Intermountain West Climate Summary

by The Western Water Assessment

Issued June 17, 2005

June 2005 Climate Summary

Hydrological Conditions – Much of Colorado and Utah is in the near normal range with respect to Standardized Precipitation Index, water availability, and drought status. Most of Wyoming is still in drought, but conditions have improved over the past month.

Temperature – Anomalously high average temperatures in southern Utah and southern Colorado, especially in the end of May, caused rapid snowmelt and a surge of high streamflows.

Precipitation – Above average precipitation totals helped improve the drought status in Wyoming and parts of northern Colorado.

El Niño – ENSO-neutral conditions are expected through early 2006.

Climate Forecasts – Based on long-term trends, an increased risk of above normal temperatures is predicted. CPC outlooks suggest a weak southwest monsoon, favoring dry conditions in the western part of the region. Long-term temperature trends continue to indicate above normal temperatures for parts of the Intermountain West region.

June Transitions in the Intermountain West

June is a time of transition for hydrologic and water supply conditions. Snow melts, filling streams and reservoirs with what are typically the largest streamflows of the year. This month's summary reflects the transition in both climate conditions and the interests of water management: the snowpack maps and streamflow outlooks are gone because the NRCS produces the last updates of the season in May. The reservoir supply page shows increases in storage across the Intermountain West, with storage higher across the region than in several years. June also marks the transition in how some hydrologic indices are calculated: the components of the Colorado Surface Water Supply Index (SWSI) in winter are snowpack, reservoir storage, and precipitation. During the summer (May-Oct, the June 1 - Nov. 1 SWSI values) the components are streamflow, reservoir storage and precipitation.

Snowpack maps and streamflow outlooks will return to the Summary next winter. Until then, to see streamflow water supply, and snowmelt peak flow outlooks, consult the web pages shown on the back page of this Summary to link to NOAA River Forecast Center for your basin.

This month, the Summary features an article about a recent workshop with water managers and paleoclimate scientists to supplement the historical hydrologic record with paleoclimate reconstructions to assist decision support in the Colorado River Basin. The focus page highlights a relatively new climate guidance product: an experimental seasonal climate forecast for the Interior Southwest, developed by Dr. Klaus Wolter of CDC and the Western Water Assessment. His product may be familiar to some, because he has been a regular presenter at the Colorado Drought Task Force for several years.

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

Contact Us - We want to hear your questions and feedback! Please e-mail us at WWAoutlook@sciencepolicy.colorado.edu

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The Intermountain West Climate Summary is published monthly by Western Water Assessment, a joint project of the University of Colorado and the NOAA Climate Diagnostics Center, researching water, climate and societal interactions.

Workshop Report: "Developing Hydroclimatic Reconstructions for Decision Support in the Colorado River Basin"

BY Connie Woodhouse, paleoclimatologist at the NOAA National Climatic Data Center in Boulder, CO.

Western Water Assessment and NOAA scientists have been exploring ways to expand paleoclimatic research activities to address larger regional concerns in the southwest and Colorado River Basin. Paleoclimatic reconstructions, such as those based on tree rings (Figure 1a), provide a record of climate variability in the past. In May 2005, they worked with researchers at the University of Arizona to conduct a workshop to broaden the use of paleoclimatic data and to expand its applications to management and decision-making.

The Colorado River is a critical water resource for a wide array of economic, political, and environmental concerns in seven western U.S. states and Mexico. Water management within the basin must balance the competing demands and changing needs of an expanding population, agricultural and natural ecosystems, interstate and international compacts, and the uncertain impacts of global climate variability and change. Many operational water management procedures and decision processes consider only hydroclimatic variability based on the range of hydroclimatic extremes experienced in the 20th century. This approach presumes that the range of streamflows in the 20th century adequately represents the full range of variability. To supplement the 20th century record of hydroclimatic variability, policy makers and water resource managers are starting to use dendrochronological reconstructions of streamflow as a decision support resource (For example see Figure 1b). These partnerships between scientists and water managers are occurring in the Colorado Front Range and the Salt River valley of Arizona.

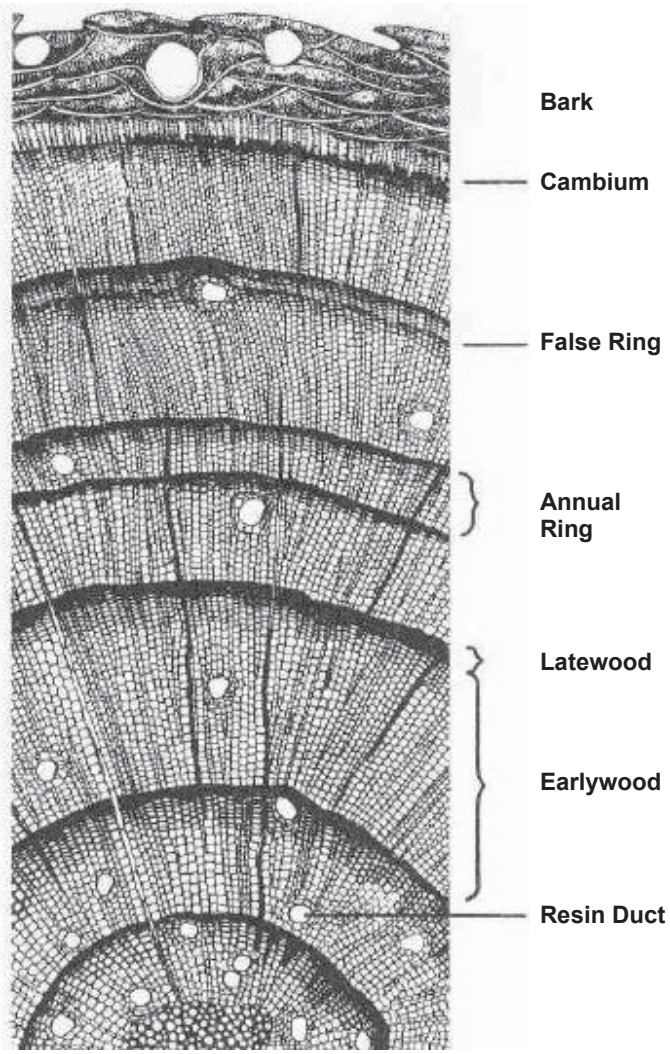


Figure 1a. A cross section of a tree showing the growth rings. The size of a tree ring can tell scientists about the amount of water the tree received that year.

The Workshop

The goals of the workshop were to learn about resource management and decision-making needs, to explore ways in which decision support systems can integrate tree-ring reconstructions, and to develop plans for collaborative work between paleoscientists and resource managers. The workshop participants listened to presentations and participated in multiple discussion groups.

The workshop brought together a diverse set of over 50 participants, almost evenly split between scientists from academic institutes and government agencies, and water resource managers from both national and local entities, including governmental agencies and private water providers. All seven upper and lower basin states were represented. It took place in Tucson, AZ on May 5, 2005 and was hosted by the University of Arizona Institute for the Study of Planet Earth (ISPE) and Climate Assessment for the Southwest (CLIMAS), with funding by NOAA's Office of Global Programs.

The workshop began with presentations made by water resource engineers from Denver Water, the Salt River Project, and Hydrosphere Resource Consultants. In all three talks, the presenters focused on the collaboration of decision makers and scientists to apply tree-ring reconstruction of streamflow to water management issues. Denver Water, Colorado's largest water provider, is using the full range of streamflow reconstructions for the South Platte and upper Colorado River developed by several NOAA scientists in Boulder, CO in their water supply model to determine the level of demand that the current system could

accommodate. Likewise, the Salt River Project (SRP), which provides water to the Phoenix metropolitan region, is working with University of Arizona scientists at the Laboratory of Tree-Ring Research to explore the utility of tree-ring reconstructions of streamflows for the Salt, Gila, and Colorado Rivers in long-term planning for drought. Finally, Hydrosphere Resource Consultants, based in Boulder, CO, which serves clients from many Colorado Front Range municipalities, remarked on some of the benefits, limitations, and challenges of using tree-ring reconstructions of streamflows in water resource management planning decisions. All three speakers recognized that while tree-ring data helps explain past climate variability, the reconstructions are not suitable for predicting future flows, particularly due to the uncertainty of future regional impacts of global climate change.

Following this session, six panelists from federal and state water management agencies, presented a diverse set of perspectives on long-term planning and the role for paleoclimatic reconstructions. They discussed topics ranging from the levels and types of uncertainty confronted in water management to the politics related to water management and growth. This panel included representatives from the U.S. Bureau of Reclamation reservoir operations, drought planning in New Mexico, and water resource management for the California Department of Water Resources. Although few had experience using tree-ring data in their policy decisions, all acknowledged the potential utility of long-term streamflow records provided by the tree-ring reconstructions.

The next segment of the workshop included presentations on the science behind tree-ring based reconstructions of streamflow to help the water managers and policy makers understand how scientists generate hydroclimatic reconstructions. The audience learned about the entire process from field collections to the calibration of tree-ring data with streamflow data to generate reconstructions. One intriguing presentation reported the results of an updated reconstruction of streamflow for Lees Ferry, which is the point of measurement for the Upper Colorado River basin annual flows. This reconstruction, which updates the well-known work of Stockton and Jacoby in 1976, utilizes a larger network of tree-ring data and an extended calibration period for the reconstruction. Like the 1976 reconstruction, this new version found that while droughts of the 20th and 21st centuries are not unusual in the context of the past five centuries, the early decades of the 20th century, the period of record upon which the Colorado River Compact was based, does appear to be one of the wettest periods in the full reconstructed history.

