

INTERMOUNTAIN WEST CLIMATE SUMMARY



by The Western Water Assessment

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June 2007 Climate Summary

Hydrological Conditions – Drought is expected to persist over Utah, western Colorado, and western Wyoming, but there has been some decrease in drought status in central and northeastern Wyoming.

Temperature – Temperatures were 0 – 4°F above average around most of the region in May.

Precipitation/Snowpack – Precipitation was below average in western Wyoming and north-central and western Utah in May, but it was above average in north-central Wyoming, southeastern Utah, and southern Colorado.

ENSO – ENSO-neutral conditions prevail in the Pacific, and there is about a 55% chance of La Niña conditions developing by the fall (Sep-Nov 2007) although these conditions have not developed yet.

Climate Forecasts – ENSO is not a factor in climate forecasts for the region for the impacts during the July-September 2007 season; La Niña may develop and become a factor in the fall.

WWA DIRECTOR TESTIFIES AT SENATE SUBCOMMITTEE HEARING

Brad Udall, Director of WWA, testified before the United States Senate Subcommittee on Water and Power on June 6 about the impacts of climate change on water supply and availability in the western United States. Udall began his testimony with, “All water planning is based on the idea of a static climate.” Udall’s testimony focused on three main points, which explain why and how water planning should proceed for a future of increasing climate variability and change. First, future water availability on the Colorado River is uncertain due to a likely change in hydrological and climate processes, regional growth, over-consumption, and uncertainty of Compact entitlements. Second, Udall called for better federal management of climate change science in order for water resource decision-makers to prepare for and understand the impacts of climate



change on water resources in the West. He called for the creation of a National Climate Service, an overseeing entity that would connect climate science to the needs and questions of decision makers. Third, he recommended the expansion and proper funding of region-specific climate modeling and data collection efforts that cater to decision-makers. Other witnesses at this hearing included: Terry Fulp (USBR), Christopher Milly (USGS), Philip W. Mote (Univ. of Washington’s Climate Impacts Group), Patrick O’Toole (Family Farm Alliance), Tim Brick (The Metropolitan Water District of Southern California), Jack Williams (Trout Unlimited), and Tim Culbertson (National Hydropower Association). For more information about the Subcommittee hearing, visit: <http://energy.senate.gov/public/index.cfm>, or see a link to the testimony on the WWA homepage.

Upcoming Conference: Symposium on Southwest Hydrometeorology in Tucson, AZ on Sept. 20-21, 2007. See the Drought Outlook page for more information.

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New Climate Divisions for Monitoring and Predicting Climate in the U.S.

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This article describes a long-term effort to create a more rational, statistically based set of national climate divisions that would help improve drought monitoring and climate forecasting in the U.S.

Motivation

Near-real time climate monitoring, long-term climate change assessments, and statistical climate predictions in the U.S. are often based on so-called “Climate Divisions” (Figure 1a; Guttman and Quayle, 1996). These come from century-long efforts to organize climate observations across the country, which were finalized in the 1950’s to match up with crop reporting districts, county lines, and/or drainage basins. Perhaps surprisingly given their use, the representation of the underlying climate was not an explicit consideration (Guttman and Quayle, 1996). The vast majority of data used in climate division analyses comes from climate stations that are part of NOAA’s voluntary Cooperative Observer Program (COOP). This network of climate stations has been collecting daily high and low temperatures, precipitation, and snowfall since 1890. Climate division time series are computed by simply averaging all available, “representative” COOP station data since 1931 into single monthly values, while older time series (between 1895 and 1931) were derived from state-wide averages.

Climate divisions are used in many climate-related monitoring products, like the U.S. Drought Monitor, regional SPI, and temperature assessments, because they allow for an easy calculation

of regional averages, and a comparison of recent climate anomalies against a century-long record. The Climate Prediction Center (CPC) has used so-called “mega-divisions” (based on merging smaller climate divisions) as targets for statistical climate predictions, and for verification purposes.

The 344 U.S. climate divisions allow for up to ten divisions per state; however, they cover the conterminous United States rather unevenly (Figure 1a). Many states do have ten divisions (such as Wyoming and Idaho), but some rather large states do not. Colorado is a large state with complex topography whose regional climates are not accurately represented by only five climate divisions, for example, there is only one division covering the mountainous western third of the state. Decisions about how to organize climate divisions were made on a state-by-state basis rather than from a national perspective (Guttman and Quayle, 1996). For more information about traditional climate divisions, and to view monthly time series for each one, go to: <http://www.cdc.noaa.gov/USclimate/USclimdivs.html>.

Climatologists have long suspected that the simple averaging of COOP stations into climate divisions is not optimal for depicting regional climate anomalies, especially for precipitation. We verified that suspicion by correlating individual COOP station



Figure 1a. Climate division map for the lower 48 states in the U.S. (numbered separately for each state).



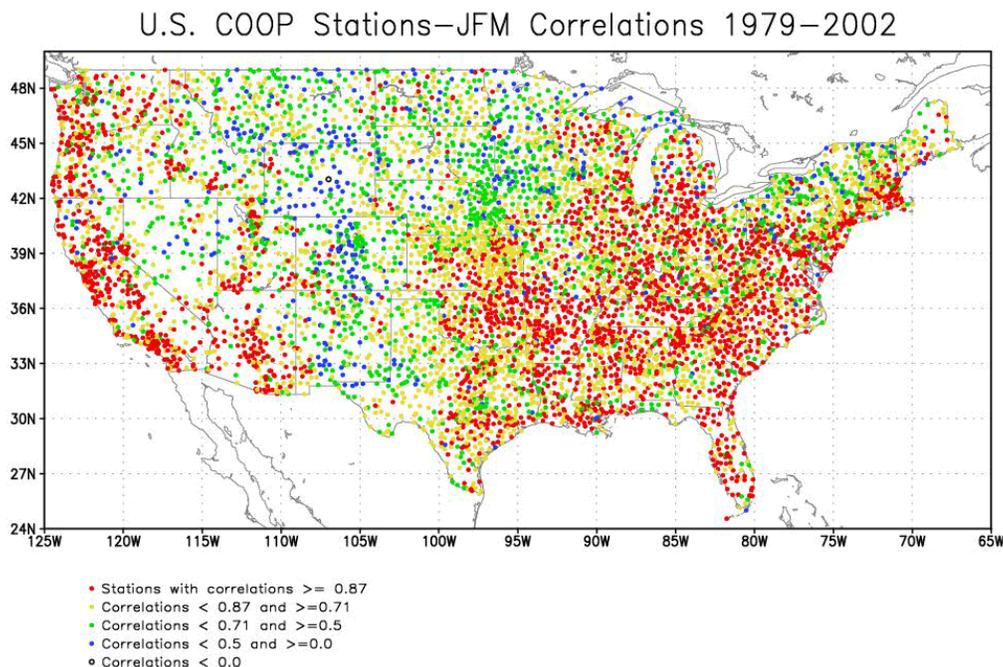


Figure 1b. Seasonal correlations between Climate Division time series and COOP station time series during Jan-Mar 1979-2002 (for precipitation). Green and blue dots show that divisional indices carry less than 50% of the local seasonal precipitation variance in the Great Basin, along the Rocky Mountain Front Range, and even in the Upper Midwest.

time series against divisional averages (Figure 1b). Results show that much of the Interior West is not well represented by divisional averages, particularly those including the higher terrain of Wyoming and Colorado. During the winter snow accumulation season in parts of the Interior West, there are poor correlations between individual stations and the associated climate division (Figure 1b), and the situation is even worse in the summer (not shown).

Low correlations between individual COOP stations and divisional averages translate into poor reliability when large-scale drought assessments or ENSO-related forecasts based on these divisions are scaled down to the station level. This is one reason why drought monitoring and seasonal climate forecasting are difficult in the Interior West. In addition, some of the higher elevation SNOTEL sites may correlate negatively with their climate division time series. This is due to orographic effects of the Rocky Mountains: during the winter season, strong westerly winds yield large snowfall amounts on the windward side of this mountain range, while the valleys to the east may experience chinook-like windstorms and dryness. Because most COOP stations are located in valleys, climate division averages may end up with negative precipitation anomalies, while SNOTEL-based assessments of the snow pack often show a surplus. This type of precipitation pattern is not well captured by traditional climate division data, and the winter of 2005-06 is a recent example.

Analogous maps for seasonal temperature correlations do not show the same disparity between station and climate division data, most likely due to the larger spatial coherence of temperature anomalies. Nevertheless, wintertime regional temperature anomalies are also not well represented by climate divisions in the orographic regions of the Interior West.

In 2003, we embarked on a long-term effort to create a more rational, statistically based set of national climate divisions that would help improve drought monitoring and climate forecasting in the U.S. The rest of this paper documents the employed method for deriving these new experimental climate divisions, the latest version of this product, and follow-up deliverables.

Methodology: Statistical Approach to Experimental Climate Divisions

In order to ascertain which climate stations have the tendency to exhibit the same climate anomalies, we performed analyses on temperature (T), precipitation (P), and combined (T,P) records. We found that the last approach (with combined time series) yielded better defined climate regions, than either precipitation or temperature records alone.

From currently available records for 17,575 COOP stations in the lower 48 states, we selected 4,324 stations with both sufficient precipitation and temperature records to perform statistical analyses for Water Years 1979 through 2006 (October 1978 through September 2006). For much of the U.S., this translates



into at least one station per 1000 square miles; but some less populated regions, such as the deserts in the Interior West, have less dense spatial coverage.

There are several thousand more precipitation-only COOP stations of similar quality that have been used for supportive analyses. In addition, there are more than 500 SNOTEL sites in the higher elevations of the Western U.S. that have sufficient precipitation records since WY79 to be analyzed as well. However, their temperature records typically only start in the late 1980s and have been somewhat unreliable.

We used the following statistical approach to develop new experimental climate divisions:

1. For every climate station, we computed average temperatures and precipitation totals for every three-month season from October 1978 through September 2006 (these 'sliding' seasons include all Oct-Dec, Nov-Jan, ..., Sep-Nov time periods within the 28-year record). Individual seasonal anomalies were calculated by subtracting the 28-year average for that same season. For missing data, anomaly values were set equal to zero to keep all station anomaly time series to the same length.
2. Multivariate cluster analyses were used to find out which stations tended to experience climate anomalies of the same sign (i.e., above average or below average), based on correlation matrices among all of them. The two cluster analysis techniques applied here were "Average Linkage",

and "Ward's" method, which are both well established techniques, and superior to other clustering methods (Wilks, 1995, pp. 419-428).

3. Results from both clustering methods were compared against each other, and used to group stations with similar temperature and precipitation anomalies into "core regions". A large majority of these cores could be identified via simple overlapping station counts, but some less clear-cut groupings were settled by correlating the respective cluster time series against each other. After this initial classification, core time series were computed based on normalized temperature and precipitation time series at the station level. These were used to calculate correlation coefficients between all stations and all cores.
4. The assignment of stations to cores was refined iteratively, until no further changes occurred. In particular, if a station was not classified as belonging to a core, but correlated highly with a near-by core, it was admitted to that core. On the other hand, if a station had been (mis-)classified as being inside a core, but did not correlate highly with the core time series, it was removed from that core. (This was a rare event in the combined temperature-precipitation analysis suite, but more common in precipitation-only analyses). A third scenario involved the transfer of a station from one core to another, if its correlation with the new core was substantially higher than with the old core.

