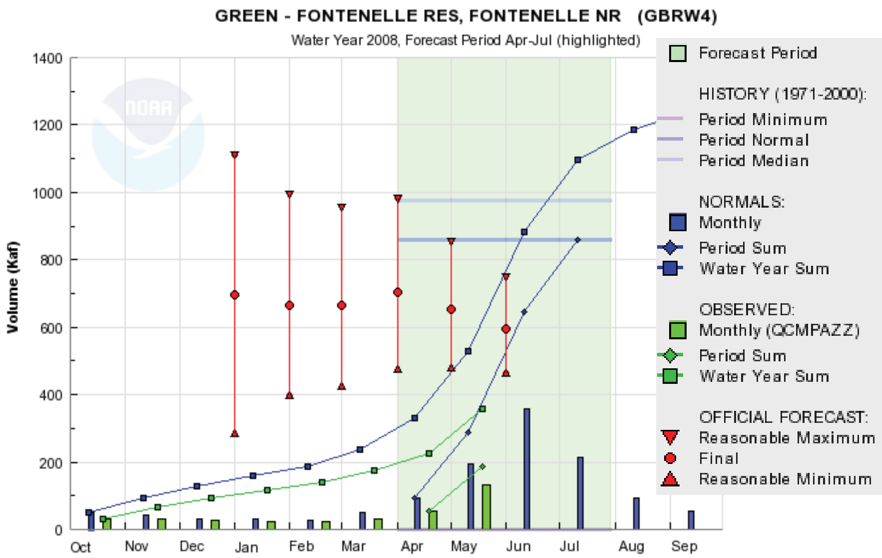


Figure 8b. Streamflow volume (kaf) forecast graph for inflow into Fontenelle Reservoir on the Green River. Forecasts generated by the NOAA/NWS (data through June1, 2008). Below average snowpack since April has resulted in a decrease in April-July streamflow volume forecasts since the forecast issued on April 1. The forecast is for 495 kaf, compared to average of 860 kaf.

On the Web

- For current streamflow information from USGS, Figure 8a, visit: http://water.usgs.gov/waterwatch/
- The NOAA/NWS Seasonal Runoff Volume Forecast (Figure 8b) website is: http://www.cbrfc.noaa.gov/westernwater.
  For individual site-specific streamflow forecasting information, click on desired region and drag mouse over square box.
  For individual forecast point plot graphs click on the desired square box.
- The Wyoming SWSI, along with more data about current water supply conditions for the state can be found at: http://www.wrds.uwyo.edu/wrds/nrcs/nrcs.html.
- 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.
- Wyoming Water Resource Data system's drought page is located at: http://www.wrds.uwyo.edu/wrds/wsc/dtf/drought.html.

Utah Water Availability

As of June 4, 2008, the majority of the USGS streamflow sites in Utah had values in the average category (25th-75th percentile; Figure 9a). The exceptions were Duchesne River at Myton, UT at much below average (6%), Weber River near Coalville at 2%, Rock Creek near Mountain Home at 4% and Virgin River near Hurricane at 5%. The Colorado River near the Utah, Colorado state line was much above average at 91%.

May 2008 had unusually large temperature changes, which affected snowpack and streamflows. First, above average temperatures on May 20 caused snow to melt very fast and streamflows to increase to above average. Then the next day, high temps were 20 degrees below average, which quickly halted snowmelt. At Trial Lake (headwaters of the Bear, Provo, Weber and Duchesne Rivers) the maximum temperatures ranged between 55 °F to 60 °F degrees for four days in a row and then dropped to the high 30's and low 40's. Highs in this lower range prevent substantial snowmelt. Lower melt rates allow a greater proportion of that melt to infiltrate to deeper levels of the watershed and less to run off into streams. Cool springs prolong the melt period, and the longer the melt period, the greater the potential loss to various sources. Warm springs shorten the melt period, which leads to a higher proportion of the snow entering streams and reservoirs rather than seeping into the ground.

Reservoir inflow forecasts for Strawberry Reservoir are just below average (Figure 9b). This is similar to other reservoirs for central and northern Utah. Reservoir inflow forecasts for that part of the state range from 70-110% of average, according to the NWS Western Water Supply Forecast website (see On the Web box). The highest reservoir projections are in the southeast, on the San Juan and Colorado Rivers (110-130% of average). The lowest reservoir inflow forecasts are on the northern tributaries to the Colorado River and on the Virgin river in the southwest (less than 70% of average).

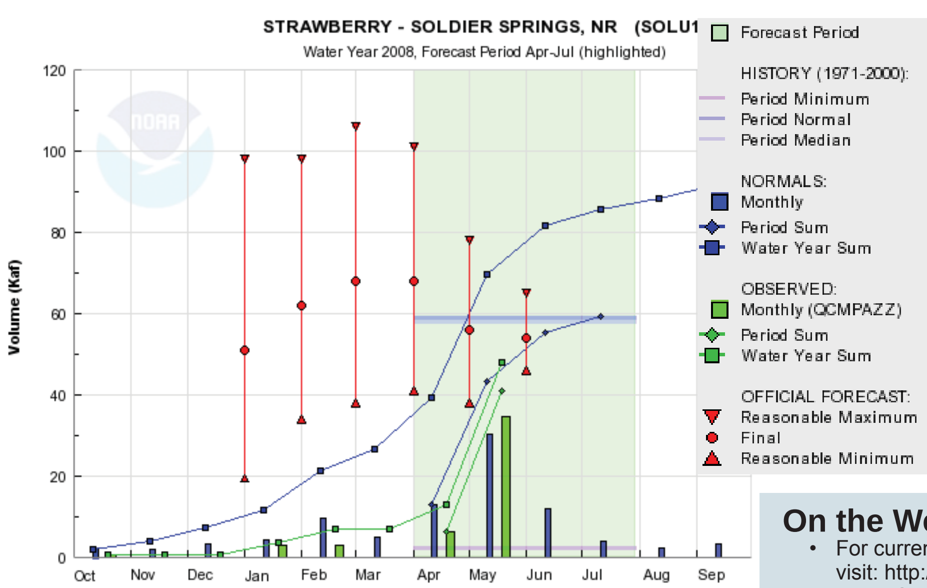


Figure 9b. Streamflow volume (kaf) forecast graph for inflow into Strawberry Reservoir (at Soldier Springs), generated by the NOAA/NWS (data through June 1, 2008). The forecast is for 54 kaf compared to average of 59 kaf. Below average snowpack in April and May has resulted in a decrease in April-July streamflow volume forecasts since the forecast issued on April 1.