Finally, audience members were asked to participate in breakout discussion groups that allowed water managers and policy makers to provide input to climate scientist about their future streamflow reconstruction needs, and it allowed climate scientists to provide clarification for these decision makers. The workshop organizers divided the discussion topics into two broad topics: strategic issues (e.g., planning and decision-making issues that could benefit from long-term records, or possible limitations in the tree-ring data for optimal use by resource managers) and tactical issues (needs for updated or

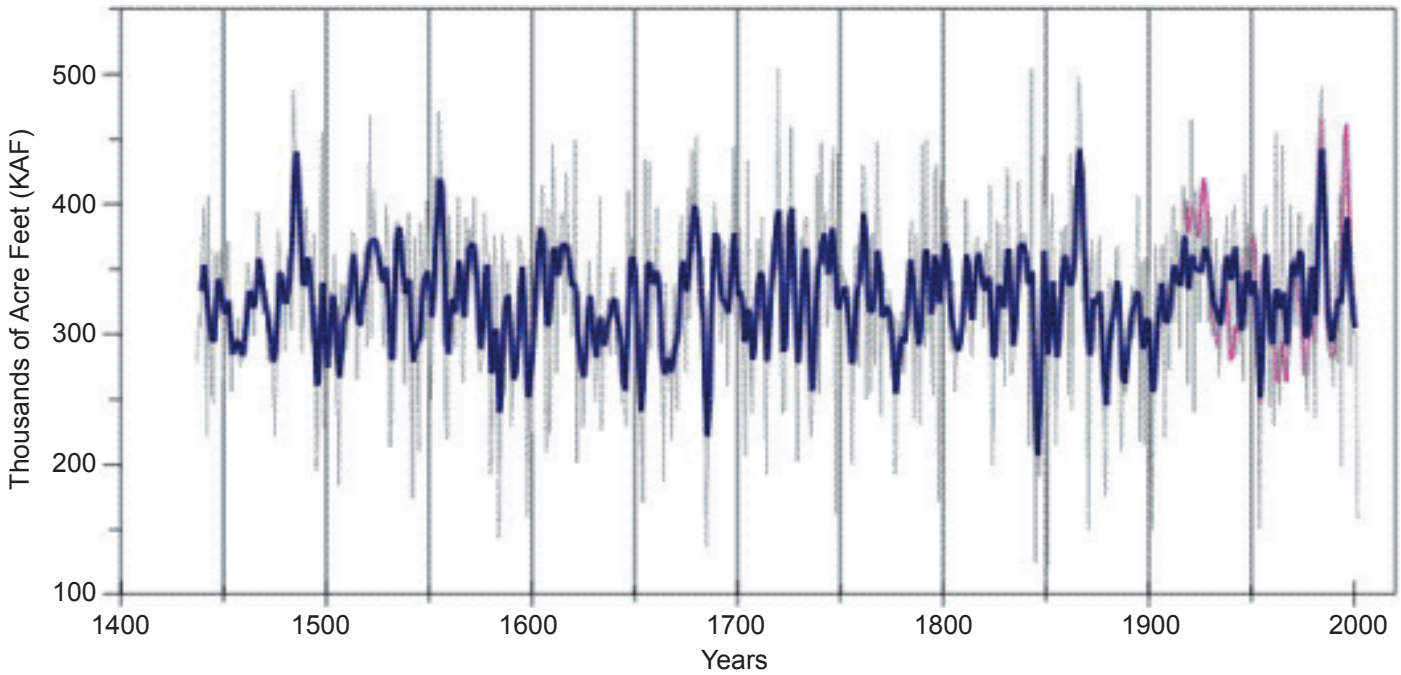


Figure 1b. Three gages on tributaries of the upper Colorado River (Blue, Fraser, and Williams Fork Rivers) were reconstructed by Connie Woodhouse and summed for this annual streamflow reconstruction. The graph shows the full reconstruction, 1427-2002, with annual values in gray and smoothed values in dark blue. Also shown are the gage values, smoothed, in pink. The reconstructions can be found at the NOAA Tree Flow site: http://www.ncdc.noaa.gov/paleo/streamflow/reconstructions.html

additional tree-ring data). The outcomes of these discussion groups will help climate scientists focus their research on the practical needs of the decision makers.

Workshop Outcomes

The water managers expressed concerns about the skill of the reconstructions and the methods used to develop reconstructions. One participant suggested developing a common method for all paleoclimatic scientists to use in creating "skill scores" to assess and compare reconstructions. While the concept of uncertainty and the use of probabilistic information are familiar to water managers, tree-ring scientists need to better characterize the uncertainty in the reconstructions. To make tree-ring data usable in water management, it was recommended that the research community work towards providing a single time series accompanied with a range of probabilities for streamflow estimates. New techniques, such as ensemble reconstructions, offer a promising way to accomplish this.

Water resources managers also voiced a desire to manipulate the paleohydrologic data themselves. To achieve a true partnership, the research community must first provide better documentation of the reconstruction methods and verification measures, as well as enhanced characterization of uncertainty associated with the data. These steps would make the information "transparent," which would help scientists feel more comfortable providing raw data to the water managers and policy makers.

Scientists also need to understand the language and vocabulary of water managers. Water managers recommended that scientists could better promote their work to non-scientific audiences through newsletters, journals, and meetings of water and engineering professional societies.

Overall, workshop participants identified the tree ring reconstructions as valuable to put the instrumental record within a broader context of hydroclimatic variability. Furthermore, participants agreed that reconstructions are potentially useful decision support resources for developing scenarios to evaluate system reliability. It is clear that collaborative partnerships are key to developing and providing useful information for decision support. Managers attending the workshop expressed interest in future collaborations and requested follow up technical training meetings and additional workshops.

Figure 1c. Workshop attendees: 26 water managers, policy makers, and planners, 24 scientists, and 5 graduate students.

Temperature through 6/12/05

Source: High Plains Regional Climate Center

Because this month's climate summary is being released later than usual in the month, we present average temperatures (Figure 2a) and departure from average temperatures (Figure 2b) for the period of May 14 to June 12. Two additional maps show the departure from average temperatures last year because the High Plains Regional Climate Center provides this information in whole-month segments (Figures 2c and 2d).

Between mid-May and mid-June 2005, average temperatures in the Intermountain West region ranged from the upper 60s in parts of south-central **Utah** and southeast **Colorado** to the 40s in western **Wyoming** and the mountains of north-central **Colorado** (Figure 2a). Southern **Colorado** and southern **Utah** temperatures were 3°F – 4°F above normal, while **Wyoming** and northern **Utah** temperatures ranged from 1°F – 4°F below normal (Figure 2b).

According to the NOAA National Weather Service and the Federal Emergency Management Agency, high temperatures in late May caused rapid snowmelt throughout the Intermountain West. As a result, high water levels and flooding caused problems throughout the region. In **Utah**, bridges and roads were washed out and sandbagging ensued, dangerous amounts of debris filled creeks disturbing water treatment intakes and filling small dams. In **Colorado**, lowland areas experienced flooding and damage to highways and other roads, while **Wyoming's** rivers ran at bankfull for several days. Denver tied the record high temperature on both May 20th with 91°F and on May 24th with 87°F.

Last year's temperatures were similarly above normal in most of the Intermountain West region, with the exception of parts of northwestern Wyoming (May 2004, Figure 2c). June 2004, however, was 2°F – 4°F below normal in most of Wyoming and eastern Colorado, while Utah stayed at or slightly above normal for the month (Figure 2d).

Notes

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.

These continuous color maps are derived by taking measurements at individual meteorological stations and mathematically interpolating (estimating) values between known data points. Interpolation procedures can cause aberrant values in data-sparse regions. For maps with individual station data, please see web sites listed below.

Figures 2a-d are experimental products from the High Plains Regional Climate Center. This data is considered experimental because it utilizes the newest data available, which is not always quality controlled.

On the Web

- For most recent versions of these and other climate maps, 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.

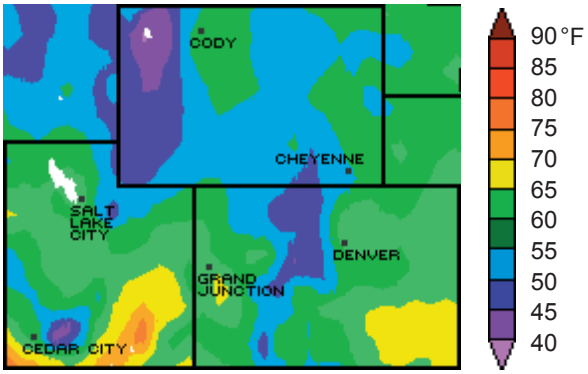


Figure 2a. Average temperature for the previous 30 days in °F (May 14, 2005 – June 12, 2005).

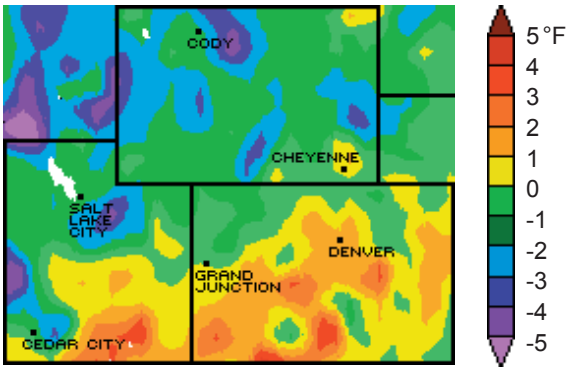


Figure 2b. Departure from average temperature for the previous 30 days in °F (May 14, 2005 – June 12, 2005).

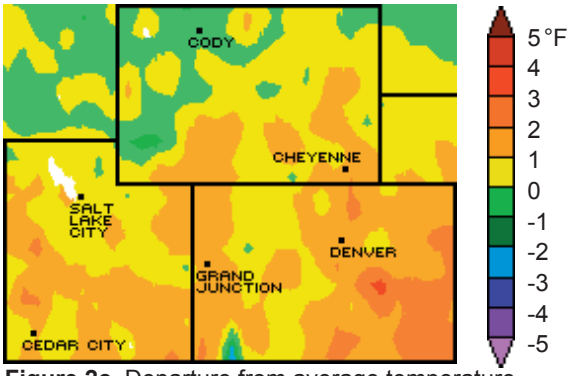


Figure 2c. Departure from average temperature in °F for May 2004.