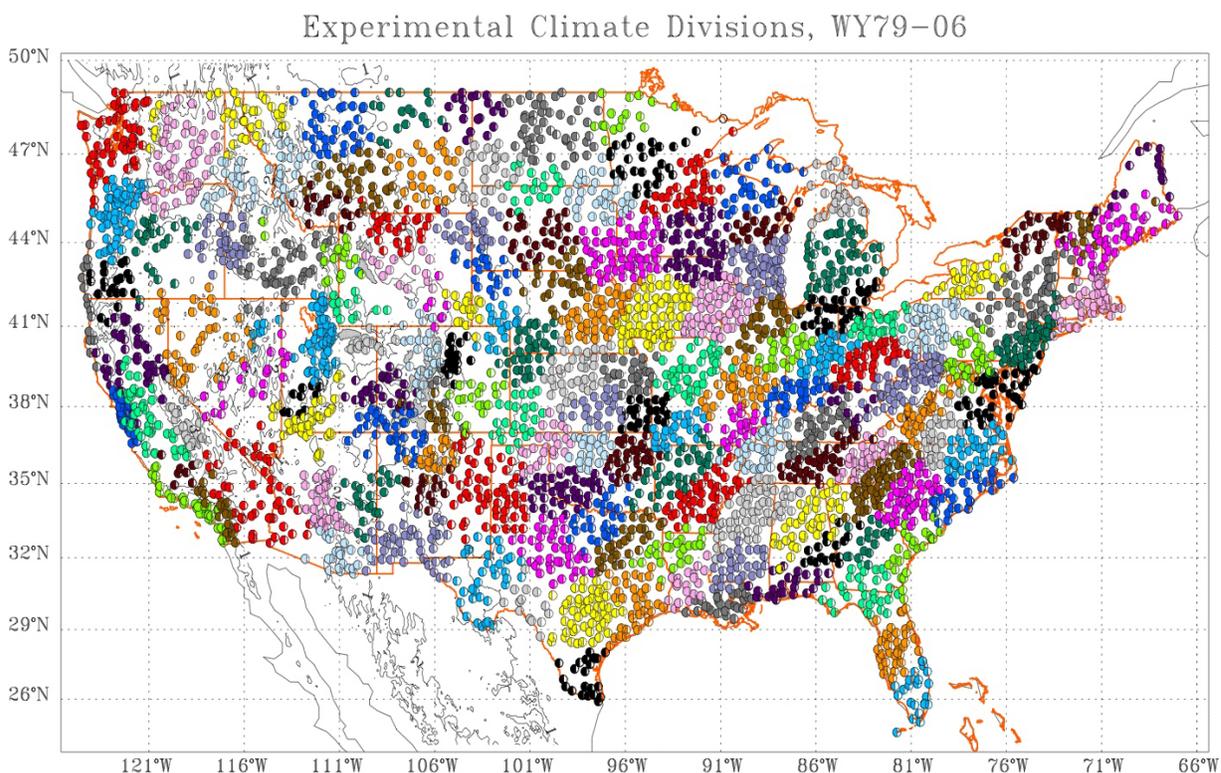


Figure 1c. Near-final map of new climate divisions, based on temperature and precipitation station data. Each dot is a COOP station and a cluster of dots of the same color represents a new climate division.



5. While there was some experimentation with correlation thresholds, the basic procedure always remained the same and yielded similar results. Transfers between core regions required at least a 1% increase in explained variance for that station, and the “drop”-correlation threshold had to be lower than the “add” correlation threshold. The final correlation thresholds were in the 0.55-0.60 range to allow for virtually all stations to be classified. One final check consisted in correlating all new climate division time series against each other to flag regions that were extremely well correlated ($r > 0.90$), thus being prime candidates for mergers, as long as the resulting new division did not exceed certain size limitations.

The current version of the new 139 combined core regions (i.e. new climate divisions) for Water Years 1979 through 2006 (October 1978 - September 2006 data) is shown in Figure 1c. From the pool of 4324 COOP stations with sufficient temperature and precipitation data, the initial core map classified 3112 stations as being within 145 initial “intersection” clusters (Step 3). Using the iterative methodology described above, the remaining stations were gathered into core regions, resulting in a stable classification of all but one station by the 7th iteration in 139 final core regions (Steps 4 and 5; Figure. 1c). While there was no requirement for stations within a core to be spatially adjacent to each other, it is reassuring to see that virtually all of them are indeed ‘neighbors,’ even in the more challenging terrain of Wyoming, Colorado, and Utah.

While all analyses were performed on the national scale, let us now focus on the Intermountain West region. Figure 1d shows how the COOP stations are grouped into the new climate divisions (by color) in the region. Despite a total count of only 139 new divisions (compared to 344 in the older system), Wyoming has added one new division (now 11 total), Utah has two new divisions (now 9 total), and Colorado has more than doubled its divisions (now 13 instead of 5) (compare Figure 1a against Figure 1d), which is more representative of the diverse climate throughout each state. With the new map, climate divisions are no longer bounded by state lines. For example, note the yellow division that contains parts of southeast Wyoming, northwest Nebraska and one station in northeast Colorado. In addition, there is no

upper limit of ten divisions per state.

One of the goals of this project was to integrate SNOTEL sites into the analysis. We found that SNOTEL data correlates well with the new climate divisions (compare Figure 1e against Figure 1d). Most of the SNOTEL sites match up well with the nearest COOP-based climate division, with a few exceptions in northwest Wyoming (Absorka Mountains) and northwest Utah (intersection of Wasatch and Uinta mountain ranges).

Other products and Plans

With the creation of the joint temperature and precipitation maps presented in the last section (Figures 1c, d, and e), this project is almost complete. The main remaining stage is to fine-tune the new division boundaries with precipitation data from SNOTEL and precipitation-only COOP stations. For more information on the new climate divisions, including additional spatial analyses on precipitation data alone, visit: <http://www.cdc.noaa.gov/people/klaus.wolter/ClimateDivisions/>. This web page also gives access to long-term time series for each new climate division. We are working on the following additional products (this list is not complete, see the website for more details):

- Additional time series of temperature and precipitation averages in each new climate division, both from 1978-2006, and from 1948-1978, based on new climate divisions for that period. The time series will be available in monthly and seasonal formats, both as straight anomaly time series and as standardized anomaly time series.
- Final new climate division maps, including boundaries, spatial coverages (in percent of area), and new state-wide averages.

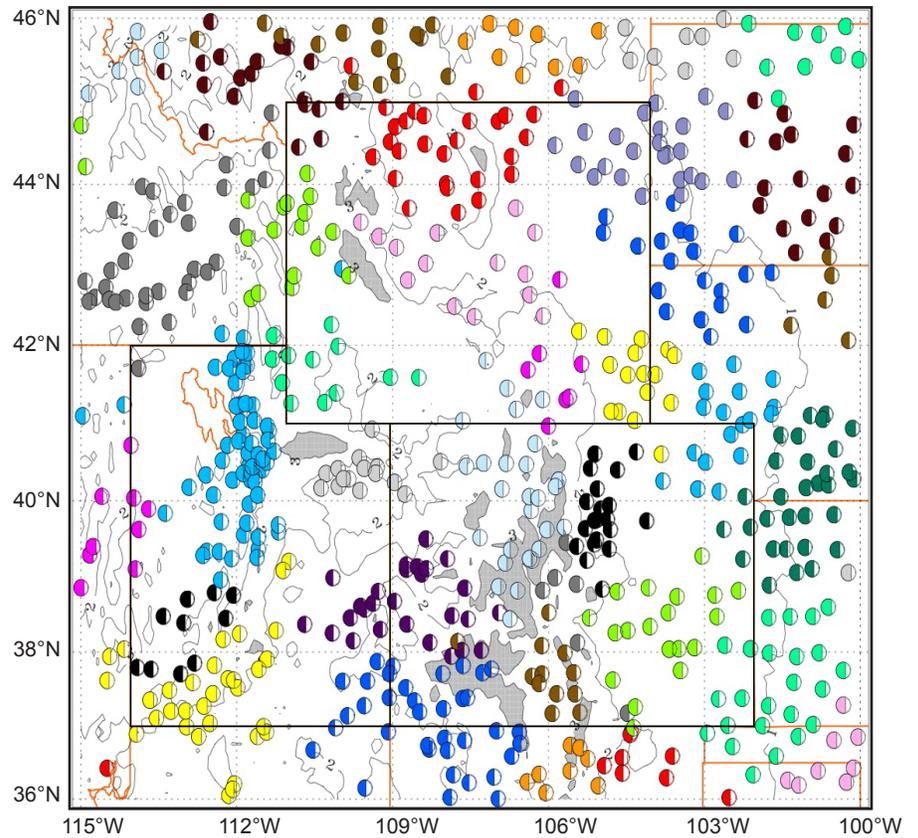
References

- Guttman, N.B., and R.G. Quayle, 1996: “A historical perspective of U.S. climate divisions.” *Bull. Amer. Meteor. Soc.*, **77**, 293-304.
- Wilks, D.S., 1995: *Statistical Methods in the Atmospheric Sciences*. Academic Press, San Diego, xi + 467pp.



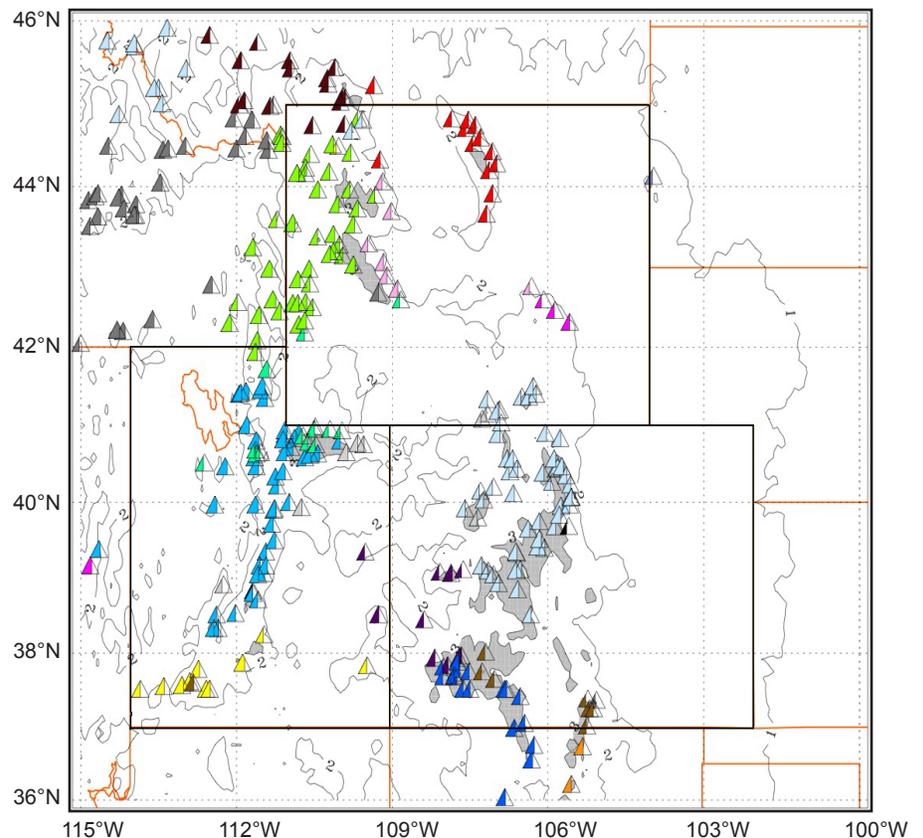
Experimental Climate Divisions, WY79-06

Figure 1d. Near-final map of new climate divisions in the interior western U.S., based on temperature and precipitation station data. Each circle represents a COOP station, featuring the same color within the same climate division. The amount of color in each station symbol represents the amount of local variance that is explained by the new climate division time series.