Notes

The average streamflow conditions for the past 7 days are compared to streamflows during the same time period in past years (Figure 9a). The "near normal" or 25th – 75th percentile class indicates 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. This data is provisional and may be subject to significant change.

Site-specific forecast graphs (Figure 9b), feature observed and forecasted streamflow information from the NWS Western Water Supply Forecast website (see On the Web box). Users click on a region of the map and then on specific forecast points to load forecast information displayed as a graph. The most probable forecasts (50% exceedence probability) for the current water year are displayed as red circles. Streamflow forecasts are based on NRCS monthly forecasts and other NOAA/NWS RFC forecast points. See May 2007 Intermountain West Climate Summary (IWCS) focus page (see On the Web for URL) for detailed description of the graph.

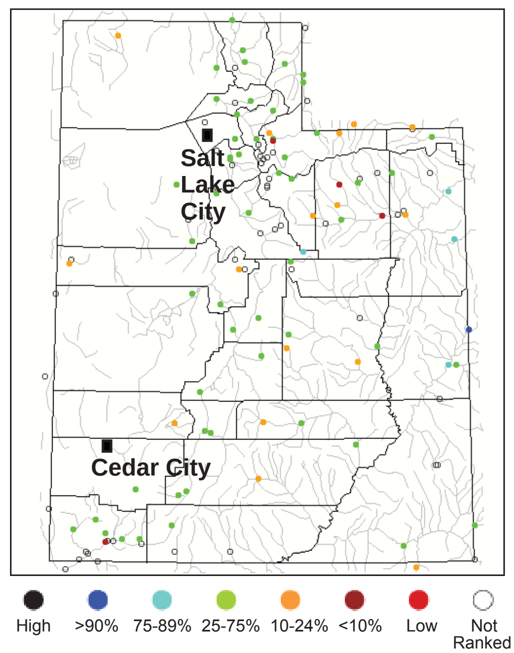


Figure 9a. 7-day average streamflow conditions for points in Utah as of June 4, 2008, recorded at USGS gauging stations.

On the Web

- For current streamflow information from USGS, Figure 9a, visit: http://water.usgs.gov/waterwatch/
- The NOAA/NWS Seasonal Runoff Volume Forecast (Figure 9b) website is: http://www.cbrfc.noaa.gov/westernwater. For individual site-specific streamflow forecasting information, click on desired region and drag mouse over square box. For individual forecast point plot graphs click on the desired square box.
- See Wyoming or Colorado state pages for additional links

Temperature Outlook July - September 2008

The latest temperature outlooks from the NOAA Climate Prediction Center indicate that in July 2008 and the July-September season, Utah, parts of western Colorado and southwestern Wyoming have an increased chance of above average temperatures (Figure 10a-b). For the August-October season, the area of increased probability of above average temperatures still includes most of the southwestern U.S. but only parts of southwestern of Utah and none of Colorado (Figure 10c).

The July 2008 temperature forecast will be updated on June 30th 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 has increased skill over the half-month lead forecasts shown here. The Seasonal Outlooks are updated on the third Thursday of the month, and the next one will be issued on July 17th.

Notes

The CPC seasonal temperature outlooks predict the likelihood (percent 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 skill of the temperature outlooks 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 map depicts the probability that temperature will be in the above-average (A, orange shading) or below-average (B, blue shading) 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 more detailed description, see notes on the precipitation outlook page.

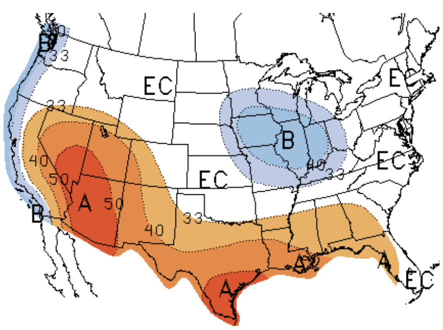


Figure 10a. Long-lead national temperature forecast for July 2008 (released June 19, 2008).

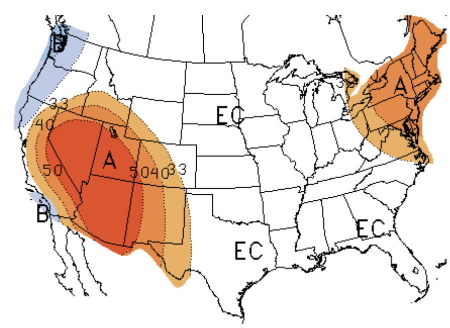


Figure 10b. Long-lead national temperature forecast for July – September 2008 (released June 19, 2008).

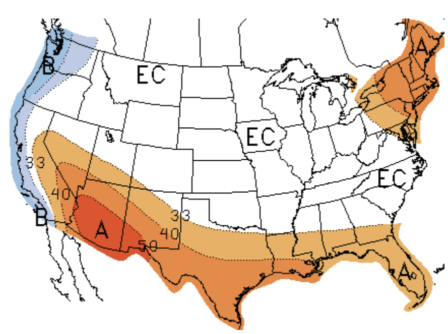


Figure 10c. Long-lead national temperature forecast for August – October 2008 (released June 19, 2008).