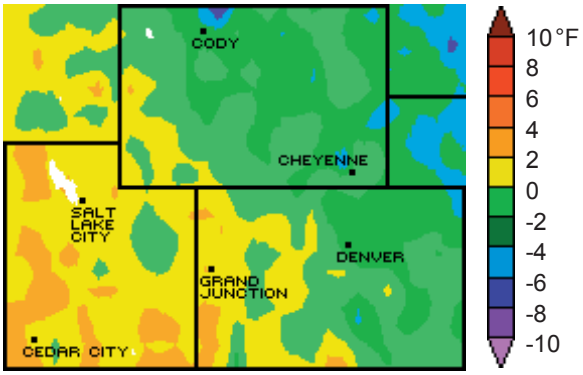


Figure 2d. Departure from average temperature in °F for June 2004.

Precipitation through 6/13/05

Source: NOAA Climate Diagnostic Center, NOAA Climate Prediction Center

As for the recent temperature maps, the precipitation maps this month feature averages for the period between the middle of May and the middle of June in order to provide the most current information.

From mid-May to mid-June, **Wyoming** received the most precipitation in the Intermountain West region with almost the entire state getting over 1 inch. The northwest and southeast areas both had over 3 inches (Figure 3a). This rain improved the drought status and water availability of the state (see page 11 for more details). Increased rain in Wyoming gave them closer to average precipitation levels for the first time since the start of the water year (Figures 3b - c).

Utah continued to have above average precipitation across the state, which means they are still at risk for flooding this spring and summer. In Utah, precipitation totals increased to the north, with amounts between 0-1 inches in the south to over 3 inches around Salt Lake. Similarly, in **Colorado** precipitation totals increased in a gradient to the northeast. Precipitation in this period was above normal in northwestern Colorado, an area that has had below average precipitation since the beginning of winter.

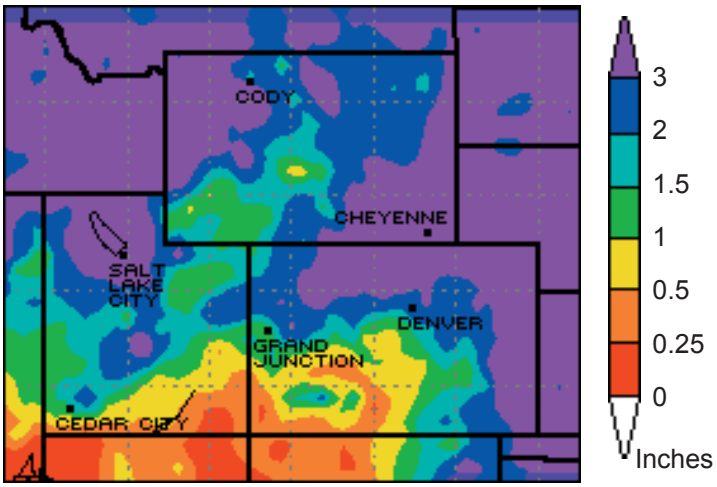


Figure 3a. Average precipitation for the previous 28 days in inches (May 12, 2005- June 12, 2005).

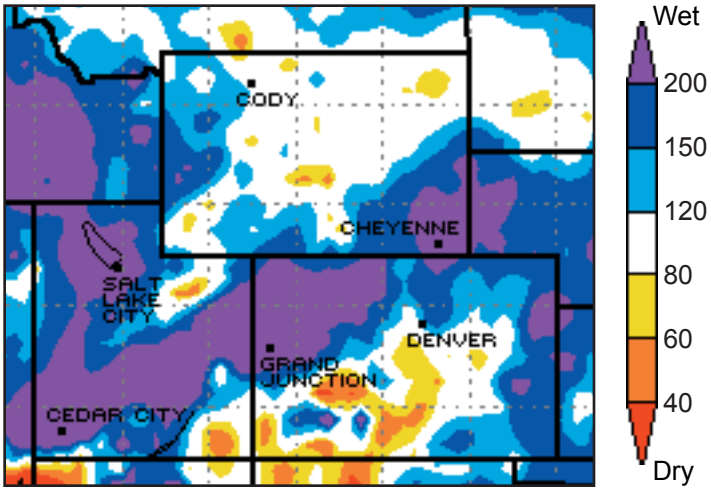


Figure 3b. Percent of average precipitation for the previous 30 days (May 15, 2005- June 13, 2005).

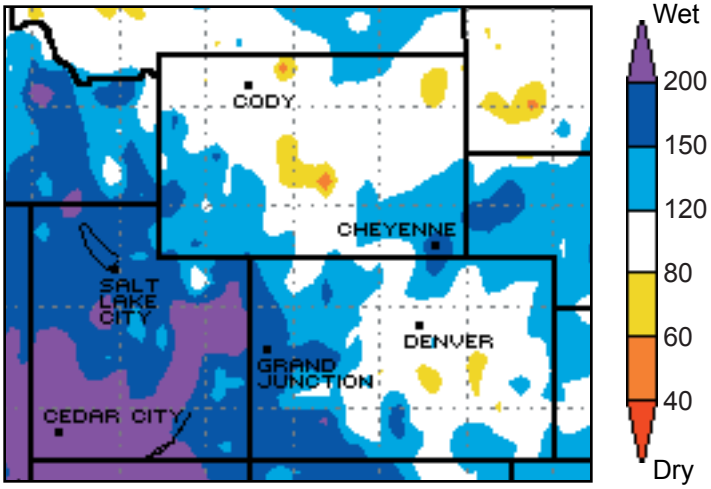


Figure 3c. Percent of average precipitation accumulated since the start of the water year (October 1, 2004- May 1 2005).

Notes

The water year begins on October 1 and ends on September 30 of the following year. As of October 1, 2004 we are in the 2005 water year. The water year is a more hydrologically sound measure of climate and hydrological activity than is the standard calendar year. It reflects the natural cycle accumulation of snow in the winter and runoff and use of water in the spring and summer.

Average refers to the arithmetic mean of annual data from 1996-2004. This period of record is only nine years long because it includes SNOTEL data, which has a consistent record beginning in 1996. Percent of average precipitation is calculated by taking the ratio of current to average precipitation and multiplying by 100.

The data in Figures 3a - c come from NOAA's Climate Prediction Center, but the maps were created by NOAA's Climate Diagnostics Center, and they are updated daily (see website below). These continuous color maps are derived by taking measurements at individual meteorological stations and mathematically interpolating (estimating) values between known data points. Interpolation procedures can cause aberrant values in data-sparse regions.

On the Web

- For these precipitation maps, which are updated daily visit: http://www.cdc.noaa.gov/Drought/.
- For precipitation maps similar to the temperature maps on the previous page, visit http://www.hprcc.unl.edu/products/current.html and http://www.wrcc.dri.edu/recent_climate.html.
- 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/2002/perspectives.html.
- For a list of weather stations in Colorado, Utah, and Wyoming, visit: http://www.wrcc.dri.edu/summary.

U.S. Drought Monitor conditions as of 6/14/05

Source: U.S. Department of Agriculture, National Drought Mitigation Center, National Oceanic and Atmospheric Administration

Drought status has not changed significantly in **Colorado** and **Utah** in the last month. Areas along the Colorado River in both states, along the Green River in Utah, and in the northeast corner of Colorado remain in an abnormally dry (D0) or moderate state (D1). However, **Wyoming** drought status has improved. According to the Drought Monitor, "assessment of the long-term hydrological conditions in the northeast part of that state led to the removal of extreme drought (D3) in this area. Reservoir levels continue to be low in northeast Wyoming, and actually lag the early June levels in 2004. This is the first time since June 26, 2001 (206 consecutive weeks!), that Wyoming has not had D3 within the state."

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 Michael Hayes of the National Drought Mitigation Center.