SNOTEL vs. Experimental Climate Divisions, WY79-03

Figure 1e. Color-coded match of SNOTEL precipitation records against new climate divisions. Each triangle represents a SNOTEL station, featuring the same color within the same climate division. The amount of color in each station symbol represents the amount of local variance that is explained by the new climate division time series that correlates highest with the individual SNOTEL precipitation record.



On the Web

- Project web site: <http://www.cdc.noaa.gov/people/klaus.wolter/ClimateDivisions/> . We will update the web site as this project progresses. Feedback welcome - contact us at: Klaus.Wolter@noaa.gov or (303) 497-6340.



Temperature 5/1/07 - 5/31/07

Monthly average temperatures for May 2007 for the Intermountain West region ranged from 35 – 65°F (Figure 2a). The warmest areas (above 55°F) were across most of **Utah**, the eastern and western thirds of **Colorado**, and eastern and north-central **Wyoming**. Temperatures across most of the region were 0 – 4°F above average. Isolated areas in central and southern **Colorado** were 0 – 2°F below average, and **Utah** had the highest temperatures anomalies recording temperatures 4 – 8°F above average in the northwest (Figure 2b).

The NWS, Salt Lake City reports **Utah** remains very warm and that many record high temperatures were set in May. Throughout the state, 61 record daily high maximum temperatures were tied or broken and 29 daily high minimum records were set. One of the oldest records broken was on May 17, with a record high minimum temperature of 65°F, breaking the old record of 60°F, set in 1948. The Utah Center for Climate and Weather reports that the average statewide temperature for May 2007 was 58.5°F. This was 3.0°F above the 1901-2000 average (55.5°F), and the 22nd warmest May in 113 years.

Temperatures in May 2006 were slightly higher than temperatures in May 2007 throughout much of the IMW region (Figure 2c). In May 2006, most of the region was 2 – 6°F above average, whereas it was mostly 0 – 4°F above average in May 2007. These above average temperature anomalies in May 2006 and 2007 led to an early spring snowmelt in **Colorado** and **Utah** (see page 12 for **Colorado** water availability and page 14 for **Utah** water availability).

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>.

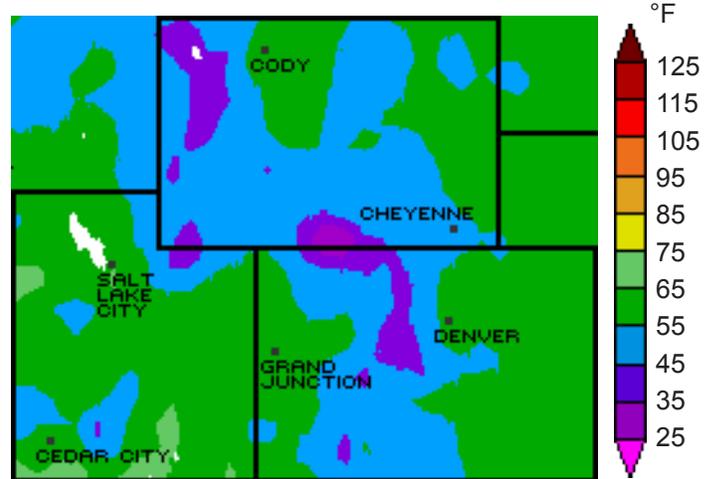


Figure 2a. Average temperature for the month of May 2007 in °F.

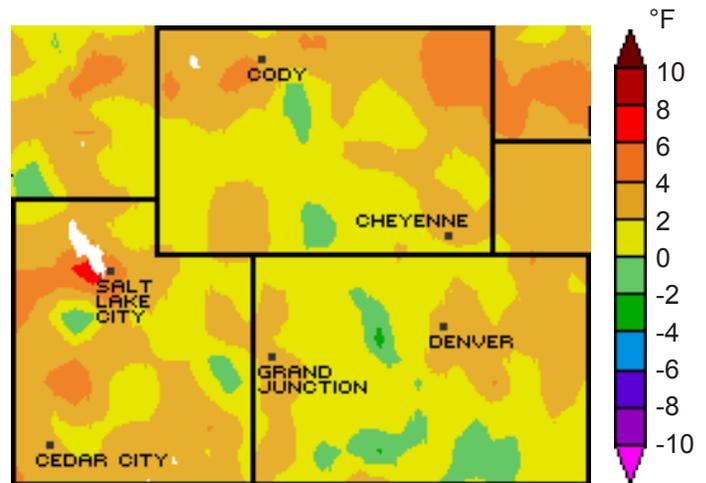


Figure 2b. Departure from average temperature for the month of May 2007 in °F.

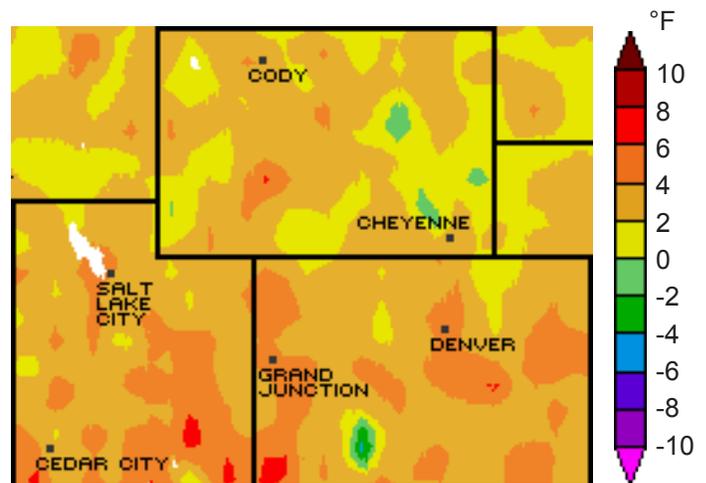


Figure 2c. Departure from average temperature in °F for last year, May 2006.



Precipitation 5/1/07 - 5/31/07

Total precipitation for May 2007 in the Intermountain West regions ranged from 0 to 3+ inches (Figure 3a). Eastern **Wyoming**, especially the northeast, and central and eastern **Colorado** received the highest totals (1.5 – 3+ inches). Southwest **Utah** received the least precipitation amount (< 0 to 0.5 inch).

Much of southwest and central **Colorado**, southeast **Utah** and northeastern **Wyoming** received 120-200% of average precipitation in May (Figure 3b). According to NWS River-ton, **Wyoming**, May precipitation in Casper was 2.86 inches, which is 0.48 inches above average. Both Denver and Salt Lake City had below average precipitation in May. NWS Salt Lake City, **Utah** reports that precipitation total for May was 0.57 inches, which is 27% of average. Southwest **Utah** received less than 40% of average precipitation in May. In **Colorado**, NWS Denver/Boulder reports precipitation at DIA finished with a total of 1.79 inches, which is 0.53 inches below average (2.32 inches). May 2007 marked the 6th May in a row with below normal precipitation for Denver.

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

Notes

The data in Figures 3 a-c come from NOAA's Climate Prediction Center. The maps are created by NOAA's Earth System Research Laboratory and are updated daily (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. As of October 1, 2006, we are in the 2007 water year (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 at high elevation sites. Prior to 1996, this dataset did not include SNOTEL. Percent of average precipitation is calculated by taking the ratio of current to average precipitation and multiplying by 100.

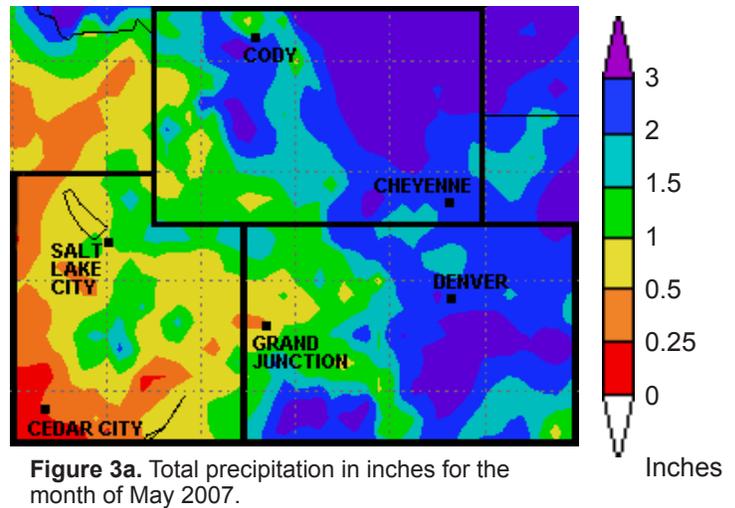


Figure 3a. Total precipitation in inches for the month of May 2007.

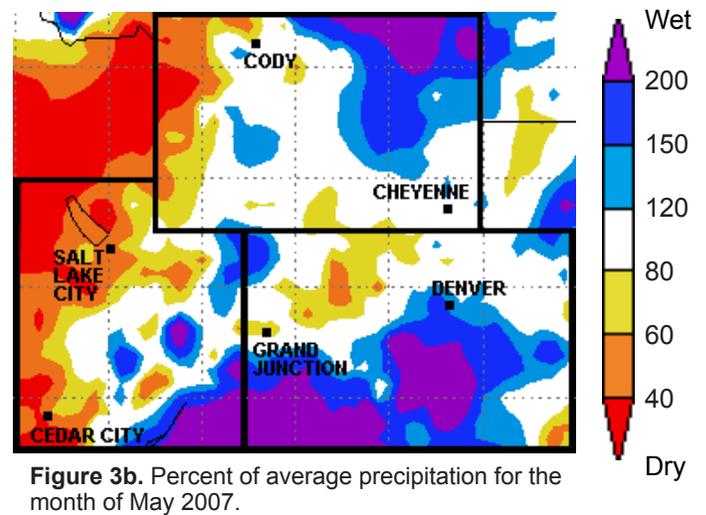


Figure 3b. Percent of average precipitation for the month of May 2007.