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 July - October 2008

The CPC precipitation outlook for July 2008 shows "EC" or equal chances for above, near-, or below-average precipitation for the interior West, indicating no skillful information on precipitation (Figure 11a). For the July-September season, Wyoming and northern Utah are included with the Pacific Northwest in an area likely to receive below average precipitation (Figure 11b). In the August-October season, only northern Utah is likely to have below average precipitation (Figure 11c). In subsequent seasons into the winter of 2008-2009 (not shown), there is no information in the forecast for the IMW region, i.e., only equal chances (EC) of above, near, and below average precipitation are depicted on the maps.

In the Interior West, June is typically a relatively dry period before monsoon-related rains begin. However, the North American Monsoon has not yet begun, so little if any rainfall is expected from that phenomenon during the next two weeks. Although there are no strong indications at this time regarding the strength and duration of this monsoon season, rainfall during July through September typically improves conditions from southeastern Arizona and New Mexico in to southeastern Utah and parts of Colorado.

The July 2008 precipitation forecast will be updated on June 30th . 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 has increased skill over the half-month lead forecasts shown here. The Seasonal Outlooks are updated on the third Thursday of the month, and the next one will be issued on June 30th.

Notes

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

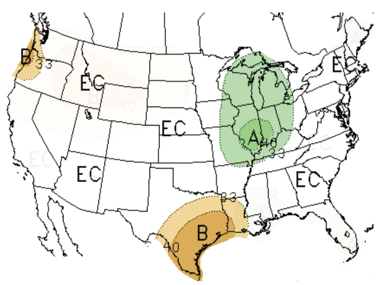


Figure 11a. Long-lead national precipitation forecast for July 2008 (released June 19, 2008).

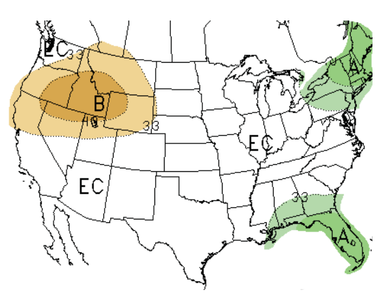
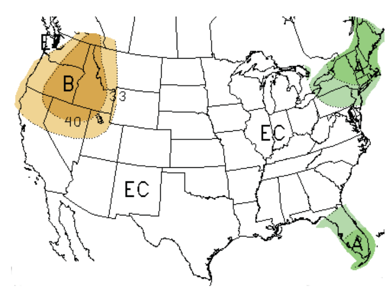


Figure 11b. Long-lead national precipitation forecast for July – September 2008 (released June 19, 2008)



EC = Equal Chances

A = Above

40.0–49.9%

33.3–39.9%

B = Below

50.0–59.9%

40.0–49.9%

33.3–39.9%

Figure 11c. Long-lead national precipitation forecast for August – October 2008 (released June 19, 2008).

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.noaa.gov/products/predictions/90day/fxus05.html.
- For IRI forecasts, visit: http://iri.columbia.edu/climate/forecast/net_asmt/.
- More information about precipitation 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.The NOAA/ESRL experimental guidance product, including a discussion and executive summary, is available on the web at: http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/index.html.

Precipitation Outlook Cont.

The experimental forecast guidance for the late summer season (July-September 2008) shows a 5% tilt in the odds towards a wetter-than-average season from southwestern New Mexico into eastern Colorado, corresponding to an enhanced North American Monsoon over that region (Figure 11e). On the other hand, eastern New Mexico and the northern Front Range show signs of a suppressed monsoon season, with a 5% shift in the odds for dryness in north Central Colorado, and a 5% shift towards wetter conditions in the eastern plains of Colorado. However, only the increased chances for a wet monsoon season in southwestern New Mexico and a dry monsoon in northeastern New Mexico are supported by high verification skill since 2000. La Niña summers are often dry in much of the southwestern U.S. (except for Arizona), and that is still a possibility.

This outlook is based on a variety of forecast indicators that include near-coastal SST in the Gulf of Mexico and eastern Pacific in particular in addition to ENSO conditions. This forecast is one of those included in discussions to develop the CPC offical outlooks.

A more detailed discussion of these forecasts will be updated on the web by June 23rd, 2008.

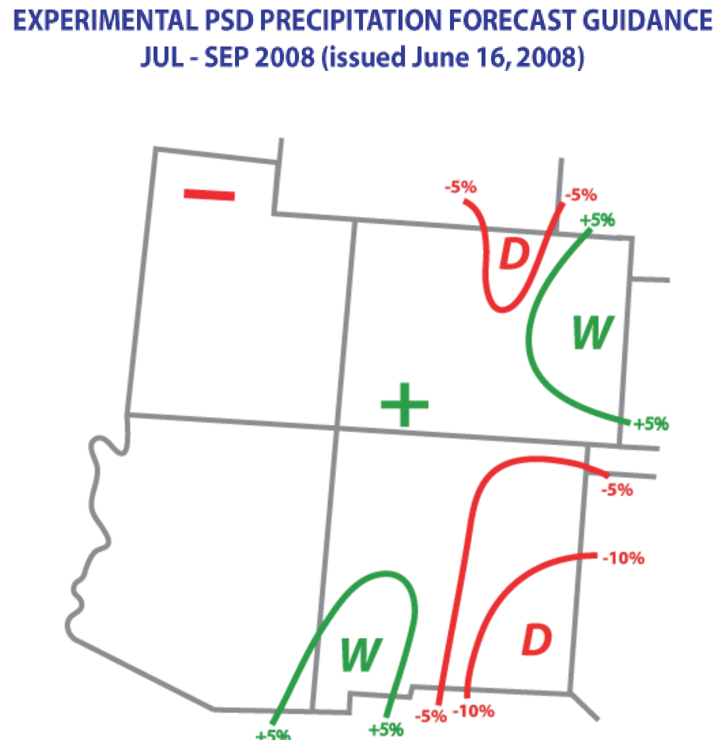


Figure 11e. Experimental Precipitation Forecast Guidance. Forecasted shifts in tercile probabilities for July - September 2008 (released June 19, 2008).