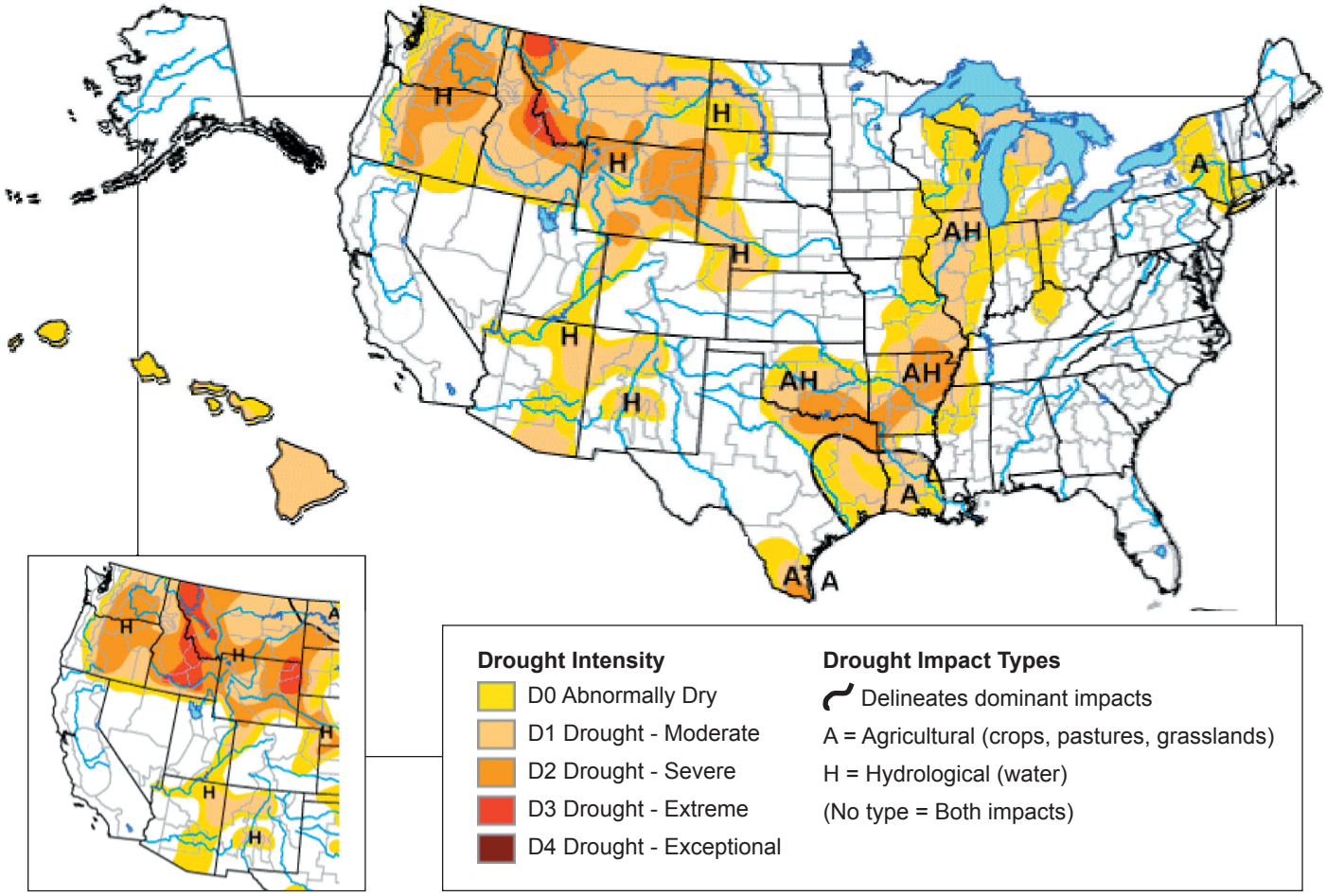


Figure 4. Drought Monitor released June 16, 2005 (full size) and last month May 19, 2005 (inset, lower left) for comparison.

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.

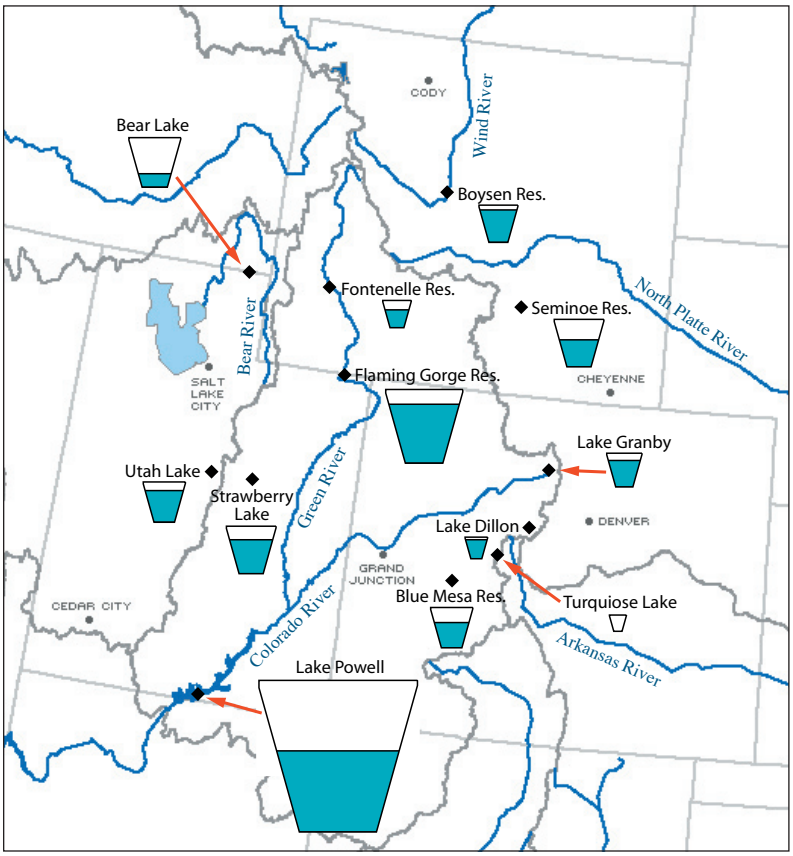
Reservoir Status

Source: Denver Water, U. S. Bureau of Reclamation, Natural Resources Conservation Service, and Central Utah Water Conservancy District

The majority of inflow to most western reservoirs is from snowmelt in April-July. All of the reservoir levels in Figure 5 have increased since the beginning of May. In contrast to recent years, some reservoirs in the region are projected to fill. However, Lake Powell on the Colorado River and Blue Mesa on the Gunnison River are not. Hydrologists with the U.S. Bureau of Reclamation (USBR) do expect a 45-foot increase at Powell though July. According to data from the USBR, Lake Powell has risen more than 15 feet since early April with over six feet of the increase occurring in the first three weeks of May. (*Deseret Morning News*, April 26). In early May, Secretary of the Interior Gale Norton announced that current water releases from Lake Powell would be sustained for the remainder of the 2005 water year (U.S. Department of the Interior News Release, May 2). While the Interior Department expects a normal flow year for 2005, concerns of continued drought caused the Secretary to ask the seven Colorado River Basin states to help her write a drought management plan for the river. The plan is expected to be completed by December 2007 (*Associated Press*, June 9).

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 percentage shown in the table is the current contents divided by the total capacity, it is NOT the percent of average water in the reservoir for this time of year. Reservoir statuses are updated at different times, so for the most recent information, see the web-sites listed in the "On the Web" box.



Reservoir	Current Water (KAF)	% Full	Total Capacity (KAF)
Colorado			
Blue Mesa Res.	532.3	64%	829.5
Lake Dillon	244.8	96%	254.0
Lake Granby	558.6	87%	639.8
Turquiose Lake	no data	no data	129.4
Utah			
Bear Lake	244.8	19%	1,302.0
Lake Powell	11,435.1	47%	24,322.0
Strawberry Lake	828.5	75%	1,106.5
Utah Lake	758.0	87%	870.9
Wyoming			
Boysen Res.	683.8	92%	741.6
Flaming Gorge Res.	3,059.1	82%	3,749.0
Fontenelle Res.	220.6	64%	344.8
Seminoe Res.	587.8	58%	1,017.3

KAF = Thousands of Acre Feet

Figure 5. Tea-cup diagram of several large reservoirs in the Intermountain West Region. All data from 6/12/05, except Utah Lake and Bear Lake data from 5/31/05.

On the Web

- Lake Dillon, operated by Denver Water ["check res. levels" pdf]: http://www.water.denver.co.gov/indexmain.html
- Turquoise Lake, Lake Granby, Boysen Reservoir, and Seminoe Reservoir, operated by the U.S. Bureau of Reclamation (USBR) – Great Plains Region: http://www.usbr.gov/gp/hydromet/teacup_form.cfm
- 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 Lake, 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 5/31/2005

Source: Western Regional Climate Center, using data from NOAA Climate Prediction Center, NOAA National Climatic Data Center and NOAA National Weather Service

The Standardized Precipitation Index (SPI) can be used to monitor conditions on a variety of time scales. 3- and 6-month SPIs are useful in short-term agricultural applications and longer-term SPIs (12 months and longer) are useful in hydrological applications. The 12- month SPI for the Intermountain West region (Figure 6) reflects precipitation patterns over the past 12 months (through the end of May 2005) compared to the average precipitation of the same 12 consecutive months during all the previous years of available data.

Overall, SPI in the Intermountain West region improved during the month of May. **Wyoming's** May rains increased the SPI in the northeastern part of the state, so now the entire state is in the near normal range. Near normal SPI means that the total precipitation for the past 12 months is near the long-term average for one year. Precipitation in western and southeastern **Colorado** also raised those areas up from near normal to moderately wet conditions, and the north-central part of the state remains moderately wet. **Utah** is still very or exceptionally wet and has become wetter for several months.

Notes

The Standardized Precipitation Index (SPI) is a simple statistic generated from accumulated precipitation totals for consecutive months compared to the historical data for that station. An index value of –1 indicates moderate drought severity and means that only 15 out of 100 years would be expected to be drier. An index value of -2 means severe drought with only one year in 40 expected to be drier. (courtesy of the Colorado Climate Center)