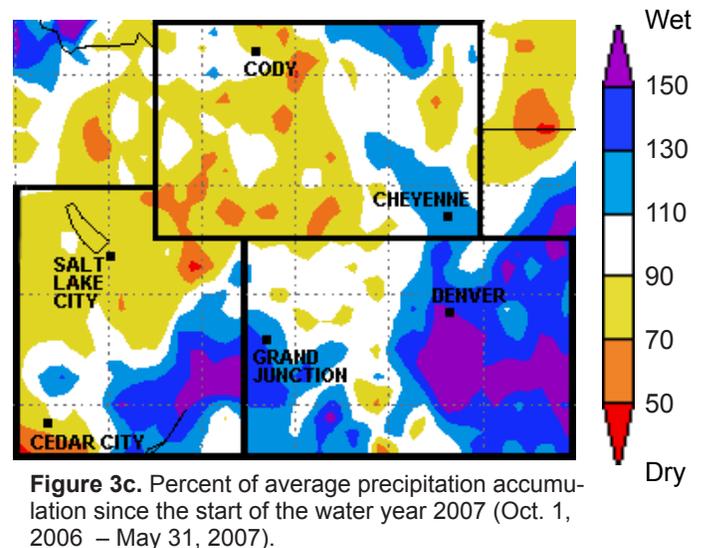


Figure 3c. Percent of average precipitation accumulation since the start of the water year 2007 (Oct. 1, 2006 – May 31, 2007).

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 6/19/07

The Drought Monitor (DM) has changed little since last month, except for parts of northern Wyoming (Figure 4). According to the DM discussion, short-term moisture was adequate or excessive in central and northeastern **Wyoming**, so drought intensity status moved from an abnormally dry (D0) to the non-drought category. Southwestern **Wyoming** remains in severe drought status (D3), and that area now extends slightly more northward than last month. Drought status remained the same in **Utah** and western **Colorado**, with conditions ranging in the abnormally dry (D0) to moderate (D1) categories. The southwest corner in **Utah** remains in severe drought (D2). All of central and eastern **Colorado**, with the exception of a small area in the northeast corner, is now in a non-drought category.

According to the Drought Impact Reporter, the bald eagle population is declining in the Monte Vista National Wildlife Refuge, in Alamosa and Rio Grande counties of southern **Colorado**. The park manager attributes the decline primarily to drought impacts on waterfowl which are prey for the eagles. The manager reports that about half as many eagles entered the area in 2006 as in 1996. In north-central Wyoming, farmers planted fewer sugar beets because

there is insufficient irrigation water, according to the Wyoming Sugar Company chief executive. While the company does not anticipate cuts in the number of employees, there will not be as much work for them.

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 the several agencies: the author of this monitor is David Miskus, CPC/NOAA.

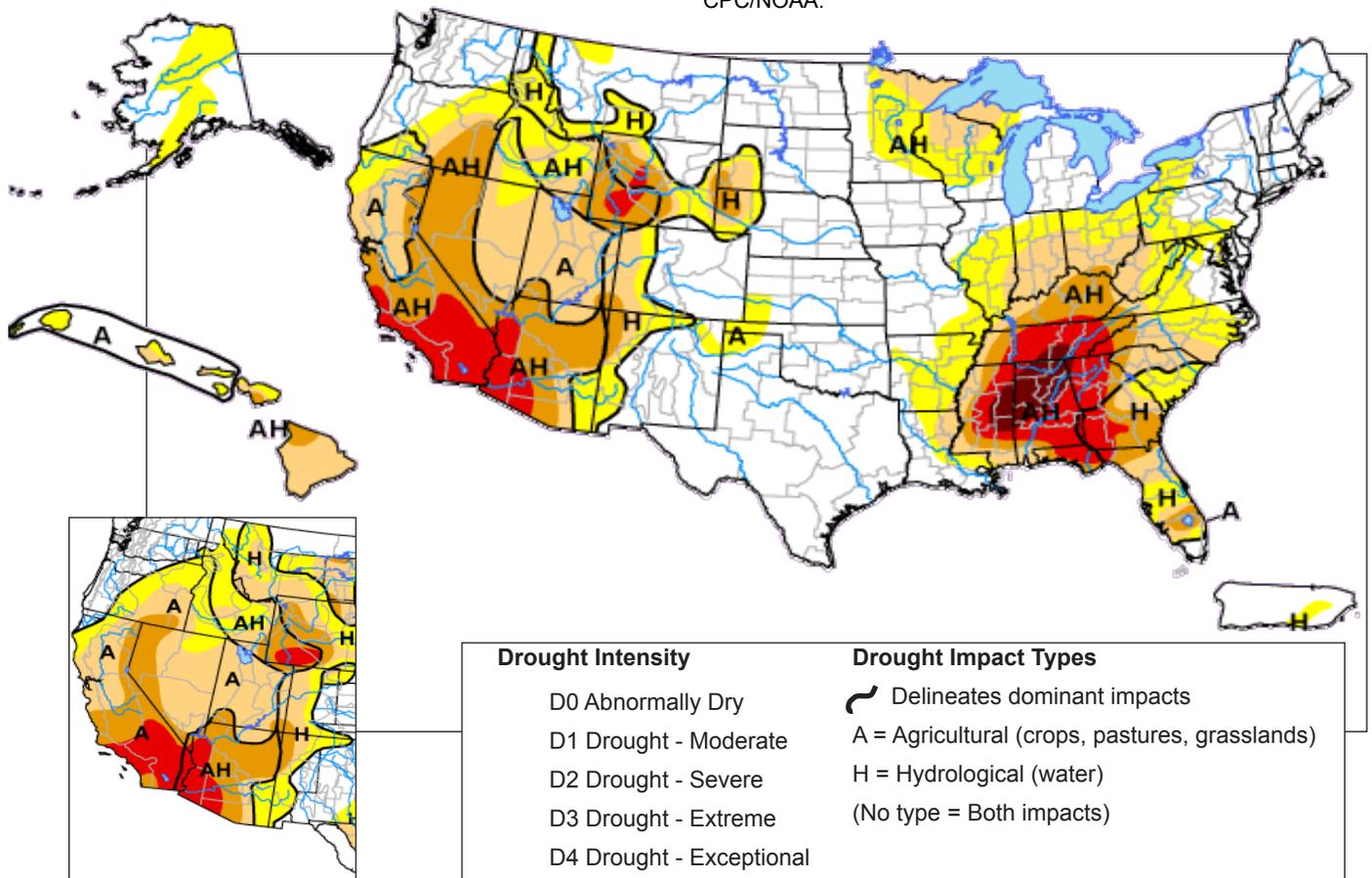


Figure 4. Drought Monitor released June 21, 2007 (full size) and last month, May 15, 2007 (inset, lower left) for comparison.

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

June is part of the peak snowmelt and runoff season, when streamflow is high, and reservoir content increases significantly. The differences between two sets of reservoir data – reservoir storage as percent of capacity and as percent of average – relate to water management decisions at each reservoir (Figure 5). Based on water supply forecasts, water managers balance the two goals of filling reservoirs and preserving space for flood control. For instance, if water supply forecasts are above average, water managers may leave room in the reservoir (“flood control space”) to accommodate higher inflows, but if water supply forecasts are below average and the risk of flooding is low, water managers will capture all available water supplies to ensure enough water in storage for the rest of the year. This year, inflow forecasts were low for most reservoirs (Lake Dillon is an exception), and snow melted early due to warm spring temperatures. Although most reservoirs are far from being full, management responses to these conditions have yielded above average storage levels in the beginning of June.

For example, the latest NWS projection for unregulated April-July inflow at Blue Mesa is 62% of average – a drop of 15,000 acre feet from May’s forecast. In response to declining inflow forecasts since March, the USBR decreased reservoir releases beginning in March to retain storage. Therefore, in the beginning of June, the Gunnison Basin had the highest percent of average

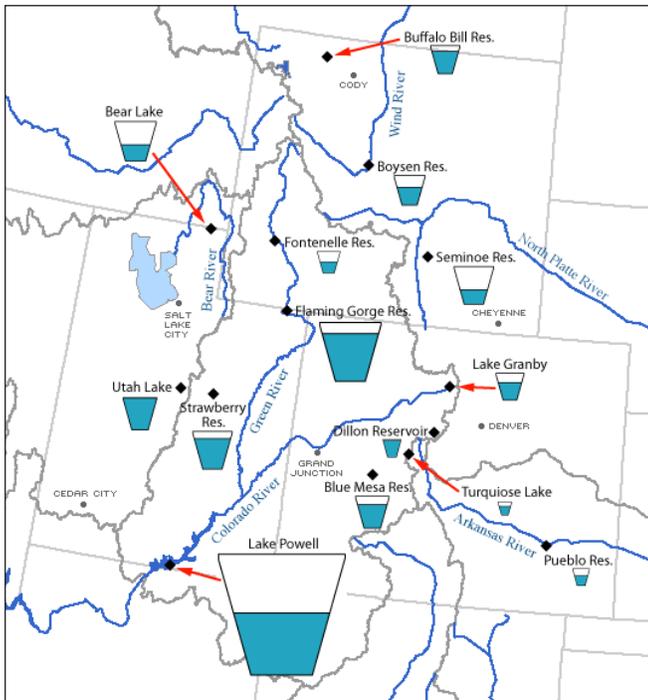
reservoir storage in **Colorado** (129% of average). However, Blue Mesa is not expected to fill, in contrast to last year when it was near capacity and managers were maintaining flood control space.

In **Utah**, above average temperatures also caused an earlier snowmelt resulting in above average inflow rates into reservoirs state-wide. Utah Lake has filled, and Strawberry reservoir is at 83% full and 131% of average. Bear Lake has the lowest storage level of the reservoirs in Figure 5 at 56% of average. Due to below average snowpack in the Colorado River basin, the USBR anticipates that Lakes Powell and Mead are nearing their peak storage for this year, at 52% and 50% of capacity respectively.

In **Wyoming**, reservoir storage ranges from a low of 72% of average for Seminoe to a high of 163% of average for Buffalo Bill. The NWS June forecast for April-July unregulated inflow volume for Flaming Gorge was reduced to 34% of average; at the beginning of June, Flaming Gorge storage was at 84% capacity and 104% of average, but it was not expected to fill.

Notes

The size of each “tea-cup” in Figure 5 is proportional to the size of the reservoir, as is the amount the tea-cup is filled. 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, so see the websites below for the most recent information.



Reservoir	Current Water (KAF)	Total Capacity (KAF)	% Full	% of Average
Colorado				
Blue Mesa Res.	664.8	829.5	80%	129%
Lake Dillon	250.6	254.0	99%	112%
Lake Granby	367.1	539.7	68%	109%
Pueblo	194.7	354.0	55%	108%
Turquoise Lake	96.0	129.4	74%	117%
Utah				
Bear Lake	586.6	1,302.0	45%	56%
Lake Powell	12,691.1	24,322.0	52%	61%
Strawberry Res.	918.6	1,106.5	83%	131%
Utah Lake	950.8	870.9	109%	105%
Wyoming				
Boysen Res.	483.0	741.6	65%	94%
Buffalo Bill Res.	562.4	644.1	87%	163%
Flaming Gorge Res.	3,148.0	3,749.0	84%	104%
Fontenelle Res.	188.5	344.8	55%	104%
Seminoe Res.	430.3	1,017.3	42%	72%

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 June 1-4, 2007.