Notes

The experimental guidance for seasonal future precipitation (in Figure 11e) shows the most recent forecast of shifts in tercile probabilities precipitationfor April – June 2008. In order to be shown on this map, a forecast tilt in the odds has to reach at least 3% either towards wet (above-average), dry (below-average), or near-normal (average). Shifts towards the wettest (driest) tercile are indicated in green (red), and are contoured in 5% increments, while near-normal tilts of at least 3% are indicated by the letter "N". Shifts over 10% considered significant. Positive (negative) shifts between three and five percent are indicated by a green (red) plus (minus) sign, while minor shifts of one or two percent are left blank in this display.

On the Web

- More information about precipitation 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.The NOAA/ESRL experimental guidance product, including a discussion and executive summary, is available on the web at: http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/index.html.

Seasonal Drought Outlook through July 2008

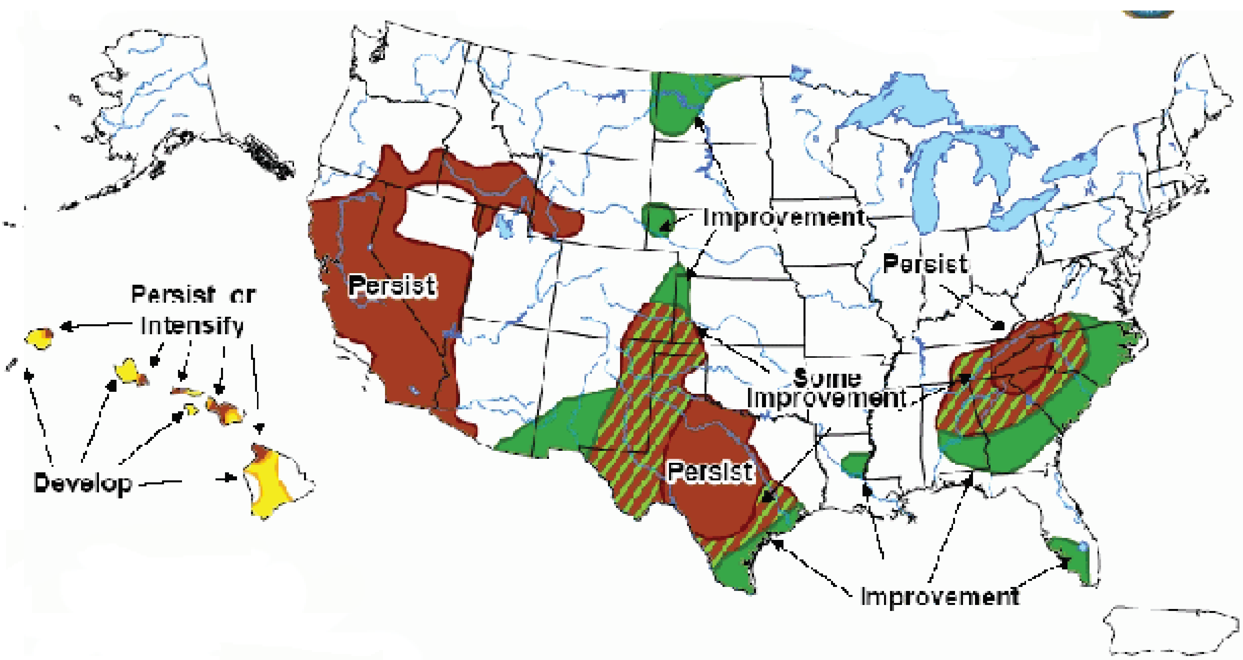
According to the U.S. Drought Monitor (page 9), drought conditions exist across a swath of central **Wyoming**, most of **Colorado** east of the Continental Divide, and along the western border of **Utah**. The U.S. Seasonal Drought Outlook (DO) builds on the DM categories to project how these drought areas might change or where new drought areas might develop. The DO issued June 19th, projects likely improvement for the southeast corner of Colorado (Figure 12), mostly because June-August is typically one of the wetter 3-month periods of the year in this area. "Improvement" indicates at least a one-category change in the DM classification.

Drought in southwestern **Wyoming** is designated as likely to persist. Although June - August is typically one of the wetter times of the year, the official CPC precipitation forecasts favor below average precipitation through August for **Wyoming**, northern **Colorado**, and northern **Utah** (page 15).

There are no new areas of drought development in the Interior West indicated in this DO. The next Seasonal Drought Outlook will be issued in two weeks, on July 5th.

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 DO (Figure 12) are defined subjectively based on expert assessment of numerous indicators described above, 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 (updated weekly) see: 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.



Drought Outlook

- Drought to persist or intensify
- Drought ongoing, some improvements
- Drought likely to improve, impacts ease
- Drought development likely

Figure 12. Seasonal Drought Outlook for June 19, 2008

On the Web

- For more drought information, visit: http://www.drought.noaa.gov/.
- Forecasts of drought termination probabilities can be found at: http://www.ncdc.noaa.gov/oa/climate/research/drought/current.html.

El Niño Status and Forecast

The current La Niña episode developed during July - September 2007, and it appears to have peaked in February 2008. Below-average SSTs still exist in the central equatorial Pacific (Figure 13a), but they have been trending toward neutral since February 2008.