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

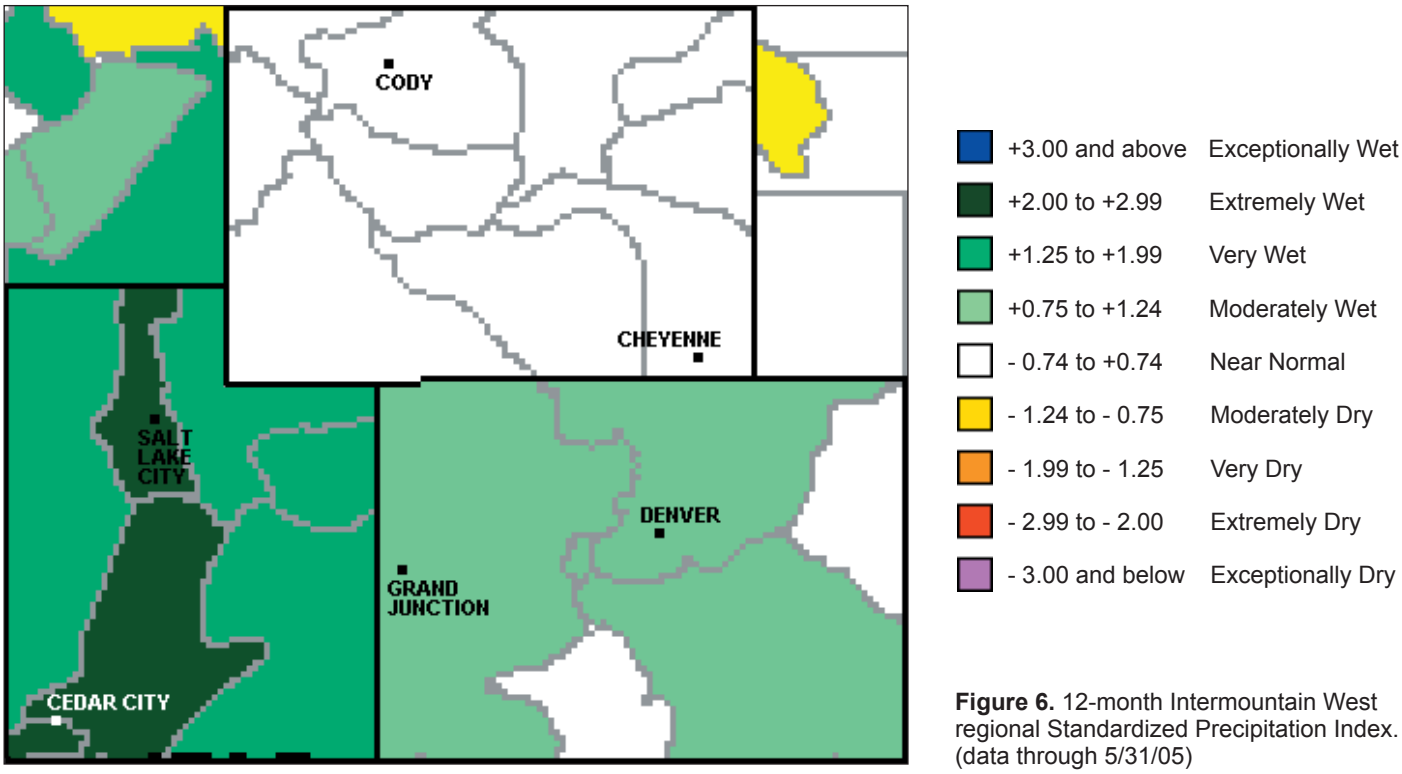


Figure 6. 12-month Intermountain West regional Standardized Precipitation Index. (data through 5/31/05)

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.

Colorado Water Availability as of 6/1/2005

Source: Colorado Division of Water Resources, State Engineer, and USDA Natural Resources Conservation Service.

While the SPI uses precipitation to calculate an index of precipitation compared to average, the Surface Water Supply Index (SWSI) is another useful measure of water availability related to streamflows, reservoir levels, and even groundwater levels.

In Colorado, the calculation of SWSI changed in June as snowpack becomes less important and streamflows become more important (see Notes below). Therefore, the difference between May and June SWSI numbers may not reflect a change in water availability, but rather a change in variables.

Water availability status continues to vary widely across Colorado, as shown by the gradient in SWSI (Figure 7). The southwestern and northeastern basins are in the near normal to abundant supply range, while the northwestern and Arkansas basins are below 0, but still in the near normal range.

Notes

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 x were computed for each of the seven major basins in Colorado for June 1, 2005, and reflect conditions during the month of May 2005.

Surface Water Supply Index June 1, 2005

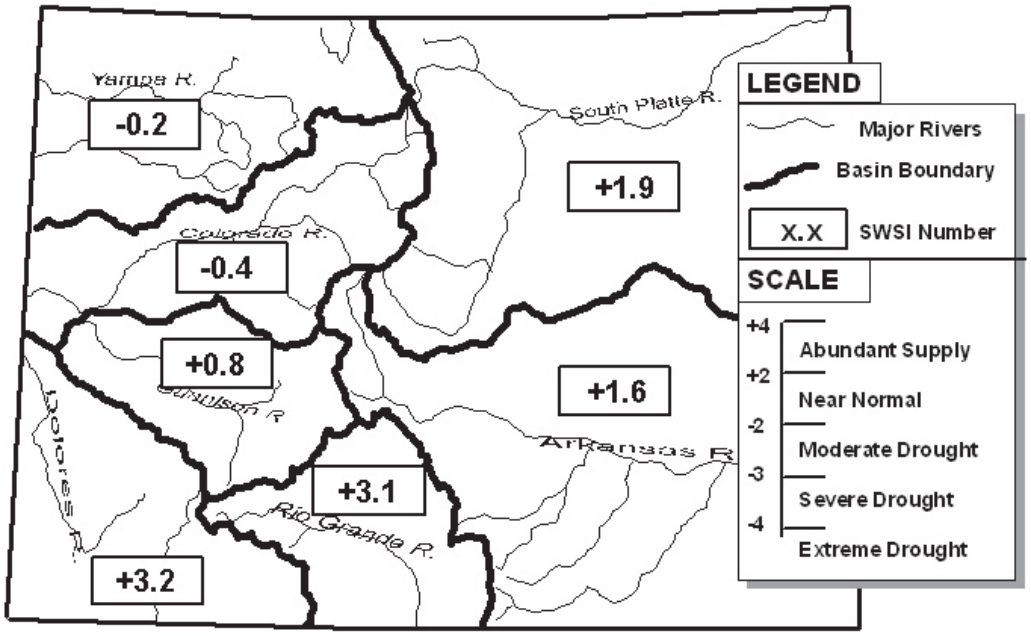


Figure 7. Colorado Surface Water Supply Index. The map shows the projected streamflows by basin for spring and summer 2005, based on current conditions as of June 1.

On the Web

- For the current SWSI map, and for the latest "Colorado Water Supply Conditions" Report from the State Engineer, go to: http://water.state.co.us/pubs/swsi.asp.
- The Colorado Water Availability Task Force's next meeting is tentatively scheduled for July 20. Agendas and minutes of this and previous meetings are available at: http://www.cwcb.state.co.us/owc/Drought_Planning/Agendas/Agendas.htm.

Wyoming Water Availability as of 6/1/2005

Source: USDA Natural Resources Conservation Service

While most of Wyoming's river basins have below normal surface water supplies (Figure 8a), all basins increased their surface water supply values during the month of May. The greatest improvements were in the Powder and Wind River basins, which improved from moderate drought to incipient wet spell. The Shoshone, Big Sandy, and Lower Green basins also improved greatly, each increasing their SWSI values over 1.5 to move into the moderately wet category.

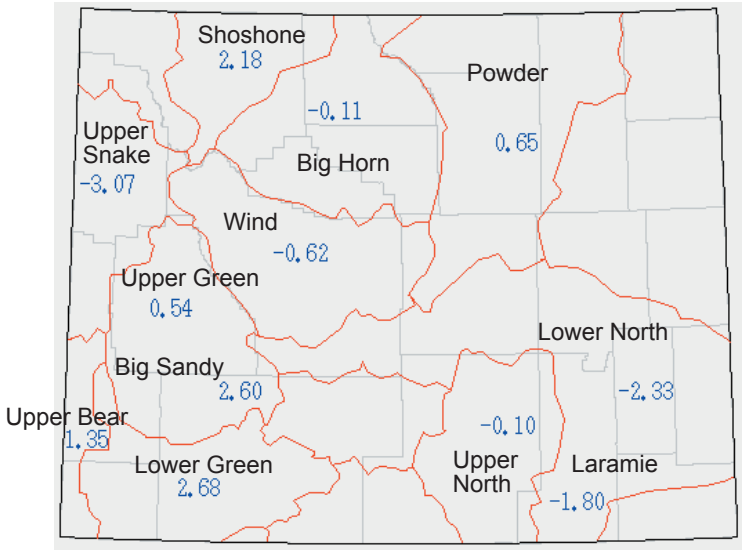
According to the Wyoming State Climatologist, Wyoming's projected drought status through August has improved through out most of the state. No counties are in drought disaster status anymore and many southern and central counties are now normal (Figure 8b).

Despite this improvement, Wyoming is contracting a $1.9 million cloud seeding project for 2005-2011. The American Meteorological Society estimates that a well-conducted winter weather modification program can result in about a 10 percent increase in precipitation. (Source: *Denver Post*, June 4)

Notes

Each state calculates their SWSI a little differently. From the WY NRCS site: "The Surface Water Supply Index (SWSI-Figure 8a) is computed using only surface water supplies for the drainage. The computation includes reservoir storage, if applicable, plus the forecast runoff. The index is purposely created to resemble the Palmer Drought Index, with normal conditions centered near zero. Adequate and excessive supply has a positive number and deficit water supply has a negative value. Soil moisture and forecast precipitation are not considered as such, but the forecast runoff may consider these values." The Drought Status (Figure 8b) is calculated by the Wyoming state climatologist, based on snow water equivalent and other data.

June 2005 Surface Water Supply Index Values

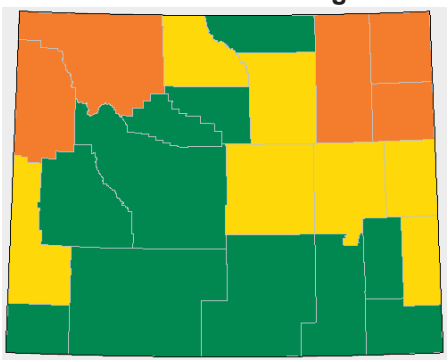


Legend

> 4.0	Extremely Wet
3.0	Very Wet
2.0	Moderately Wet
1.0	Slightly Wet
0.5	Incipient Wet Spell
0.0	Near Normal
- 0.5	Incipient Dry Spell
- 1.0	Mild Drought
- 2.0	Moderate Drought
- 3.0	Severe Drought
< - 4.0	Extreme Drought

Figure 8a. Wyoming Surface Water Supply Index (as of 6/1/05).