On the Web

- Dillon Reservoir, operated by Denver Water: <http://www.water.denver.co.gov/indexmain.html>.
- Turquoise Lake, Boysen Reservoir, Seminoe Reservoir, and Buffalo Bill Reservoir operated by the U.S. Bureau of Reclamation (USBR) Great Plains Region: http://www.usbr.gov/gp/hydromet/teacup_form.cfm.
- Lake Granby is part of the Colorado-Big Thompson project, operated by Northern Colorado Water Conservancy District and the USBR Great Plains Region: http://www.ncwcd.org/datareports/data_reports/cbt_wir.pdf.
- Blue Mesa Reservoir, Lake Powell, Flaming Gorge Reservoir, and Fontenelle Reservoir operated by the USBR – Upper Colorado Region: http://www.usbr.gov/uc/wcao/water/basin/tc_cr.html.
- Strawberry Reservoir, operated by the Central Utah Water Conservancy District: <http://www.cuwcd.com/operations/currentdata.htm>.
- Utah Lake, operated by the Utah Division of Water Rights, and Bear Lake, operated by Utah Power: http://www.wcc.nrcs.usda.gov/cgibin/resv_rpt.pl?state=utah.



Regional Standardized Precipitation Index data through 5/31/07

The Regional SPI this month varies across the region, climate divisions ranging from the very wet to very dry categories (Figure 6). In Colorado, there were no changes from last month. All climate divisions are in the near normal to very wet categories, with wetter categories on the east side of the Continental Divide. The wettest division in Colorado and the whole Intermountain West region is the Arkansas Drainage Basin in the very wet category. The Rio Grande and Platte Drainage basins are in the moderately wet category and the rest of the state is in the near normal category.

Utah's climate divisions range from moderately wet in the southeast to very dry in the west. This is the same as last month, except the Western climate division moved from the near normal to moderately dry category. The North Central climate division is also in the moderately dry category, and the small Dixie climate division in southwestern Utah is the driest division in the state, in the very dry category. The Southeast climate division is still the only one in a wet category (moderately wet).

Wyoming remains the driest state in the regions, but due to above average precipitation in the northern and central parts of the state in May, many climate divisions moved towards wetter conditions this month. The driest part of the state is still central Wyoming (Wind River climate division), but it moved from the extremely dry category to the very dry category. The Green/Bear and Upper Platte climate divisions in southeast and south-central Wyoming moved from the very dry to the moderately dry

category. Finally, two eastern climate divisions (Powder/Little Missouri/Tongue and Lower Platte) moved from the moderately dry to the near normal category. The rest of the state is in the near normal category as well.

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 6) 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 graphic in Figure 7 comes from the Western Regional Climate Center, which uses data from the NCDC and the NOAA Climate Prediction Center.

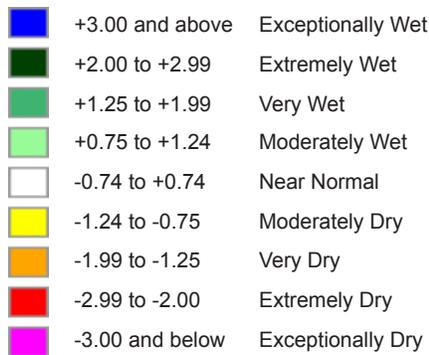
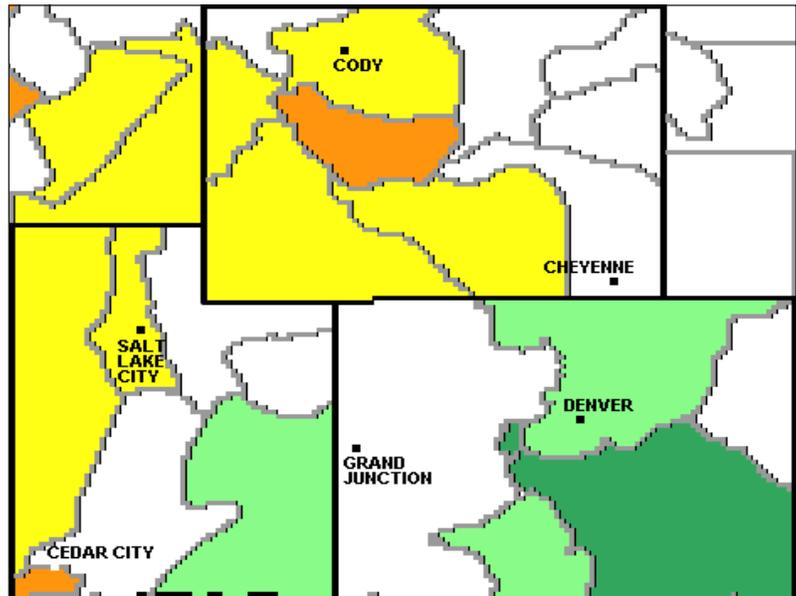


Figure 6. 12-month Intermountain West regional Standardized Precipitation Index (data through 5/31/07).



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 from the NCDC, visit: <http://lwf.ncdc.noaa.gov/oa/climate/research/prelim/drought/spi.html>. These maps use the same data as Figure 6, but the categories are defined slightly differently.



Colorado Water Availability

Remaining snowpack, rate of snowmelt, precipitation amounts, and reservoir storage levels shapes water supply conditions in June. According to the NRCS, snowpack on June 1 is highest in the South Platte Basin at 69% of average and lowest in the Yampa and White River basins, at 20% of average.

Statewide, June 1 snowpack is down to 40% of average. This is 157% of last year's conditions, however, unseasonably high temperatures had already melted the majority of snowpack by this time last year. By basin, snowpacks are the highest in the South Platte Basin (69% of average) and lowest in the Yampa and White River basins (20% of average). Even though snowpack conditions are higher this year, the NRCS projects that complete melt out is still expected to be three to four weeks earlier than average this year.

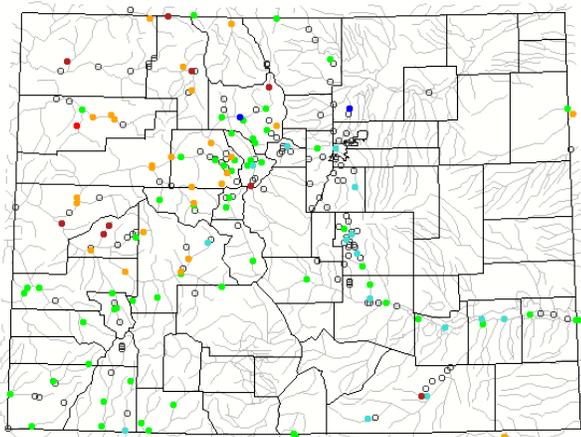


Figure 7a. Seven-day average streamflow conditions for points in Colorado as of June 3, 2007, computed at USGS gauging stations. The colors represent 7-day average streamflow compared to percentiles of 7-day average streamflow.

On June 3, the majority of USGS streamflow volumes across the state are in the normal category (25th -75th percentile) (Figure 7a). Streamflow volumes are in the near or above normal category (25th-90th percentile) on the East Slope in the Arkansas and South Platte River basins. Streamflow volumes are in the below normal category (10th -24th percentile) across the Yampa, White, Colorado, and Gunnison River basins. According to the Roaring Fork Water Conservancy District, below average streamflow volumes on the Roaring Fork River near Aspen may not meet the junior minimum instream flow water rights (see link to article in On the Web box).

SWSI values across the state all increased from last month due to above average reservoir storage, with current values ranging

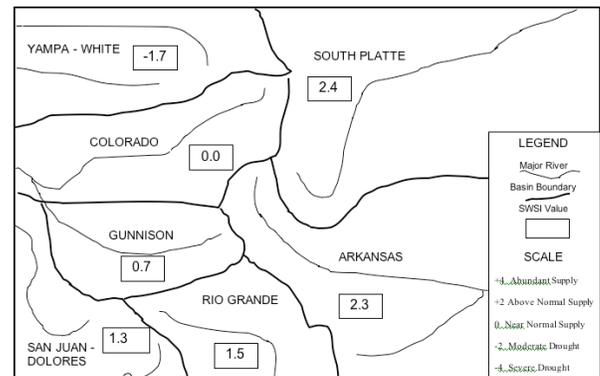


Figure 7b. Colorado Surface Water Supply Index. The map is an indicator of mountain-based water supply conditions in the major river basins of the state as of June 1, 2007.

from a low -1.7 in the Yampa and White Basins to a high of +2.4 in the South Platte Basin (Figure 7b). Along with reservoir storage, above average precipitation in the Arkansas Basin brought the SWSI value up +3.1, which is the highest SWSI increase since last month. Only the Colorado Basin SWSI values remained about the same, increasing +0.1 from last month.

Notes

The “7-day average streamflow” map (Figure 7a) 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 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), 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. The SWSI values in Figure 7b were computed for each of the seven major basins in Colorado for June 1, 2007 and reflect conditions through the end of May 2007.

On the Web

- Aspen Times Weekly, “One tough summer for Roaring Fork,” May 13, 2007, <http://www.aspentimes.com/article/20070513/NEWS/105130084>.
- For current streamflow information from USGS as in Figure 7a, visit: <http://water.usgs.gov/waterwatch/>.
- The Colorado SWSI as in Figure 7b, 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 most recent drought status assessment from the Wyoming State Climatologist (Figure 8a) indicates that eight counties in northern and eastern Wyoming have been upgraded from drought categories to the wet-normal category. According to the state climatologist Steve Gray, Laramie and Albany counties moved into the wet-normal category despite average-below average precipitation in May because of excellent range conditions and vegetation health, along with good streamflows and reservoir levels. The northern counties of Bighorn and Washakie have upgraded from drought warning to watch categories. However, the entire western half of Wyoming still remains in drought watch or warning categories. Southwestern Sweetwater county and southeastern Goshen county are still in the extreme drought category.

As of June 7, 2007, the USGS streamflow gauges (Figure 8b) indicate that in northeastern Wyoming, most streamflows are in the normal category (25th to 75th percentile), with a few above that. However, many western and southern gauges are in the below normal category (10th to 24th percentile) or much below normal category (<10th percentile). Steve Gray attributes low streamflow levels to below average winter precipitation and to above average spring temperatures causing early snowmelt.

The NRCS State Basin Outlook for Wyoming reports that SWE across the state is far below average for this time of year. Statewide SWE is 17% of average for early June. Seasonal streamflow volumes are expected to be below average across Wyoming; most probable yield (50% exceedence probability) varies from 12-90%. The lowest expected streamflow volumes are in the western basins of the Little Bear and Upper Snake Rivers and the highest expected streamflow volumes are in the north-central basins of the Big Horn, Powder, and Tongue Rivers.

Notes

The Drought Status (Figure 8a) is calculated by the Wyoming state climatologist. Five different factors are considered when making the county level maps: precipitation deficits/surplus over a number of different temporal windows going out to 3 years, available surface water supplies and streamflow values, range/vegetation condition, snow pack (when and where applicable), and soil moisture (when and where reliable data are available).

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. 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.