NOAA's official definition of ENSO anomalies involves a 3-month mean of SSTs: to be considered an El Nino or La Nina this index must exceed +/- 0.5º C. The current (March-May) value if this index is -0.84, so a La Niña is technically still in progress, however, the latest weekly index is only at -0.4º C, weaker than the -0.5º C index threshold. The Multivariate ENSO Index (MEI, not shown, see On the Web box) has weakened to -0.4 sigma (for April-May) which also suggests a transition to ENSO-neutral, while the SOI has been decreasing and recently dropped below 0, which in SOI-parlance means neutral. The SOI is a measure of atmospheric pressure that relates to the wind anomalies supporting ENSO, and the decrease in this index suggest a weakening of the atmospheric manifestation of La Niña.

A majority of the recent dynamical and statistical SST forecasts for the Niño 3.4 region indicate a transition to ENSO-neutral conditions during June - August 2008 (Figure 13b). According to the International Research Institute for Climate and Society (IRI), a NOAA partner, the probability of a La Niña conditions continuing during the June-August season in progress is about 15% and the probability of returning to ENSO-neutral conditions is 75%. During the second half of the year, the majority of models reflect ENSO-neutral conditions. However, there is considerable uncertainty during this period as some models suggest the possible development of El Niño while others show a re-development of La Niña.

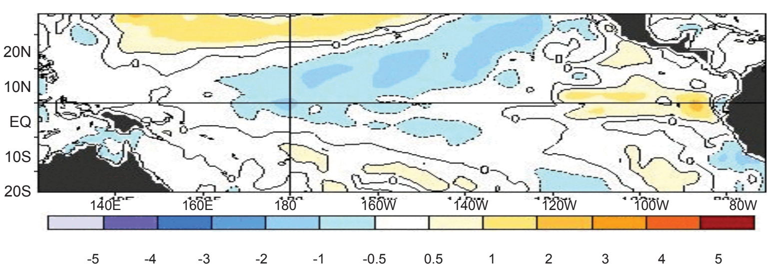
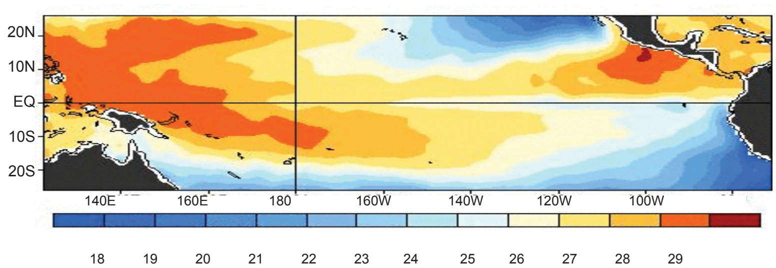


Figure 14a. Observed SST (upper) and the observed SST anomalies (lower) in the Pacific Ocean. The Niño 3.4 region encompasses the area between 120oW-170oW and 5oN-5oS. The graphics represent the 7-day average **centered on June 11, 2008.**



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. "Niño 3.4" refers to the region of the equatorial central Pacific from 120oW to 170oW and 5oN to 5oS, 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 SSTs, e.g., forecasts made between June and December are generally better than those made between February and May. Differences among model forecasts in Figure 14b reflect differences in model design, which in turn reflect uncertainty in the forecast of the possible future SST scenarios.

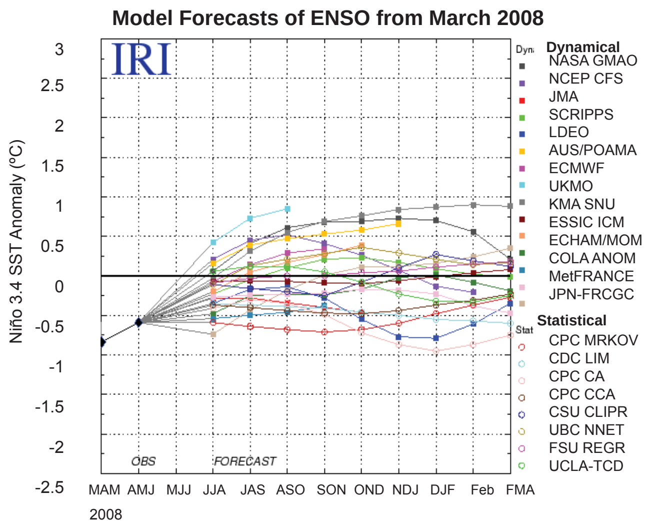


Figure 13b.Forecasts made by dynamical and statistical models for sea surface temperatures (SST) in the Niño 3.4 region for nine overlapping 3-month periods from June 2008 through April 2009 (released June 18, 2008). graphic is from the International Research Institute (IRI) for Climate and Society.08).

On the Web

- For a technical discussion of current El Niño conditions, visit the ENSO Diagnostic Discussion, a collaborative effort of the several parts of NOAA, including the research labs, the IRI, and other institutions funded by NOAA: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ (updated on the second Thursday of the month).
- For updated graphics of SST and SST anomalies like figure 13a, 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 (Figure 13b), visit: http://portal.iri.columbia.edu/climate/ENSO/. The "forecast plume" showing multiple model projections is updated on the third Thursday of the month.
- The Multivariate ENSO Index is available at: http://www.cdc.noaa.gov/people/klaus.wolter/MEI/)

Forecast Consolidation for Seasonal Climate Outlooks

By David Unger, NOAA Climate Prediction Center with Ava Dinges, WWA

As the science of seasonal forecasting has evolved, new tools have been created to produce the operational monthly and seasonal products issued by the NOAA Climate Prediction Center. This article describes a new tool that has led to the greatest single long-term skill improvement achieved since these forecasts were introduced

Introduction

A new technique developed at the Climate Prediction Center (CPC) is bringing more objectivity and uniformity to climate forecasting. Known as the "Consolidation Forecast," the new method combines forecasts from four climate models into a single forecast tool that can be used for seasonal climate outlooks. The Consolidation Forecast method has been available to CPC forecasters since 2006. Performance statistics indicate that the Consolidation Forecast has significantly improved the skill of ½ month lead seasonal (3-month) forecasts over random (climatology) outlooks. Therefore, the creation and incorporation of this new tool is helping to create more accurate seasonal forecasts that benefit various user communities.