WY State Climatologist Assessment: June 13 - Aug 31, 2005



Legend

- Normal
- Watch
- Warning
- Disaster

Figure 8b. Wyoming drought status. This map shows the Wyoming State Climatologist's assessment of the status of the drought throughout the state.

On the Web

- The Wyoming SWSI, along with more data about current water supply status for the state, can be found at: http://www.wrds.uwyo.edu/wrds/nrcs/nrcs.html.
- The Wyoming Drought Status is found at: http://www.wrds.uwyo.edu/wrds/wsc/dtf/drought.html.
- The Palmer Drought Index is found on NOAA's drought page: www.drought.noaa.gov.

Utah Water Availability **released 5/4/2005**

Source: USDA Natural Resources Conservation Service

The Salt Lake City Tribune declared, "The drought is over, time for a flood? " in Utah, after a wet winter and spring (April 12, 2005, http://www.sltrib.com/search/ci_2645702). A Salt Lake NWS hydrologist says, "We've got good snowpack, good soil moisture and we're going to fill the reservoirs." The Utah SWSI is similar to last month, with a slight decrease in conditions towards dry in north-central Utah. Four of the river basins in southwest Utah (Upper Sevier, Lower Sevier, Beaver and Virgin) are approaching 'abundant supply' due to anomalously high snowpacks this winter (Figure 9). All the other basins have a SWSI above zero with the exception of the Price and Provo Rivers that are below average and the Bear River, which is approaching 'extremely dry' conditions.

Surface Water Supply Index
May 1, 2005

Notes

Each state calculates their SWSI a little differently.

From the UT NRCS: "The Surface Water Supply Index (SWSI) is a predictive indicator of total surface water availability within a watershed for the spring and summer water use seasons. The index is calculated by combining pre-runoff reservoir storage (carryover) with forecasts of spring and summer streamflow, which are based on current snowpack and other hydrologic variables. SWSI values are scaled from +4.1 (abundant supply) to -4.1 (extremely dry) with a value of zero (0) indicating median water supply as compared to historical analysis. SWSI's are calculated in this fashion to be consistent with other hydroclimatic indicators such as the Palmer Drought Index and the [Standardized] Precipitation Index." See page 9 for the SPI.

Legend

+4.1 abundant supply
0 water supply is comparable to historical average
- 4.1 extremely dry

Figure 9. Utah Surface Water Supply Index. (released 5/4/05)

On the Web

- The Utah SWSI, along with more data about current water supply status for the state, can be found at: http://www.ut.nrcs.usda.gov/snow/watersupply/.
- The Palmer Drought Index is found on NOAA's drought page: www.drought.noaa.gov.

Temperature Outlook July – Nov. 2005

Source: NOAA Climate Prediction Center, NOAA Diagnostics Center

Because the El Niño-Southern Oscillation (ENSO) is expected to be in a neutral phase through at least spring 2006 (see p.16), the strongest predictive signals for climate anomalies in the upcoming few months are based on long term trends for higher temperatures in the West.

The NOAA Climate Prediction Center temperature outlook indicates a slightly increased chance for below normal temperatures in **Wyoming** in the July 2005 forecast period. For the July-September 2005 forecast period there is an increased chance of above normal temperatures for the summer for **Utah**, **Colorado**, and most of the southern and southwestern U.S. The forecasts of above normal temperatures are based on long term trends, and are the most confident signals in the forecast for the upcoming few months, because of the strength of the trends.

Notes

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

The NOAA-CPC outlooks are a 3-category forecast based largely on the status of El Niño and recent trends. As a starting point, the 1971-2000 climate record for each particular 1 or 3 month period is divided into 3 categories or terciles, each with a 33.3 percent chance of occurring. The middle tercile is considered the *near-average* (or normal) temperature range. The forecast indicates the likelihood of the temperature being in one of the warmer or cooler terciles--*above-average* (A) or *below-average* (B)--with a corresponding adjustment to the opposite category; the near-average category is preserved at 33.3 likelihood, unless the anomaly forecast probability is very high.

Thus, using the NOAA-CPC temperature outlook, areas with light brown shading display a 33.3-39.9% chance of above-average, a 33.3% chance of near-average, and a 26.7-33.3% chance of below-average temperature. A shade darker brown indicates a 40.0-50.0% chance of above-average, a 33.3% chance of near-average, and a 16.7-26.6% chance of below-average temperature, and so on.

Equal Chances (EC) indicates areas for which the models cannot predict the temperature with any confidence. EC is used as a "default option" representing equal chances or a 33.3% probability for each tercile indicating areas where the reliability (i.e., 'skill') of the forecast is poor.

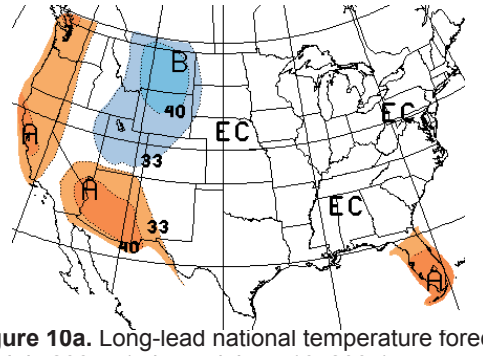


Figure 10a. Long-lead national temperature forecast for July 2005. (released June 16, 2005)

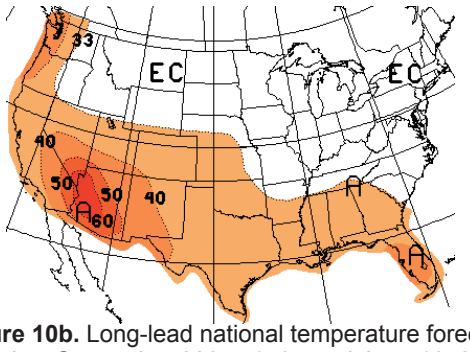


Figure 10b. Long-lead national temperature forecast for July – September 2005. (released June 16, 2005)

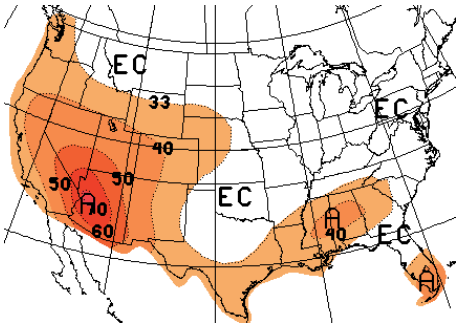


Figure 10c. Long-lead national temperature forecast for August – October 2005. (released June 16, 2005)

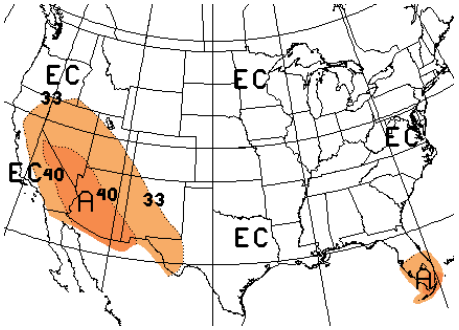


Figure 10d. Long-lead national temperature forecast for September – November. (released June 16, 2005)

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/multi_season/13_seasonal_outlooks/color/churchill.html. 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 2005** Source: NOAA Climate Prediction Center

Precipitation outlooks issued by the NOAA Climate Prediction Center indicate a slight increase in the risk of above normal precipitation in parts of western **Wyoming** and northern **Utah** for the July 2005 forecast period and for eastern **Wyoming** in the July-September forecast period. A consensus of general circulation models indicate a weak southwestern monsoon, favoring dry summertime conditions in the Southwestern U.S. and the Great Basin for July-September 2005, including western **Colorado** and **Utah**. An experimental forecast product for the southwest also projects a weak monsoon for **Arizona** (see p. 17).

There are no forecasts of anomalous conditions after the August-September 2005 forecast period due to the lack of strong predictive signals from ENSO or other sources.

Notes

The seasonal precipitation outlook in Figures 11a - d predicts the likelihood (chance) of *above-average*, *near-average*, and *below-average* precipitation, but not the magnitude of such variation. The numbers on the maps refer to the percent chance that precipitation will be in one of these three categories, they do not refer to inches of precipitation.

The NOAA-CPC outlooks are a 3-category forecast based largely on the status of El Niño and recent trends. As a starting point, the 1971-2000 climate record for each particular 1 or 3 month period is divided into 3 categories or terciles, 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 being in one of the wetter or cooler terciles--*above-average* (A) or *below-average* (B)--with a corresponding adjustment to 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 cannot predict the temperature with any confidence. EC is used as a "default option" representing equal chances or a 33.3% probability for each tercile indicating areas where the reliability (i.e., 'skill') of the forecast is poor.