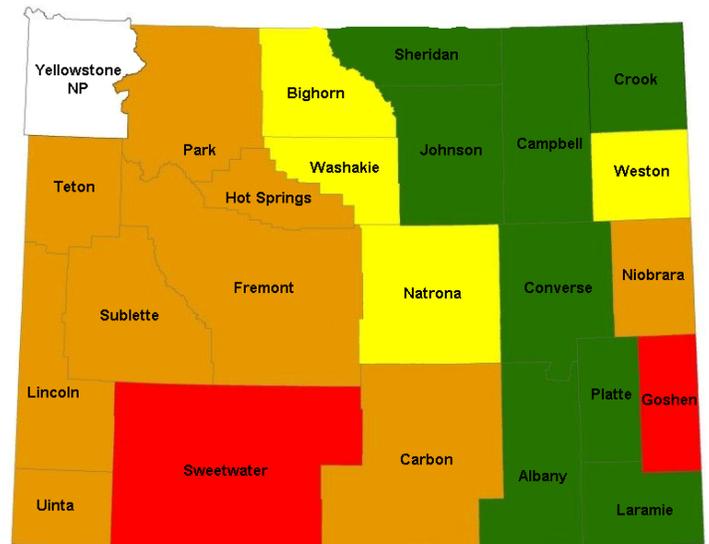


Figure 8a. Wyoming drought status. Map shows the Wyoming State Climatologists assessment of the status of the drought throughout the state as of May 30, 2007.

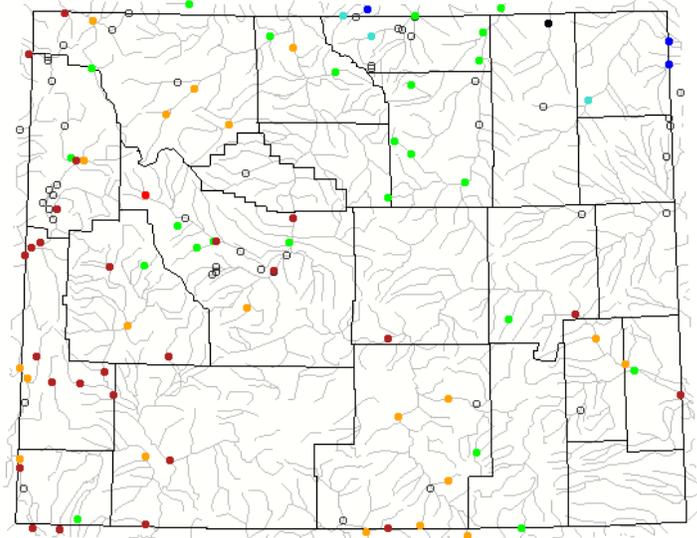


Figure 8b. Seven-day average streamflow conditions for points in Wyoming as of June 7, 2007, computed at USGS gauging stations. The colors represent 7-day average streamflow compared to percentiles of 7-day average streamflow.

On the Web

- The Wyoming Drought Status map (Figure 8a) can be found on the Wyoming Water Resource Data system's drought page is located at: <http://www.wrds.uwyo.edu/wrds/wsc/dtf/drought.html>.
- For current streamflow information from USGS as in Figure 8b, visit: <http://water.usgs.gov/waterwatch/>.
- 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>.



Utah Water Availability

According to the NWS Salt Lake City, May 2007 was warmer and drier than average. As of June 7, 2007, most of the USGS streamflow sites in Utah had values in the below normal (10th-24th percentile) or the much below normal (<10th percentile) categories (Figure 10a). Some gauges in the northern and central parts of the state are in the normal category (25th to 75th percentiles).

Using data from soil moisture sensors, the NRCS compiles monthly averages of soil moisture statewide and by individual basins. Soil moisture is at its peak for the year now because the snow is melting. Statewide soil moisture was about 66% saturation at the beginning of June (Figure 9b). This is near the same value as in June 2006, and both years were slightly below the values for June 2005. Currently, one of the driest areas in Utah is the southwest. This is also reflected in the Southwest Utah watershed chart (Figure 9c). Percent of saturation is at about 60%, which is the same as June 2006. Note that the water year began with lower soil moisture levels in the southwest watershed at 25% compared to 45% statewide, and that the southwest was also lower than the state average throughout the winter, and

much lower than in 2005. These data are being used to improve the water supply outlooks by incorporating information on soil moisture deficits. For more information on this network see the focus page in the June 2006 IMW Climate Summary.

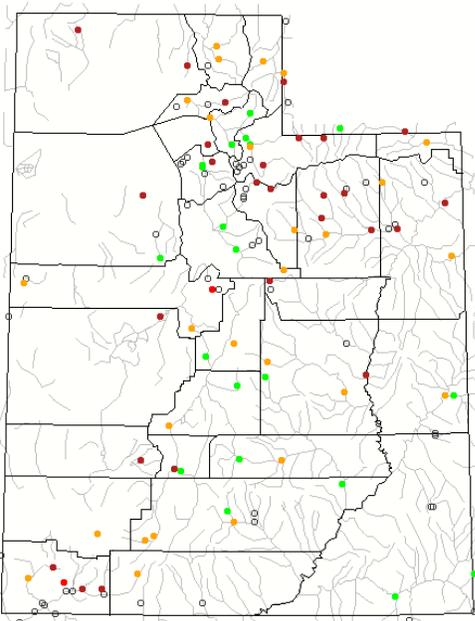
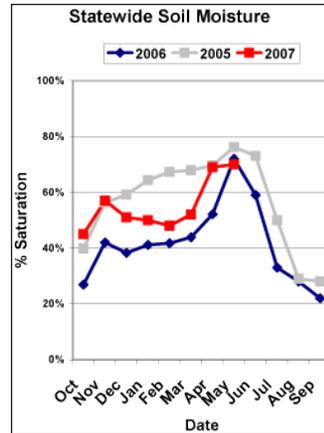
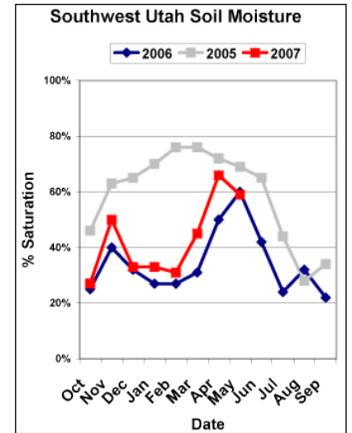


Figure 9a. Seven-day average streamflow conditions for points in Utah as of June 7, 2007, computed at USGS gauging stations. The colors represent 7-day average streamflow compared to percentiles of 7-day average streamflow for 6/07/06.



(9b)



(9c)

Figures 9b-c. Utah soil moisture charts for Utah for 2005-2007 (b) statewide; (c) southwest Utah. Data is current as of May 29, 2007. Soil moisture charts for individual watersheds are available on the Utah NRCS webpage.

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.

Figure 9b shows the average percentage of ground saturation for a watershed or region. Data are collected from sensors, which measure soil moisture as a percent of total soil volume. The sensors are typically placed at 2, 8, and 20 inch depths at 10-16 SNOTEL sites within each basin. Beginning at the surface, a 2-inch depth sensor represents the first 6 inches of soil, an 8-inch sensor represents the next 9 inches of soil and a 20-inch sensor measures the following 12 inches with a total measurement of 26 inches of soil.

On the Web

- For monthly reports on water supply conditions & forecasts for major CO river basins, visit: <http://www.wcc.nrcs.usda.gov/cgibin/bor.pl>.
- For current streamflow information from USGS as in Figure 9a, visit: <http://water.usgs.gov/waterwatch/>.
- Utah NRCS Soil Moisture plots as in Figure 9b can be found at: <http://www.ut.nrcs.usda.gov/snow/climate/>.
- 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/wsups.cgi>.



Temperature Outlook July – November 2007

There is unusually high spatial coverage for the July 2007 forecasts, meaning that there was sufficient skill to designate colored forecast regions for a large area (Figure 10a). The July 2007 temperature outlook indicates an increased risk of above average temperatures across **Utah, Wyoming, western Colorado**, and the Rio Grande Valley, largely based on recent trends. Further east, over the Great Plains, the forecast is for an increased chance of above average temperatures. This forecast reflects the wet soil moisture anomalies currently found in that region (see <http://www.cpc.ncep.noaa.gov/soilmst/img/curr.w.anom.daily.gif>); wet soil conditions tend to moderate temperatures. Forecasts which take advantage of soil moisture anomalies have shown skill for regional climate prediction during the summer. The July 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 have increased skill over the half-month lead forecasts.

In July-September 2007, the Intermountain West and the Southwest show increased risk of above average temperatures (Figure 10b). However, in subsequent forecast periods (Aug – Oct and Sep – Nov 2007) most of **Wyoming, parts of Colorado and Utah**, and most of the Great Plains and have equal chances (EC) of below- near- or above normal temperatures (Figures 10c-d). The IRI multi-model world temperature forecast also indicates a slightly increased risk for above average temperatures across much of the region in its July- September 2007 forecast period (not shown, see “On the Web”).

CPC does not expect any El Nino or La Nina impacts on the climate of the United States during the June-August 2007 season; La Nina a factor in fall forecasts for some regions of the U.S., but does not have a significant impact on the temperature of the Intermountain West.

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	B = Below
 60.0–69.9%	 40.0–49.9%
 50.0–59.9%	 33.3–39.9%
 40.0–49.9%	
 33.3–39.9%	EC = Equal Chances

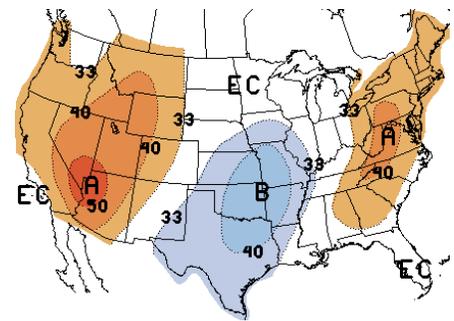


Figure 10a. Long-lead national temperature forecast for July 2007 (released June 21, 2007).

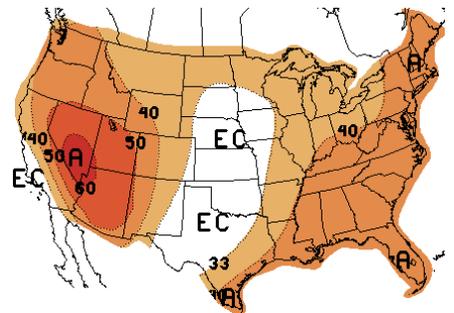


Figure 10b. Long-lead national temperature forecast for July – September 2007 (released June 21, 2007).

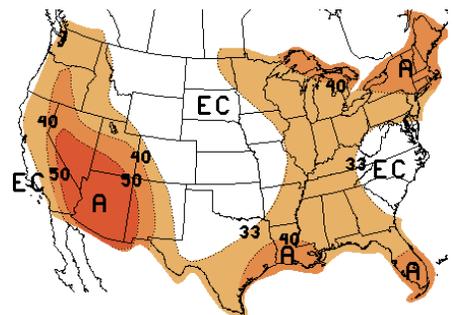


Figure 10c. Long-lead national temperature forecast for August – October 2007 (released June 21, 2007).

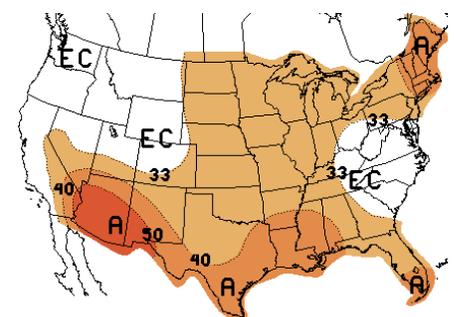


Figure 10d. Long-lead national temperature forecast for September – November 2007 (released June 21, 2007).