Ensemble Forecasting

The Consolidation Forecast, also known as the CON, is an example of a multi-model ensemble technique that combines "ensembles" from several models. A forecaster examines many different ensemble-based models to create many of today's climate forecasts. An "ensemble" is created by running a single model multiple times in order to give an idea of the wide variety of potential climate outcomes for the seasons ahead. The different forecasts from a single model are created by adjusting the "initial conditions" slightly from run to run. These initial conditions are based on the most recent atmospheric and oceanic observations. The average of the ensembles is a single "ensemble mean" forecast, which is more reliable than just one single forecast from just one initial condition. Then to create a climate forecast, the forecaster considers the ensemble mean from many different climate models. However, in order to create an official climate outlook, the forecaster still has to use his/her best subjective judgment to combine ensemble forecasts from the multiple statistical and dynamical models. The Consolidation Forecast technique improves upon the subjective method by using the independent skill of each ensemble forecast to combine the forecasts from multiple models. This new technique results in a single objective climate forecast for many seasons into the future and generally exceeds the predictive skill of a single climate forecast model.

Consolidation of Multiple Forecast Tools

The consolidation method uses ensembles from four different climate forecasting tools to make a single climate forecast. Each forecast tool uses different equations to model relationships between climate conditions and outcome variables (e.g. temperature and precipitation). The four climate forecasting tools used by the CPC in the CON are the Climate Forecast System, Canonical Correlation Analysis, Screening Multiple Linear Regression, and Optimal Climate Normals.

The Climate Forecast System (CFS) is the only dynamical model out of the four climate forecasting tools. It is a state-of-the-art global climate model (GCM) run at the NOAA National Centers for Environmental Prediction. A dynamical model predicts the atmospheric and oceanic responses to elements that are known to affect climate, such as sea surface temperatures (SSTs), soil moisture, snow cover, and ocean/atmosphere interactions. The CFS model is run many times during the course of a given month to produce an ensemble forecast for the coming seasons, out to about nine months.

The other three climate forecasting tools are statistical models, which means they leverage a statistical relationship among multiple variables (i.e. SSTs, temperature, precipitation) in order to make a forecast several seasons into the future. The Canonical Correlation Analysis (CCA) technique relates patterns in SSTs and upper level atmospheric circulations from a point in the past to the patterns of observed temperature and precipitation observed over the U.S. in the following months. The Screening Multiple Linear Regression (SMLR) tool uses some of the same variables as the CCA, but it also includes local soil moisture conditions. The SMLR has the added advantage of being more tailored to individual locations than the CCA, which is more global in scale and can miss local climate signals. Finally, the Optimal Climate Normals (OCN) tool measures temperature and precipitation trends to determine when past trends can be used to make meaningful climate predictions. The climate often exhibits decadal changes and trends that can be used to help predict the likely seasonal temperatures or precipitation in the upcoming seasons.

The new Consolidation Forecast provides an objective method for forecasters to combine ensembles from the four tools (described technique that produces a probability density for each variable (i.e. seasonal temperature and precipitation). The consolidation technique weights each tool's ensemble forecast based on how well the tool performed at each forecast location over all the past cases for which forecasts are available. The final step of the consolidation forecast is to add the trend based on the OCN tool. An example of how the Consolidation Forecast combines the information from several tools into a single forecast is shown in Figure 14 a-c of the June 2008 Intermountain West Climate Summary. Even though the CON is an objective tool, the forecaster is still permitted to alter the forecast based on his or her knowledge of the climate system. For example, a forecaster can choose to emphasize a forecast tool that may have a better skill at predicting the climate effects of La Nina when La Nina conditions are anticipated. This was the case in November 2007, when CPC forecasters improved the winter Consolidation Forecast by adjusting temperatures over the northern Great Plains and Pacific Northwest to account for the expected moderate to strong La Niña.

The CON can have some drawbacks. For example, this tool may produce an area of unrealistic spatial patterns where there are weak predictive signals (i.e. areas that are harder to predict) and the forecaster can either ignore or alter them to improve spatial consistency. In creating the outlooks made in June 2008 for July 2008 and subsequent 3 month seasons, the forecaster left out weak signals for below normal temperatures in western Texas and the Southeast because of conflicting signals nearby. Other times, the CON predicts anomalies where the cause is unclear. The forecaster chose to ignore forecasts for above median rainfall in the northeastern U.S. for lack of a clear physical cause (Figure 14c). In the end, the official seasonal climate outlook may not always look exactly like the CON because of these subjective decisions made by the forecaster, but the addition of this new forecast tool results in a more skillful seasonal outlook overall.

Skill Improvement

Forecasters at CPC have documented the improvement in skill of the official forecasts when they take advantage of the CON forecast. Heidke skill scores are often used to assess how forecasting techniques compare to one another. Heidke skill scores range from negative infinity to 100 with 100 indicating perfect forecasts, zero being no improvement over the baseline forecast, and negative infinity indicating the worst possible score. A simplistic way to consider skill scores is to consider the score as a percent improvement (or decline in the case of negative skill) over the baseline forecast. Thus, a score of 20 would indicate a 20% improvement over the baseline forecast (e.g. climatology A recent study compared the skill of the CON with real-time official 0.5 month lead 3- month temp forecasts (like Figure 10b) from 1995 to 2005 and found a significant improvement compared to climatology and the official forecasts (O'Lenic et al. 2008). The skill for the official forecasts in use during that period (without consolidation) was 22, i.e., a 22% improvement compared to random or climatology, but the skill of the CON-based forecasts is 26, or a 26% improvement over climatology. For precipitation forecasts at the same 0.5 month lead, the skill score for the official forecasts is 4, but the skill score of the CON-based forecasts is a 12, or 12% improvement over climatology. This comparison reveals that the forecasts produced using this tool outperformed the official forecast during this period. When used as a tool in creating outlooks, the CON has thus lead to improvements in the skill of the official forecast. Consolidation Forecasts are expected to improve with time as more tools are included in the consolidation and as forecasters find more accurate methods to weight the input tools.