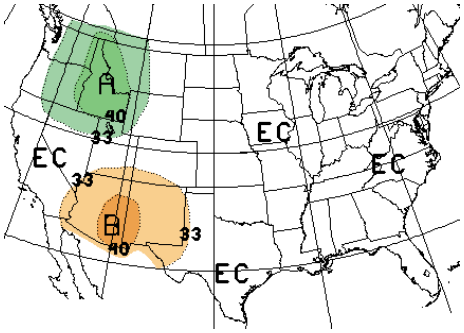


Figure 11a. Long-lead national precipitation forecast for July 2005. (released June 16, 2005)

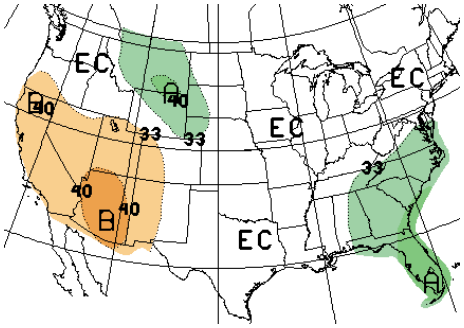


Figure 11b. Long-lead national precipitation forecast for July – September 2005. (released June 16, 2005)

A = Above
- 40.0–49.9%
- 33.3–39.9%

B = Below
- 40.0–49.9%
- 33.3–39.9%

EC = Equal Chances

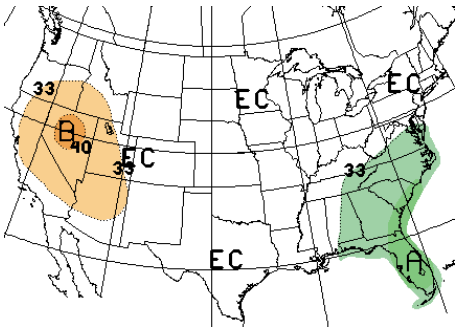


Figure 11c. Long-lead national precipitation forecast for August – October 2005. (released June 16, 2005)

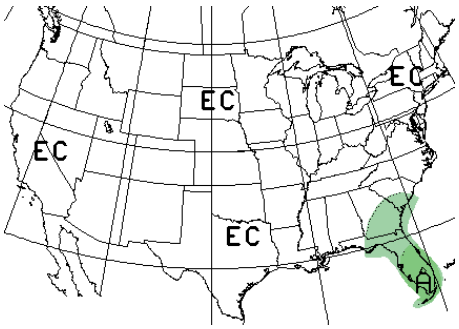


Figure 11d. Long-lead national precipitation forecast for September – November 2005. (released June 16, 2005)

On the Web

- For more information and the most recent forecast images, visit: http://www.cpc.ncep.noaa.gov/products/predictions/multi_season/13_seasonal_outlooks/color/churchill.html. 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.

Seasonal Drought Outlook through September 2005

Source: NOAA Climate Prediction Center

According to the NOAA Climate Prediction Center, a wet spring generally improved the drought situation in the Northwest and northern Rockies including limited improvement in most of **Wyoming**, and recent storms have reduced drought in the northern and central Plains. The July-August-September precipitation outlook period (see p. 14), suggests a slightly increased risk for above average precipitation in eastern **Wyoming**, and limited improvement in drought conditions. In contrast, a trend for above-normal temperatures and below-normal rainfall (based on the seasonal outlooks) during July-September should result in little or no improvement over eastern Arizona and northern New Mexico. A trend during the last half of June toward hot and dry weather across the Plains contributes to the outlook for persisting or developing drought in parts of the southern Plains.

Notes

The delineated areas in the Seasonal Drought Outlook (Figure 12) are defined subjectively and are based on expert assessment of numerous indicators, including outputs of short- and long-term forecasting models. "Ongoing" drought areas 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.

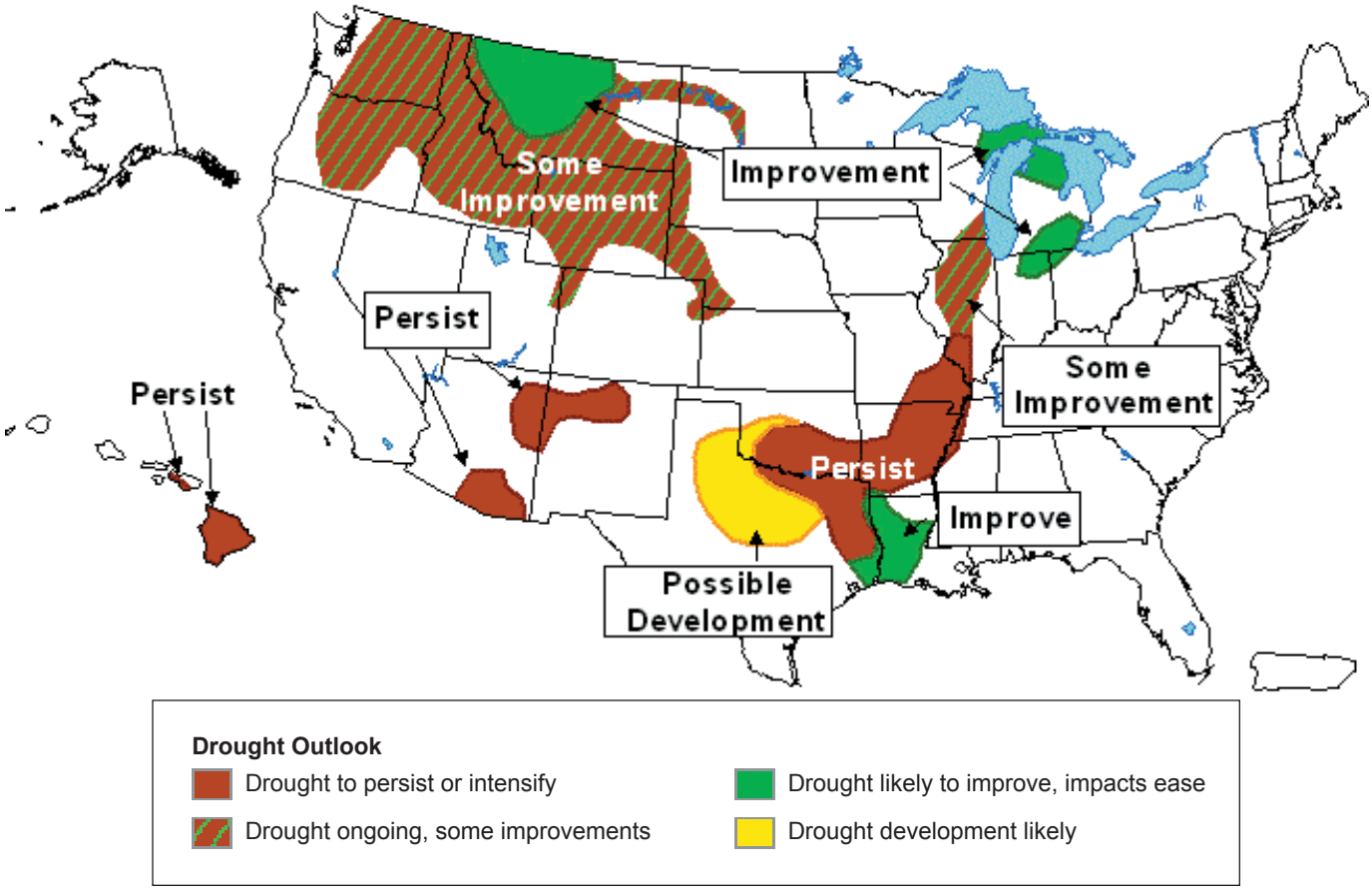


Figure 12. Seasonal Drought Outlook through September 2005 (released June 16, 2005).

On the Web

For more information, visit: http://www.drought.noaa.gov/.

El Niño Status and Forecast

Source: NOAA Climate Prediction Center

According to the NOAA Climate Prediction Center, there are no significant sea surface temperature (SST) anomalies across the equatorial Pacific, although SSTs vary from slightly below normal along the South American coast to slightly above normal along the equator westward of about 130°W. SSTs of 29-30°C and higher in the western Pacific, and a "cold tongue" stretching westward from the South American coast are typical for this time of year.

ENSO-neutral conditions are expected to prevail through early 2006, based on good consensus among both statistical and dynamical ENSO prediction models. In addition to SSTs, another factor in the El Nino-Southern Oscillation (ENSO) are subsurface ocean temperatures in the upper layers of the tropical oceans: significant subsurface anomalies may surface over time to influence SSTs and atmospheric processes. However, subsurface ocean temperatures in the eastern Pacific are also quite close to normal (not shown), indicating that neutral ENSO conditions will likely persist for the next few months.

SSTs throughout the tropical North Atlantic Ocean extending into the Caribbean Sea are well above normal and are expected to favor an active Atlantic hurricane season.

Notes

Figure 13 consists of two graphics showing the observed SST (upper) and the observed SST anomalies (lower) in the Pacific Ocean. NOAA produces these graphics from data from a system of 70 moored buoys spread out over the Pacific Ocean, centered on the equator. This system, called the TOGA/TAO Array, measures temperature, currents and winds in the Pacific equatorial band and transmits data around the world in real-time. NOAA uses these observations to predict short-term (a few months to one year) climate variations.