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 – November 2007

The July 2007 CPC precipitation outlook is based on unusually good agreement among traditional forecast tools and strong initial soil moisture anomalies over large areas of the country. Soil moisture anomalies are a major contribution to predictive skill for regional climate in the summer season. The forecast indicates an increased chance for below average precipitation in most of **Wyoming** and **Utah**, and in northwestern **Colorado** (Figure 11a). CPC indicates that the U.S. has been – for some time – in a pattern of cool and wet in the center of the country and warm and dry in the Southwest and the Southeast. This general pattern is likely to continue during the last 10 days of June and into July 2007. The July precipitation forecast will be updated on June 30th 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 western **Wyoming** and northwest **Utah**. These areas are on the edge of drier than normal forecasted conditions centered over the Great Basin and Pacific Northwest. A number of tools support this dry forecast, including recent trends and cool SSTs in the eastern equatorial Pacific. Dry soil moisture anomalies in the northern Great Basin (not shown, see <http://www.cpc.ncep.noaa.gov/soilmst/img/curr.w.anom.daily.gif>) also favors increased chances of below median precipitation. However, CPC says their confidence is not very high, because most precipitation variability is associated with day-to-day weather events not predictable beyond a week or so in advance.

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.

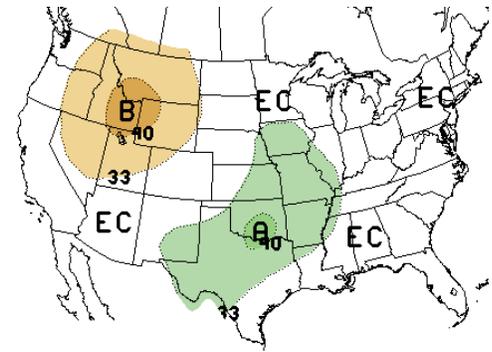


Figure 11a. Long-lead national precipitation forecast for July 2007 (released June 21, 2007).

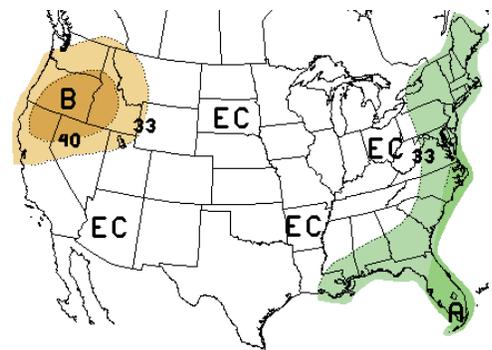


Figure 11b. Long-lead national precipitation forecast for July – September 2007 (released June 21, 2007).

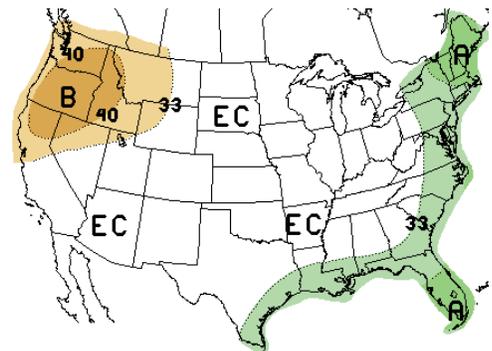


Figure 11c. Long-lead national precipitation forecast for August – October 2007 (released June 21, 2007).

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

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>.



Precipitation Outlook *cont.*

According to Klaus Wolter, the experimental forecast guidance for precipitation for the monsoon season (July-September) is “mild” for much of the interior southwestern U.S., with only one significant shift in the probabilities towards dry conditions (in New Mexico). He says, “the northern Front Range in **Colorado** are more likely to see a dry summer,” supported by good verification skill for his forecast procedure in the last seven forecast summers. If La Niña were to take off in the near future, a dry and hot summer would be even more likely in much of **Colorado, Utah, and New Mexico**.

Notes

The experimental guidance for seasonal future precipitation in Figure 11d shows most recent forecast of shifts in tercile probabilities for April - June 2007. 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.

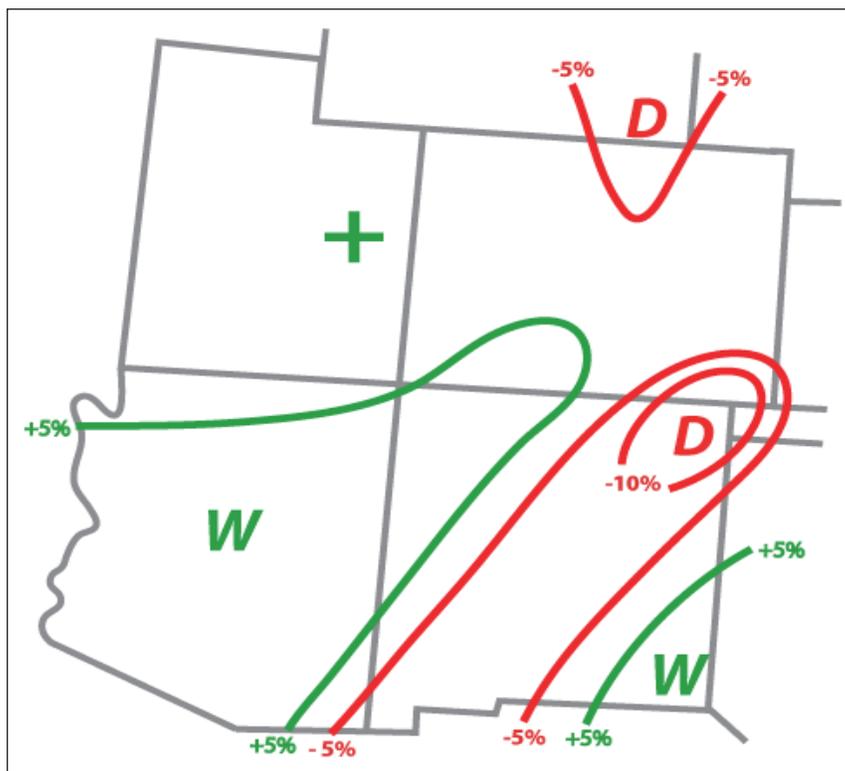


Figure 11d. Experimental Precipitation Forecast Guidance Jul – Sep 2007 (released June 21, 2007).

On the Web

- The WWA 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 August 2007

The Drought Outlook (DO) depicts general, large-scale trends through the end of September 2007 (3.5 months, Figure 12). This product begins with the designations from the U.S. Drought Monitor, which designates most of the western U.S. as in drought, and projects changes in status. The western drought area extends from California into the Great Basin, including **Utah** and western **Colorado** and **Wyoming**. The dry season has begun in this area, so little lasting relief is expected, and drought is expected to persist and even extend northward into Idaho. However, the summer thunderstorm season running from July into September should bring some relief to Arizona.

The next DO will be issued in two weeks, on July 5th. CPC is increasing the frequency of issuance of this product, which – until now – has been issued once a month on the 3rd Thursday with a valid period of about 3.5 months after issuance. As of this month, CPC will also issue the DO on the 1st Thursday of the month with a valid time covering the rest of the month plus the next two months (i.e. just under 3 months after issuance). This will provide an improved and more consistent level of service.

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. Abstracts are due 15 July 2007. 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.

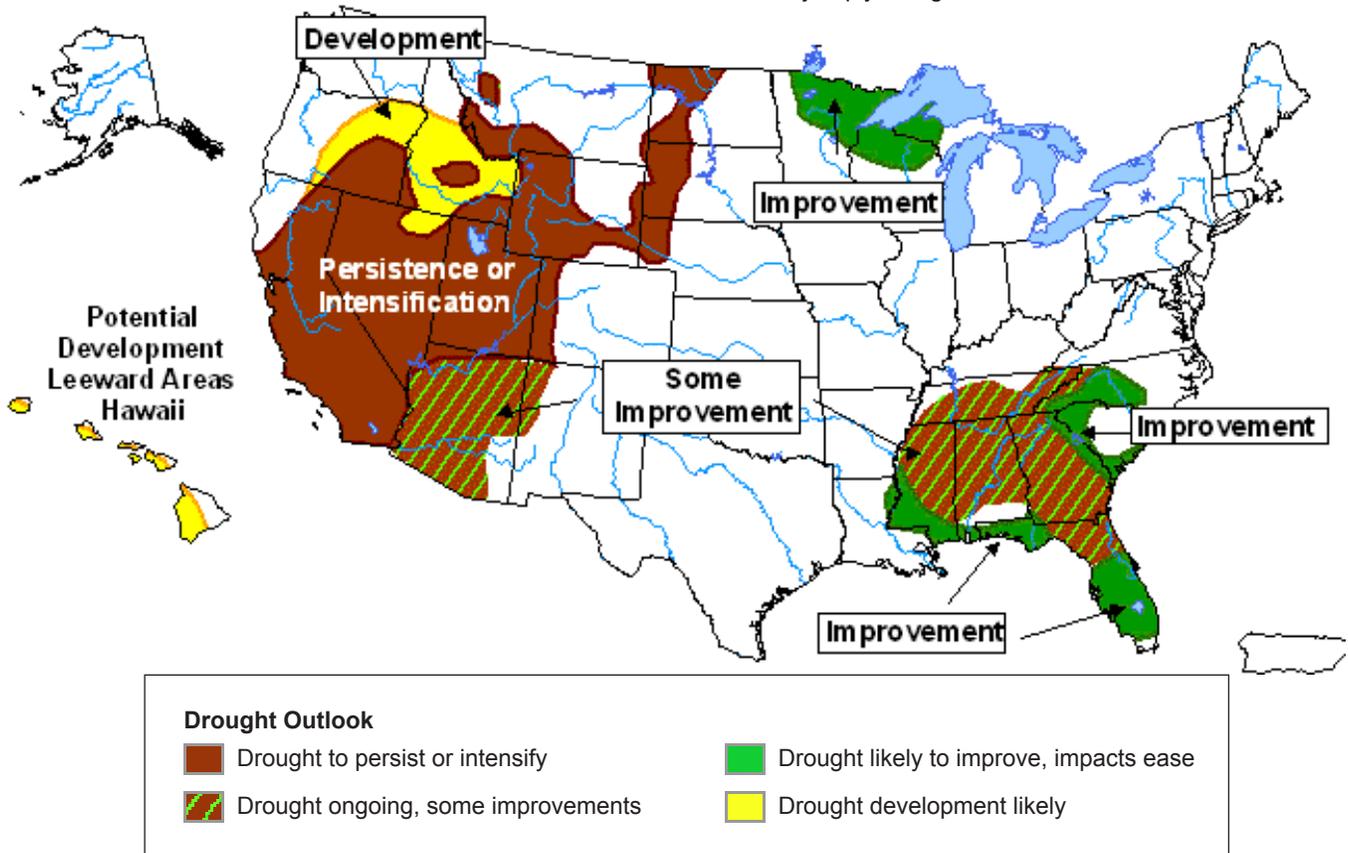


Figure 12. Seasonal Drought Outlook through September 2007 (release date June 21, 2007).