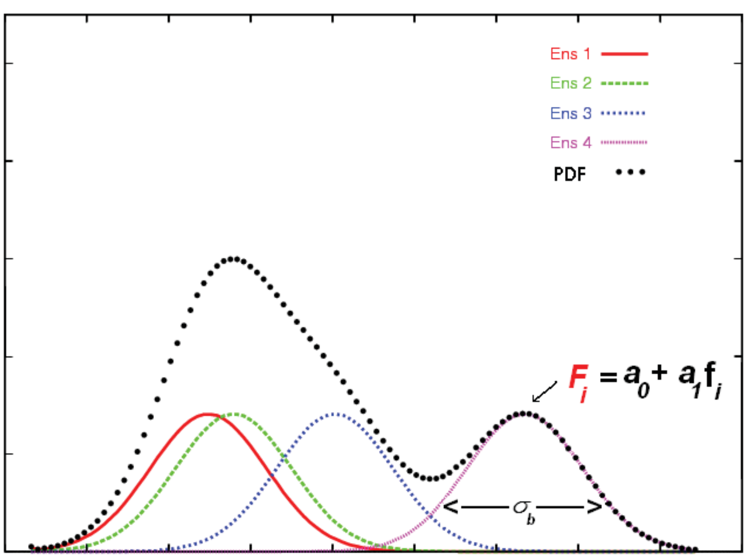
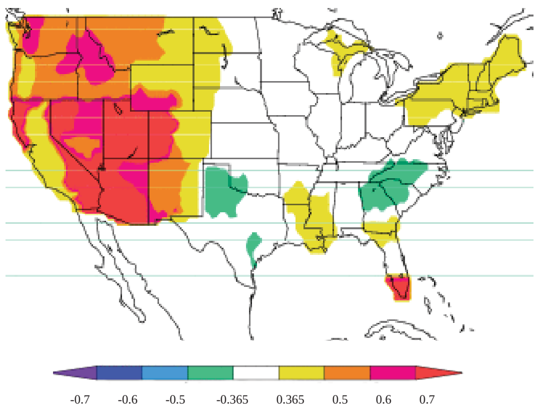


Figure 14a. Schematic illustrating how different forecast tools contribute to the Consolidation forecast. In this case there are 4 tools each with equal skills (as illustrated by the small error distributions associated with each tool - σ_b, which are all the same size) but with different forecasts (determined by the different locations on the x axis). The consolidation method determines the appropriate contribution from each tool and combines the information into a single forecast (dark line).

Key

Consolidation Forecast
Numbers are the estimated probabilities of the observation falling into one of three equally probable categories: above, near, or below normal. Elevated chances of above normal temperatures (below median precipitation amounts) are shown in yellow/red colors, and below normal temperatures (above median precipitation amounts) in green/blue. White areas are approximately equal chances.

Official Forecast
Shaded areas represent the percent chance of temperature or precipitation being in the above or below average tercile. For a detailed description see pages 14 and 15.



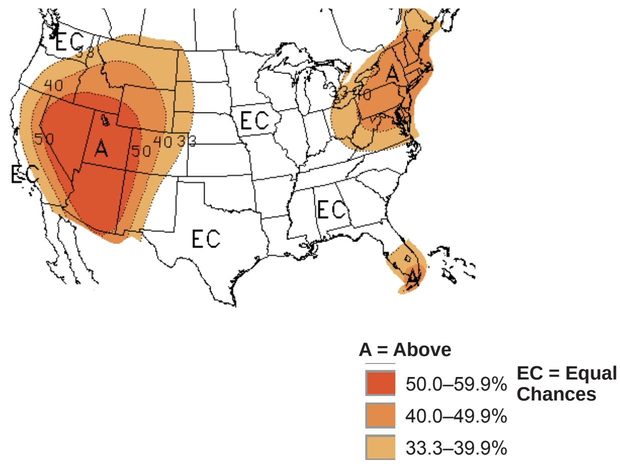
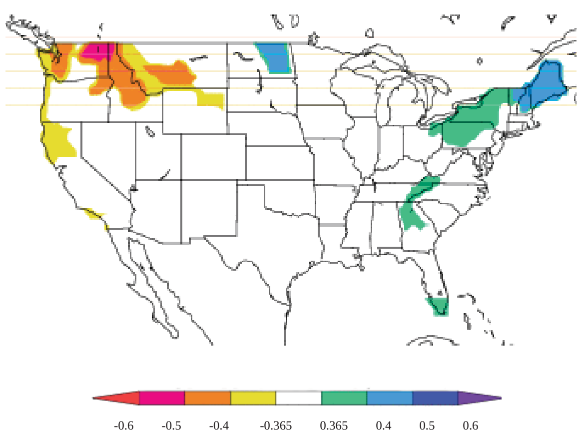


Figure 14b. The latest CPC consolidation forecast (left) and official forecast (right) for seasonal mean temperature over the continental U.S. for June through August, issued in April 2008.