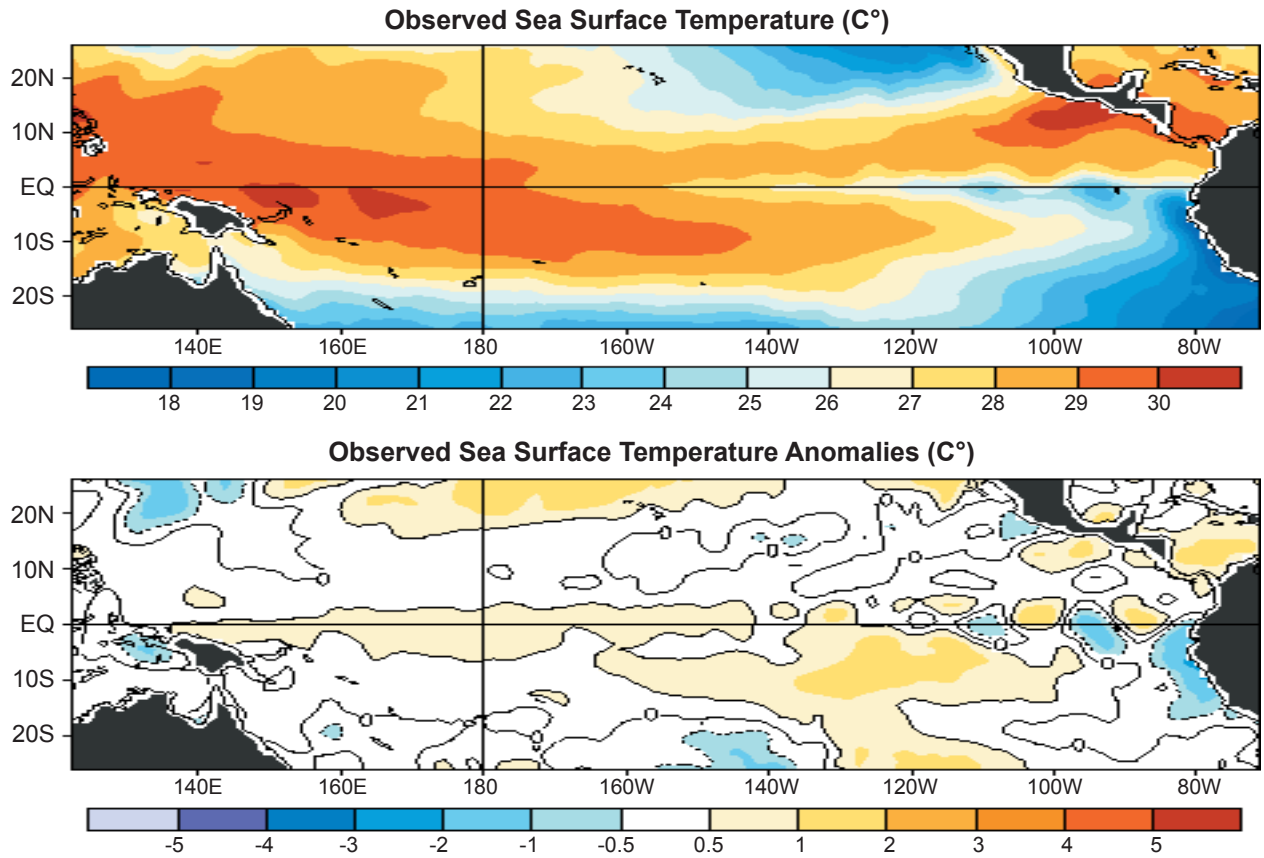


Figure 13. Two graphics showing the observed SST (upper) and the observed SST anomalies (lower) in the Pacific Ocean. The Niño 3.4 region encompasses the area between 120°W-170°W and 5°N-5°S. The graphics represent the 7-day average centered on April 27, 2005.

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/.

Improving Climate Forecasts for the Southwest

By Klaus Wolter, Climate scientist at the NOAA-CIRES Climate Diagnostics Center

Dr. Klaus Wolter, a climate scientist with the NOAA-CIRES Climate Diagnostic Center (CDC) and the Western Water Assessment, has been conducting research to improve climate forecasting in the American Southwest. In this work, he hopes to make improvements over the current official climate forecasts issued by the NOAA Climate Prediction Center by incorporating information on factors influencing Southwest climate that are only used in a limited way in the official forecast (see page 14).

The Current State of Forecasting

NOAA's Climate Prediction Center (CPC) began producing and disseminating seasonal climate forecasts for the U.S. in the 1950s. The devastation to agricultural land and the economy caused by the dust bowl in the 1930s motivated the Federal government to develop forecasts inspired by prior efforts to predict the Indian monsoon[1]. Over the years, the most reliable tools have proven to be the state of ENSO and its climate impacts over the U.S. and "Optimum Climate Normals" (OCN), which are long-term trends in climate. CPC forecasters used these two tools in tandem with significant success in the late 1990s, but continued improvement in CPC forecasts has been elusive due to weak ENSO conditions since 2001 and, according to Dr. Wolter, the limited use of other climate factors in the CPC forecast.

The debate surrounding the best climate factors to use in forecasting reflects the subjective nature of much current climate forecasting, in which forecasters use their professional judgment to choose the appropriate mix of predictors to create the forecast. Furthermore, due to the chaotic nature of the climate system, climate forecasts are 'probabilistic', with a range of possible outcomes. Most climate forecasts assign probabilities to the occurrence of above-, below-, and near-normal conditions (terciles)[2] , because it would be scientifically unjustified to claim an exact and single possible outcome.

New Strategies for Forecasting

For the past five years, Dr. Wolter has been researching the utility of other predictors for climate forecasts in the interior Southwest. Along with ENSO and OCN, Dr. Wolter uses regional sea surface temperature (SST) anomalies off the shores of California, as well as the Gulf of Mexico, and Indian Ocean SST anomalies to create his monthly climate forecasts of the Interior Southwest (AZ, CO, NM, UT). These additional predictors increase the diversity of climate factors in his forecast, and Dr. Wolter believes that this helps increase the accuracy of his forecasts.

To include new predictors in his climate forecast scheme, Dr. Wolter searches for "teleconnections" between the monitored climate factor (e.g, SST) and climate impacts to the SW region (e.g, dry winters). For example, western U.S. drought conditions since late 1999 are part of a much larger drought complex spanning the globe from the Mediterranean Sea across southwest Asia and into much of the southern U.S. Although persistent La Niña conditions explained at least part of this pattern, recent modeling studies point to the persistent warmth of the Indian Ocean and western Pacific Ocean as an additional causal factor. In addition, land surface conditions in the western U.S., such as the late season snowpack, may be linked to the strength of the summer monsoon in the southwest.

To create his statistical climate forecasts, Dr. Wolter screens his predictors in a 'Stepwise Linear Regression' (SLR), a statistical approach used in climate forecasting since Sir Gilbert Walker and his co-workers applied it for Indian monsoon predictions in the early 20th century. Predictors are added to the SLR only if they explain at least 10% additional variance in the forecast. The forecasts then are cross-validated by creating ensemble forecasts based on at least five different training periods, i.e., out of a five decade period, the forecast is created for four decades and then verified against one sliding decade of data, with a different decade held out each time. The forecasts are "bias corrected" or calibrated, by checking how well anomalously dry or wet conditions are predicted in the held-out portions of the record, and the new predictions are adjusted accordingly. Finally, the forecast is assigned to the tercile categories and created as a map.

[1] Walker, G. T., and E. W. Bliss, 1932: World Weather. V. *Mem. Roy. Meteorol. Soc.*, 4, 53-84

[2] For a detailed explanation of tercile categories, see the notes sections on either the Temperature or Precipitation Outlook pages (p. 13 or 14).

A New Climate Product for the Southwest

The Climate Forecast for the Interior Southwest for July-August-September, shown here as a map (Figure 14), indicates that eastern Colorado and southeastern New Mexico have favorable odds for a wet summer, while there is increased risk for a dry monsoon season in Arizona. The remainder of Colorado has roughly climatological odds ("equal chances", in CPC terminology) for the summer. In the system of NOAA official and experimental forecasts, Dr. Wolter's climate predictions are considered experimental guidance, because CDC is responsible for experimenting with new climate products and CPC produces official forecasts. This experimental guidance product, including a discussion and executive summary, is generally updated monthly and is available on the web at: http://www.cdc.noaa.gov/people/klaus.wolter/SWcasts/index.html.

Notes

The experimental guidance for seasonal future precipitation in Figure 14 shows most recent forecast of shifts in tercile probabilities for July - September 2005. 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.

Experimental CDC July-September 2005 Precipitation Forecast June 15, 2005

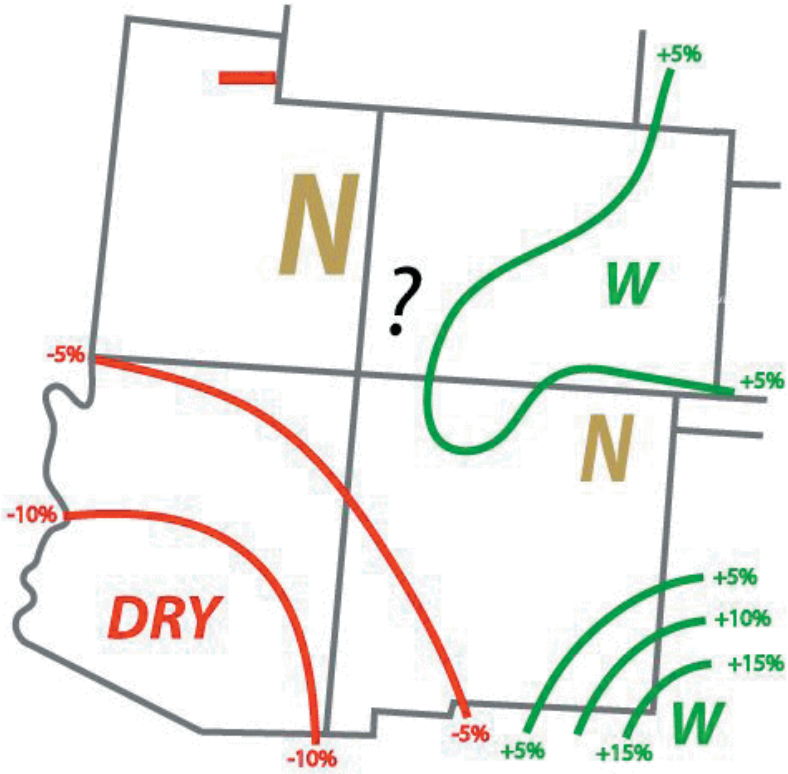


Figure 14. Experimental guidance for seasonal precipitation in the southwest for July - September 2005.

Streamflow Outlooks and Information On the Web

- For more information about NRCS water supply forecasts based on snow accumulation and access to the graph on this page, visit: http://www.wcc.nrcs.usda.gov/wsf/.
- The official NOAA streamflow forecasts are available through the following websites of individual River Forecast Centers:
  Colorado Basin (includes Great Basin): http://www.cbrfc.noaa.gov/
  Missouri Basin (includes South Platte and North Plate: http://www.crh.noaa.gov/mbrfc/
  West Gulf (includes Rio Grande): http://www.srh.noaa.gov/wgrfc/
  Arkansas Basin: http://www.srh.noaa.gov/abrfc/