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 through June 2007

According to the NOAA Climate Prediction Center, conditions in the equatorial Pacific in the first part of 2007 indicated that a La Niña might develop by mid-2007. These conditions included a rapid decrease in sea surface temperature (SST) anomalies in the central Pacific, and the development of below average SSTs near the equator along the South American coast. However, below average SSTs have not continued to develop in the central Pacific, and sub-surface ocean temperatures in the central Pacific have recently become slightly above average (Figure 13a). These indicators make a transition to La Niña conditions much less likely in the next few months than was thought earlier in the year. Most dynamic models continue to predict a transition to weak La Niña conditions by late summer, although statistical models predict that central Pacific SSTs will drift only slightly downward (Figure 13b). Thus, there is a large amount of uncertainty in this prediction.

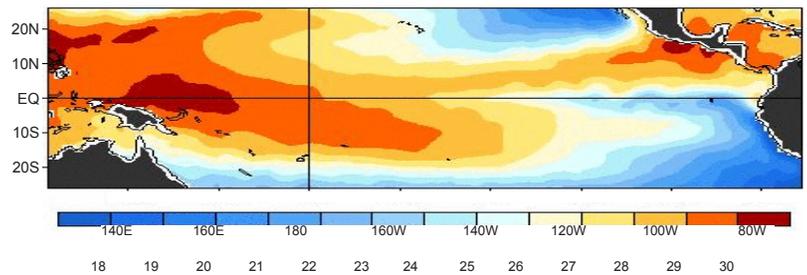
At this time neutral ENSO conditions are anticipated through the July-September season with the development of La Niña conditions possible later in the fall, although at this time it appears that La Niña conditions would be weak. Thus ENSO has a limited impact on the forecasts made this month for the U.S. The CPC ENSO Diagnostic Discussion will be updated on July 12th, and the IRI ENSO "Quick Look" on July 19th.

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.

Observed Sea Surface Temperature (C°)



Observed Sea Surface Temperature Anomalies (C°)

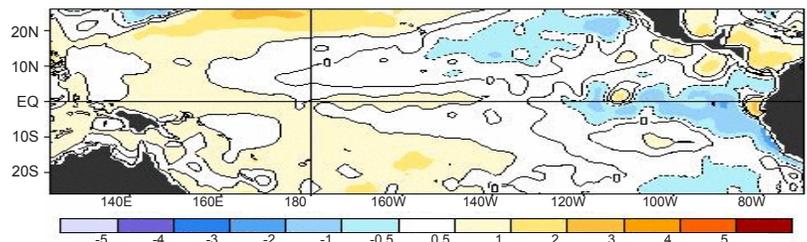


Figure 13a. Observed SST (upper) and the observed SST anomalies (lower) in the Pacific Ocean. The Niño 3.4 region encompasses the area between 120°W-170°W and 5°N-5°S. The graphics represent the 7-day average centered on June 13, 2007.

Model Forecasts of ENSO from May 2007

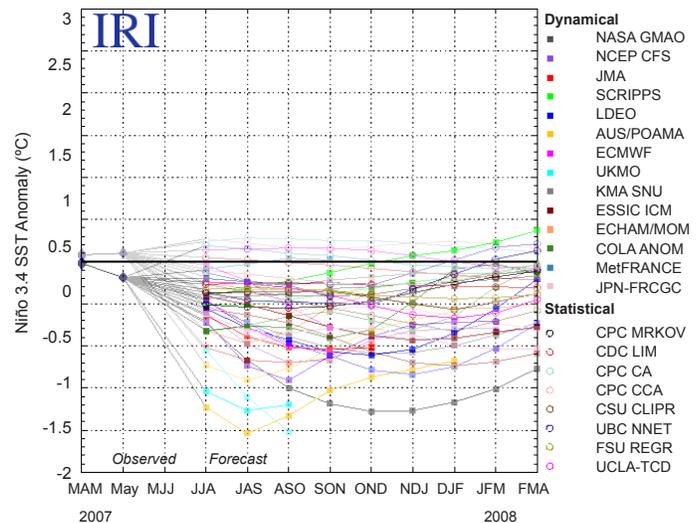


Figure 13b. Forecasts made by dynamical and statistical models for sea surface temperatures (SST) in the Niño 3.4 region for nine overlapping 3-month periods from June 2007 through April 2008 (released June 20, 2007). Forecast graphic is from the International Research Institute (IRI) for Climate and 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://iri.columbia.edu/climate/ENSO/>.



Climate and Tourism on the Colorado Plateau: A Workshop Summary

By Christina Alvord, WWA, Patrick Long, Leeds School of Business, University of Colorado, Roger Pulwarty, NOAA, and Bradley Udall, WWA

This article is a summary of a workshop on Climate and Tourism co-hosted by WWA, Center for Sustainable Tourism in Leeds School of Business at the University of Colorado, and the National Atmospheric Research Center (NCAR) on January 23-24, 2007 in Boulder, Colorado.

In the Colorado Plateau (Arizona, Colorado, New Mexico, and Utah), skiing, rafting, fishing, biking, and other outdoor activities bring a large portion of each state's annual revenue. Because climate conditions play a primary role in industry success and long-term viability, these industries are especially vulnerable to climate variability and change. The Climate and Tourism Workshop examined how climate influences daily operations, seasonal revenue, and long-term business sustainability on the Colorado Plateau. Thirty participants ranging from Arizona Golf Association, Vail Resorts, Colorado River Water Conservation District, State Parks, and others gathered at this two-day workshop conducted in a participant-driven, open discussion format. Workshop goals included: communicating climate information to tourism industry professionals, identifying impacts of climate variability and change on tourism operations, exploring potential adaptation and mitigation strategies to increase industry viability, and pinpointing the role of the scientific community in helping industry professionals better manage the effects of climate on business. The latter three topics are summarized in this article.

Impacts of Climate Variability and Change on the Tourism Economy

Roger Pulwarty of NOAA emphasized that the "goal of this workshop is to distinguish how seasonal climate variability as well as long-term changes in climate impact Colorado Plateau-based tourism." Climate experts began the workshop by presenting climate trends on the Colorado Plateau: observations show a 2°C increase in temperatures, a decline in snowpack, earlier timing of spring snowmelt, and a decrease in late season streamflow volumes.

Participants then discussed how climate variability affects tourism businesses, local economies, and tourist travel behavior. Participants agreed that unfavorable climate conditions such as below average snowpack and streamflows or above average rainfall, affect seasonal revenue and compel businesses to shorten the traditional profit-making season. For example, prolonged periods of rainfall negatively influences tourist willingness to go whitewater rafting, camping, or golfing. And historically, below average snowpack and streamflows lowers revenue generated by snow and water based recreation industries in comparison to wet years. So, considering the impact that seasonal climate vari-



Figure 14a. Vail Mountain, Gore Range, Colorado. Warmer temperatures tied to climate change decreases snowpack, affecting seasonal revenue for ski resorts in the West.

ability already has on tourism, a continued decrease in snowpack and streamflow volumes attributed to global warming threatens the long-term livelihood of the tourist industry. Tourism brings a large portion of the annual revenue to towns like Moab, Utah, Taos, New Mexico, Sedona, Arizona, and Telluride, Colorado, who all struggle to maintain stable business activity throughout the year. Author and journalist Allen Best suggested that if tourist visitations decline due to unfavorable climate conditions, these tourist-based communities could increasingly rely on other areas of economic growth, such as natural resource extraction, to offset economic losses. Finally, participants observed that negative public perceptions of climate conditions in destination locations are just as important as the actual conditions themselves. For instance, in the drought year of 2002, the declaration by then Governor Owens that the "entire state is in flames," led to immediate visitor cancellations in many tourism sectors across Colorado—even areas miles away from wildfires, according to Mike Hayes from the National Drought Mitigation Center (NDMC).

Adaptation & Mitigation Strategies

Discussions identified six industry and community-wide adaptive management and mitigation strategies that could offset current and potential effects of increased climate variability





Figure 14b. Whitewater rafting on the Arkansas River in Colorado. With water availability already a concern on the Colorado River, increased climate variability and change might decrease the water available for recreation.

and change. 1) Participants support the creation of an improved early warning drought system, which would give businesses additional time to adjust operations and plan for pending climate conditions. 2) Operational adaptations can offset below-average snowpack or streamflow condition by continuing to expand snowmaking operations at ski resorts and using smaller, lighter boats for whitewater rafting. 3) Industry flexibility and diversity in local economies help businesses adapt to climate variability by offering “off-season” alternative activities such as climbing, jeep tours, or road biking that take advantage of warm and dry conditions. 4) Industries can decrease their contribution to global warming by using “green” innovations, including wind power, energy efficient fuel sources, or water-efficient technologies. 5) Stronger partnerships between researchers, businesses, and local government are important to identify information gaps, and potential research collaborations. 6) Working in close collaboration with the media and developing effective marketing campaigns is important in communicating accurate climate conditions to the general public.

The Role of the Scientific Community

Workshop participants also identified opportunities for scientific and business collaborations. First, better characterization of certainties and uncertainties in climate variability and change projections would be useful to the tourism industry for long-term planning purposes. Ed Gowan, president of the Arizona Golf Association, recommended using probability confidence intervals for regional temperature and precipitation projections. For example, instead of a projection of 2-5° C increase in temperature over fifty years, a better hypothetical framing would be, “2° C increase is 60-80% likely, a 3° C increase is 40-60% likely, etc.”

Second, participants agreed that development of tourism-climate indices and corresponding threshold values could be poten-

tially useful in pinpointing at-risk industry practices. A Tourism Climatic Index (TCI) (Mieczkowski, 1985), is a quantitative evaluation of climate for the purpose of general tourism activity (e.g., shopping, sightseeing) based on the notion of ‘human comfort.’ Calculation of TCI involves combinations of monthly averages of climate variables, including daily temperature, relative humidity, precipitation, sunshine, and wind. The “climate suitability” for the location of a particular tourism activity is then rated on a scale from ‘ideal’ to ‘impossible.’

Finally, snowpack conditions, streamflows, and precipitation and temperature forecasts are used in every-day operations, but this information is currently scattered among multiple sources and it is difficult to assimilate or interpret in its current format. Therefore, participants would like access to a clearinghouse of current climate information catered towards tourism industry operations because better communication and characterization of climate information would greatly assist industry professionals in every-day operations and long-term planning purposes.

Participants wrapped up the two-day interchange by agreeing that the partnerships formed at the workshop are important in ensuring tourism industry adaptability on the Colorado Plateau. For more information about the workshop, including workshop presentations and related academic literature, visit the WWA “Climate and Tourism Workshop” webpage (see On the Web box).

Update: U.S. Senate Hearing on Climate and Tourism

Recently, the United States Senate Committee on Environment and Public Works hosted a hearing on, “The Issue of the Potential Impacts of Global Warming on Recreation and the Recreation Industry” on May 24, 2007, led by Senator Barbara Boxer (D-CA). In a statement by Senator Boxer, she recognized that, “global warming can have a profound and negative impact on our outdoor recreation opportunities and businesses.” For more information on this hearing, see On the Web box.

Sources

Mieczkowski, Z. (1985). “The Tourism Climatic Index: A Method of Evaluating World Climates for Tourism.” *Canadian Geographer*, 29 (3): 220-233.

On the Web

- WWA “Climate and Tourism Workshop” webpage, available at <http://wwa.colorado.edu/outreach/climatetourworkshop.html>.
- U.S. Senate Committee on Environment and Public Works, available at <http://epw.senate.gov/public/index.cfm?FuseAction=Home.Home>.