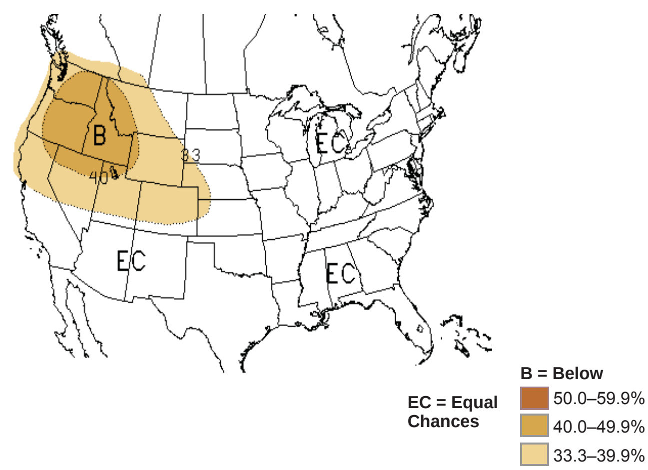


Figure 14c: The latest CPC consolidation forecast (left) and official forecast (right) for seasonal precipitation amount over the continental U.S. for June through August, issued in April 2008.

References

O'Lenic, E. A., Unger, D. A., Halpert, M. S., and Pelman, K. S. (2008, in press) "Developments in Operational Long-Range Climate Prediction at CPC." Weather and Forecasting.

On the Web

- The consolidation forecast for the both the seasonal forecasts and Niño 3.4 SSTs are currently available on CPC's seasonal forecast briefing page: http: // www.cpc.ncep.noaa.gov/products/predictions/90day/tools/briefing/; under "Cons Fcst" and "Nino 3.4: CPC" headings on the left hand frame.
- For more on seasonal forecasting in the Intermountain West, see "Seasonal Forecasting: Skill in the Intermountain West?," in the May 2005 Intermountain West Climate Summary and "How to use the climate Forecast Evaluation Tool," in the January 2006 Summary, both at http://wwa.colorado.edu

Workshop Summary: Forecast Verification for Water Supply Managers

February 19, 2008 in Boulder, Colorado

By Kevin Warner, Service Coordination Hydrologist for the NWS Colorado Basin River Forecast Center

Important water management decisions are increasingly made based on seasonal water supply forecasts. Water supply forecast groups from NOAA and NRCS partnered with Western Water Assessment to host a forecast verification workshop on February 19, 2008. The workshop was very well attended with about 70 water managers, forecasters, and academics from primarily from Colorado's Front Range. It was an opportunity for forecasters and forecast users to interact and for forecast users to gain an understanding of the methodology and skill of water supply forecasts. This article briefly describes both the water supply forecast program and the verification tools available.

NOAA and NRCS jointly produce water supply forecasts for snowmelt-dominated basins throughout the western United States. Forecasts are generated monthly beginning in January and running through the April-July snowmelt season. Forecast responsibilities are shared by six River Forecast Centers (RFCs) within NOAA's National Weather Service and the National Water and Climate Center within the NRCS. Forecasts are coordinated between the agencies for locations where both agencies produce a forecast. The coordination process involves comparisons of the different forecast techniques and a consensus coordinated forecast value.

The forecast program has a rich history dating back to the early twentieth century. Forecast capabilities have improved in recent decades from enhancements to the observation network and improvements in forecasting techniques. The NRCS SNOTEL network dramatically improved measurements of snowpack beginning in the 1970s. The implementation of continuous forecast models in NOAA beginning in the 1980s has improved forecast capabilities and forecast skill. These new technologies are used together with statistical regression models and forecaster expertise to produce monthly water supply forecasts.

As the demand for forecasts increases, forecasters and forecast users require information on forecast skill. In 2007 the NWS developed a web-based forecast evaluation tool as part of its new Western Water Supply Forecast web site (see On the Web box). This website provides a basic set of statistical tools to measure forecast performance at every NWS forecast point. Plots and statistics allow the user to:

(1) Visualize archived forecasts and observed streamflow.

(2) Calculate forecast errors as either a function of lead time or forecast year.

(3) Calculate forecast skill relative to climatology as either a function of lead time or forecast year.

These tools benefit forecasters and forecast users. By quantifying historical forecast performance, forecast users can assess the uncertainty around current forecasts. Forecasters and researchers can focus their efforts on improving forecast skill in places and times where it has been historically low.

The forecast verification tool set was the basis for a lab exercise during the February 2008 workshop. Participants were guided through exercises using the NWS web services to ascertain historical forecast performance for a basin in the headwaters of the Colorado River. Forecast skill varies in different basins for a number of reasons including the variability of spring weather and variability of streamflow. The exercise demonstrated that forecasts are less skillful during years with anomalous snow accumulation. The exercise also demonstrated the application of forecast verification metrics to the current forecast to provide information about the likely range of streamflows (error statistics in particular). You can find the lab exercise on the WWA Forecast Verification Workshop website (see On the Web box).

The NWS and NRCS are available to assist with forecast evaluations or general questions about the water supply forecast program. The verification workshop may be repeated for forecast users in a different region in the future. Please contact Kevin Werner (Kevin.werner@noaa.gov) with any questions.

Kevin is the Service Coordination Hydrologist (SCH) at the Colorado Basin River Forecast Center (CBRFC). Kevin is one of the first SCHs at an NWS River Forecast Center (RFC). The position was created in 2008 to promote hydrologic forecast services and improve applications of RFC forecasts. Kevin came to the CBRFC from a four-year position as hydrology sciences program manager for the NWS Western Region. Kevin's education is in both climate and hydrology, and he is particularly interested in working with forecast users to leverage the value of ensemble forecasts. Please feel free to contact Kevin with any questions (Kevin.werner@noaa.gov).

On the Web

- The NOAA/NRCS Western Water Supply Forecast website is: http://www.nwrfc.noaa.gov/westernwater
- For more information about Forecast Verification or the workshop, please visit: http://wwa.colorado.edu/resources/forecast_verification_workshop.html
- See the focus page, "New National Weather Service Western Water Supply Forecast Services" from the May 2007 IMW Climate SUmmary: http://wwa.colorado.edu/products/forecasts_and_outlooks/intermountain_west_climate_summary/articles/